Growth Study Of The Rat Mandible As Related To Function

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The influence of function and mechanical stress on growth and development of the inner skeletal structures and outer form is well understood (Wolff's Law[20]). There is, however, much discussion about changes in form of the jaw bone during the treatment of dentofacial anomalies or as the result of traumatic occlusion or lack of function. A survey of the literature has been published by Watt and Williams[18]. They classified their analysis into three groups:

(1) General observations and interpretation of "Wolff's Law" as applied to various fields of biology; clinical descriptions of skeletal deformities resulting from paralysis of certain groups of muscles; consideration of partial anodontia in its relation to growth of the mandible and maxilla.

(2) Observations of primitive peoples ascertaining the extent to which the architecture and density or the actual external shape of a bone were affected by hyperfunction. Therefore the studies by Williams[19] on Eskimo populations may be significant. He reported cases of malocclusion in the Eskimo exposed to civilized food habits as compared with a normal occlusion in those who lead a primitive life.

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(3) Clinical and animal experiments were critically analysed, especially in reference to the difficulty of isolating the "function" factor from others influencing growth.

Heredity is, of course, one of the principal elements determining the growth pattern. Baker[1,2] demonstrated the influence of heredity by transplanting a mandible from a fetal rat into the leg muscle of a growing rat and showed that the mandible grew to half its usual size in spite of the trauma, inadequate blood supply, and lack of function.

The problem of *function* and its influence on the actual growth process was demonstrated as early as 1864 by Sédillot (reported by Watt and Williams) who removed the greater part of the tibias in puppies leaving the whole body weight on the fibulas, which grew until they were as thick as the removed tibias would have been in the adult.

Baker extracted various teeth in different species of animals and studied the growth of the maxilla, mandible, and skull in gross specimens. The trauma and the size of teeth extracted (especially in the case of the long incisors of rats) were explained to be factors in jaw development and form. However, the small number of observations and lack of histologic analyses weaken Baker's conclusions.

In 1951 Watt and Williams fed a hard diet to thirty young (21 days old) and thirty old (270 days) rats for four months. They then compared the mandibles of these rats with those of corresponding control groups of the same ages, whose environment was the same, but their diet was soft. The weight, volume, and thickness of the mandibles in the experimental groups (hard diet) were greater than in the corresponding controls. The difference in weight was explained by the change in density of bone structure submitted to the greater mechanical stress. There were no significant differences in linear measurements. No microscopical measurements were reported. Horowitz and Shapiro[11] demonstrated that the removal of the temporal muscle in newborn rats showed a complete absence of mandibular coronoid process in the same adults.

In the last ten years much attention has been given to the complexity of the temporomandibular joint in human beings and monkeys. Two methods have been used for the study of changes during functional therapy in that region, namely, laminagraphy and histology. Since histologic studies of the temporomandibular joint in human beings can only rarely be made, laminagrams, or tomograms, represent a great improvement for a detailed roentgenographic interpretation. They are a precious tool for the student of facial growth because the image is not distorted by angular projections, there are no superimposed shadows of other osseous structures, and it is possible to compare subsequent pictures at certain anatomical reference points[10].

Ricketts[14-17] in a study of 50 boys and girls at an average age of 12 years with Class II malocclusions used laminagrams for the temporomandibular joint area and classical head films for the mandibular growth and development. After 25 months of intermaxillary treatment the observations were compared with the findings in a group of 17 untreated patients who also had Class II malocclusions. In the treated group the tomograms demonstrated a different relationship between the condyle and fossa in rest position. The condyle had changed from a down and forward malposition into a normal position in the glenoid fossa either as the result of "stimulation" of the normal process of growth and development, or by movement of the condyle due to mechanical force alone. The standard head films showed a normal amount of growth and development of the lower jaw in both the treated and untreated groups. Therefore, whatever changes occurred in the temporomandibular joint area were apparently due to simple movement into rest position as the result of treatment (Ricketts). The studies of Watt and Williams and Ricketts are the only ones which included large groups of patients and animals with statistical evaluations. Boman[6] came to the same conclusion as Ricketts.

Recently histologic observations have been reported by Baume, Häupl, and Stellmach[3]. They studied a newborn male child affected with a Pierre Robin's syndrome of micrognathia; he was treated orthodontically with extraperiosteal wire and traction at the symphyseal region from 2 to 7 months of age and then died accidentally at 9 months of age. The effects of the traction were illustrated histologically at the condyle head which indicated growth activity and an active "remodeling in the fossa". No control was available.

