

Translative and transformative growth of the rat mandible

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Duterloo, H.S. & Vilmann, H. Translative and transformative growth of the rat mandible. *Acta Odont. Scand.* 36, 25-32

The growth of the rat mandible was studied during a period from 14 to 30 days of age.

Roentgencephalometric and alizarin vital staining techniques were employed. Growth in length doubles the growth in breadth; the angle between the mandibular halves decreases slightly. Bone remodeling patterns were revealed with the alizarin technique. Posteriorly facing surfaces and the anterior end of the incisal process show apposition. Lateral facing surfaces of the posterior part of the mandibles were resorptive. A medio-posterior growth direction of these parts was found. The intermandibular articulation plays no role in the translative growth movements, in contrast to other articulations between skull bones as sutures and synchondroses, but serves primarily during biting and chewing.

Key-words: Roentgenocephalometry; vital staining

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Growth of the rat mandible has been studied histologically (3), with the aid of roentgenocephalometry (e.g. 6) and the vital staining technique (7). These studies demonstrate relations between metrically expressed changes during growth of the mandible and changes at the microscopical level. However, a systematical attempt to study the relations of the form changes to the processes of bone apposition and resorption on periosteal and articulating surfaces has never been made. The present study aims to provide such information. Attempts are made to relate measured changes in form of the rat mandible in the horizontal plan with the aforementioned surface processes.

MATERIAL AND METHODS

Wistar Albino rats were studied from 14 to 30 days of age with a combination of roentgencephalometry and vital staining with alizarin red S. The former technique provides information on changes in form of the mandible, while the latter yields information on the processes of apposition and resorption on its surfaces.

In the roentgencephalometric part two groups of rats were used. One group, comprising 18 male rats 20 days old was X-rayed twice the same day for the evaluation of errors of the method. The other group, comprising 25 male and 25 female rats was X-rayed at 14 and at 30 days. Standardized

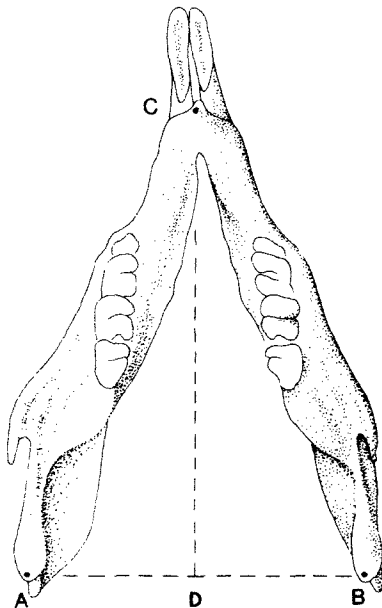


Fig. 1. The rat mandible (dorsal view)

- A. The posterior limit of the left condylar process.
- B. The posterior limit of the right condylar process.
- C. The midpoint of the intersection between the anterior most extensions of the incisal processes.
- D. The midpoint of the intersection between points A and B.

dorso-ventral cephalograms were made, using the technique described in a previous publication (10).

The following measurements were made (Fig. 1):

1. length of right half of mandible (BC)
2. length of left half of mandible (AC)
3. breadth of mandible (AB)
4. length of mandible (CD)
5. intermandibular angle (ACB).

In the vital staining part of the study the technique previously described (11) was used. Twenty rats were injected at 14 days and were subsequently killed in groups of five animals at 15, 18, 21 and 30 days. In addition, four rats were injected at 30 days and killed at 31 days.