In another study by Baume and Derichswiler[4] the temporomandibular structures of two young adult monkeys of approximately 44 to 50 months of age were subjected to wearing bite planes, and then compared with those of a nontreated animal. The treated monkeys displayed histologically increased growth activity indicated by the width of the condylar cartilage in contrast with the control.

The following experiments were designed to investigate the influence of the extraction of molars in the right maxillary quadrant on the form of the mandible, the lower molars and their surrounding structures in comparison with the intact left mandibular quadrant in normal as well as hypophysectomized rats. This study should not be considered a histological analysis; only the measurements of the condylar cartilage wére taken from microscopic specimens.

Methods, Materials, and Experimental Arrangement

Twenty-six female rats (Long-Evans strain) were used and divided into three groups: Group I consisted of 8 normal rats with the right upper molars extracted at 40 days of age and sacrificed at 100 days. The corresponding right half of the mandible was left intact. Group II included 13 hypophysectomized rats with hypophysectomy performed at 20 days and the molars extracted at 40 days. Injections with an aqueous solution of purified growth hormone were started at 150 days and continued for 60 days.* This is, therefore, a much older group of rats at autopsy and cannot be compared with Group I.

A third group included 5 hypophysectomized rats (operation at 20 days of age) which did not receive any treatment (neither extractions nor growth hormone) and were sacrificed at 210 days of age. This group served as controls for Group II. Only a hard diet was used.** For the autopsy ether anesthesia was given and the rats were tied down by their four paws and upper incisors; the extractions were performed by small elevators used interdentally and modified small forceps. For the microscopic measurements of the condylar head, the head and neck of the condyle were separated from the skull, fixed in 10% neutral formol and partially decalcified to facilitate easier dissecting of the posterior-superior portion of the mandible including the coronoid and masseter processes. The isolated portion was then completely decalcified, dehydrated, sectioned sagittally between 8 and 12 micra and stained with hematoxylin-eosin.

Results

It should be emphasized that the normal rats of Group I were in a stage of active growth and development. In the group of hypophysectomized animals the hypophysectomy retarded growth to a great extent (Chart 1).

The injected hypophysectomized rats which had their right upper molars extracted demonstrated a considerable increase in weight as compared with the third hypophysectomized control group which had no extractions nor injections of growth hormone. During the 60 days of growth hormone administration there was a mean increase in body weight to approximately twice (180

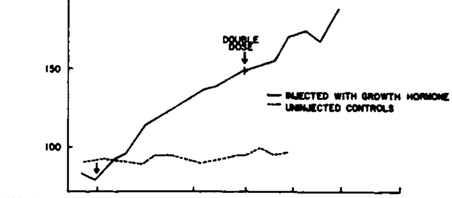

Chart I

* Dose: 0.1 mg/ daily for the first 40 days, and 0.2 mg/ daily for the last 20 days. The authors wish to express their gratitude to Dr. C. H. Li, Director of the Hormone Research Laboratory, Professor of Experimental Endocrinology and Professor of Biochemistry, University of California, for the supply of purified bovine growth hormone.

** "Wayne Lab-Blox" from Allied Mills, Chicago, Illinois.

grams) the initial weight. Growth hormone was very effective in stimulating the condylar cartilage in hypophysectomized rats as previously demonstrated by Collins, et al[7,8] and Becks, et al[5].

Gross examination of skulls (Groups I, II): After sacrifice the rats were decapitated and the heads skinned; each was examined grossly to determine possible asymmetry as reported by Baker. Only one hypophysectomized injected rat of Group II (Fig. 1) showed a deviation of the midline of the mandible toward the right. Roentgenographic measurements of the entire group, however, pointed out that this was merely an incidental finding because all other skulls showed no asymmetry.

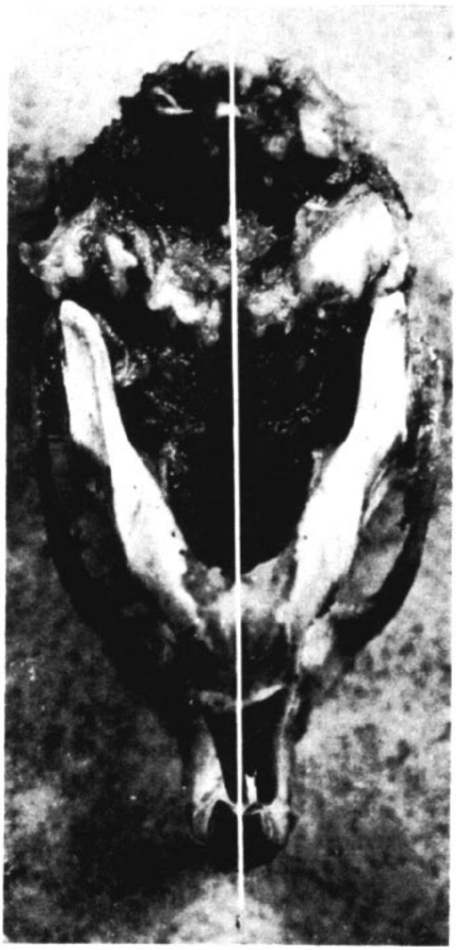

Fig. 1 Inferior view of a skull of a 210-day-old rat hypophysectomized at 20 days (Group II). Notice the deviation of the midline toward one side (Pl. #B2488)

Roentgenographic measurements of mandible: A roentgenographic reproduction of a mandible of a 60-day-old normal rat (Fig. 2) indicates the three linear measurements that were taken in order to determine differences in size between the left and right quadrants of the mandible within Groups I and II: (1) *length* of condylar head to lingual height of the alveolar crest; (2) *height* as measured from sigmoid to base of mandible; (3) *distance* of occlusal surface of first molar to the nearest point of the base of the mandible.

The measurements of the length of the mandible are approximately the same for the left and right sides within the two groups, averaging 49.6mm for the normals and 44.4mm for hypophysectomized. This also applies to the measurements of height 19.4 and 16.4 mm respectively.

For the normal as well as the hypophysectomized rats the average height of the mandible appears slightly greater for the functioning left side, but the low critical ratios (1.77 and .5) indicate that this most likely happened by chance.

Because of the lack of antagonists

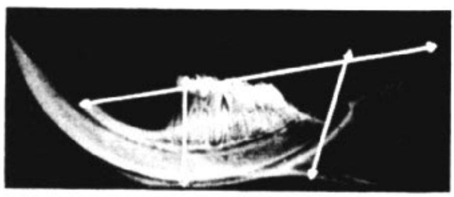

Fig. 2 Roentgenographic reproduction of the mandible of a 60-day-old rat showing the type of linear measurements taken (Pl. #B2501)

and therefore inactivity, the lower right molars erupted far more (mean 17.5 mm) during the experimental period than the active left side in both groups (normal 15.8, experimental 13.7). The distance from the occlusal surface of the first molar to the base of the mandible is significantly greater (C.R. 7.6 and 3.1 respectively) in both groups for the nonfunctioning right side. It must be emphasized that the measurements taken of the right and left halves of the mandible have been compared within each group only because the rats of Group II were older than those of Group I; but in spite of the administration of growth hormone over a period of 60 days all linear measurements of the hypophysectomized rats still remained smaller than those of Group I.

This was also borne out by histologic sections through the mandibular molars and their periodontal structures of Group I which were cut longitudinally. Figure 3 represents the molars of the left, functioning side and the right, nonfunctioning side is represented in Figure 4. It is quite evident that the differences in height of mandible and degree of occlusal wear are indeed not incidental. Interestingly enough, the bone under the bifurcation in higher magnifications (Fig. 5 and Fig. 6) has a much denser structure for the nonworking (Fig. 6) than for the working side (Fig. 5).

This is quite unexpected because these observations are in contrast with

Fig. 3 Functioning side: Longitudinal section through the first and second mandibular molars of a 100-day-old normal rat (Spec. #1229, Pl. #B2936), X 20)

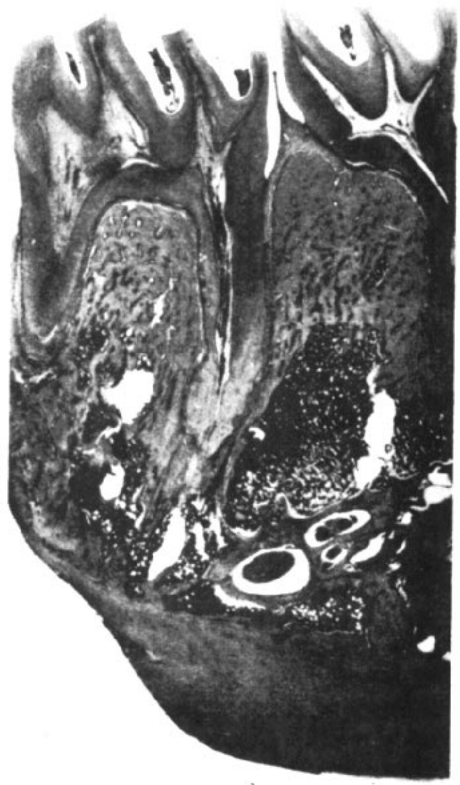

Fig. 4 Nonfunctioning side: Longitudinal section through the first and second mandibular molars of a 100-day-old normal rat (Spec. #1230, Pl. #B2937, X 20)

those of Kronfeld[12] who quoted from Gottlieb and Orban[9] and showed histologically an osteoporosis of the alveolar jaw bone as the result of inactivity in an autopsy specimen of an old individual. Our observations do agree, however, with regard to the width of the periodontal membrane which is greater on the active side (Fig. 5) than on the inactive side (Fig. 6). Preissecker[13] also extracted one quadrant of lower molars in 28-day-old rats and found, after six months, a larger periodontal space on the working side.

Condylar Head Measurements

The thickness of the cartilage of the central portion of the condylar head sectioned sagittally is usually not uniform over the entire surface and can be distorted in tangential sections. In order to be able to compare observations and measurements a precise anatomical point of reference should be chosen in each specimen. In the sagittal plane the neck of the condyle is extremely thin and flat and yields only a few sections. Therefore measurements were taken only from central sections by which the potential growth can be quickly estimated (Fig. 7). It can therefore be concluded that the measurements through the condyle and ramus can readily be compared.

The thickness of the condylar cartilage in the normal Group I is nearly the same for both the left and right sides averaging 14.75mm. However, in Group II, the right, nonfunctioning side showed slightly larger mean values in comparison with the left, 33.5mm and 31.2mm. Since the coefficient of variation (for the left 7.4% and 16% for the right) proved to be somewhat great, this difference is not significant (C.R.

Fig. 5 Higher magnification of the alveolar bone under the bifurcation of the first molar of Fig. 3 (Pl. #B2942, X 65)

Fig. 6 Higher magnification of the alveolar bone under the bifurcation of the first molar of Fig. 4 (Pl. #B2943, X 65)

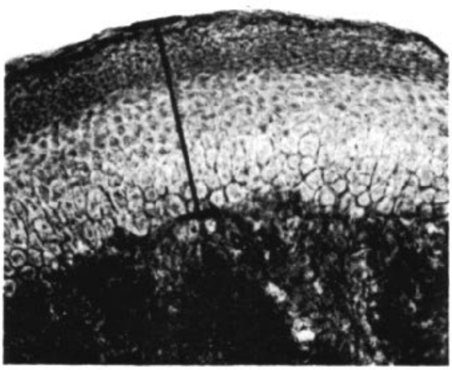

Fig. 7 Magnification of the cartilaginous portion of the condyle indicating the direction of measurements (Spec. #1295, Pl. #B2939, X 180)

= 1.3). It may be of interest here to point out that in spite of the difference in age of the two groups, the hypophysectomized plus growth hormone injected rats showed a greater cartilage width than the uninjected normal rats (Becks, et al[5]).

Summary and Conclusions

Two groups of 8 normal and 13 hypophysectomized rats were used to study the effects of maxillary molar extractions on the mandibular bone architecture and form. Each of the normal rats had the three right maxillary molars extracted at the age of 40 days; they could masticate on the left side only for the next two months. The 13 hypophysectomized rats also had their right maxillary molars extracted at 40 days but were injected daily with purified growth hormone from the age of 150 to 210 days. Only hard food was used. After sacrifice the gross skull specimens were carefully examined, linear measurements were taken from the roentgenographic reproductions of the mandible and the thickness of the condylar cartilage was measured in photomicrographs.

1. Studies of gross skull specimens indicate the possibility of development of asymmetries which, however, occurred in one hypophysectomized rat only. This does not appear at all conclusive because gross changes are likely the result of chance or coincidence.
2. The statistical analysis of the linear measurements of the mandible taken from roentgenographic reproductions give evidence that with the exception of the vertical dimension (from height of first molar cusp to base of the mandible) no significant differences were found in the other dimensions. The general form of the mandible was not affected.
3. Histological observations of the molar regions pointed out a much greater degree of attrition on the working side. The structures of the alveolar bone were denser for the nonworking side and the width of the periodontal membrane was larger for the functioning side.
4. The thickness of condylar cartilage did not show any significant difference between the functioning and nonfunctioning side; within the two groups the influence of growth hormone injections in the hypophysectomized rats, however, was marked.

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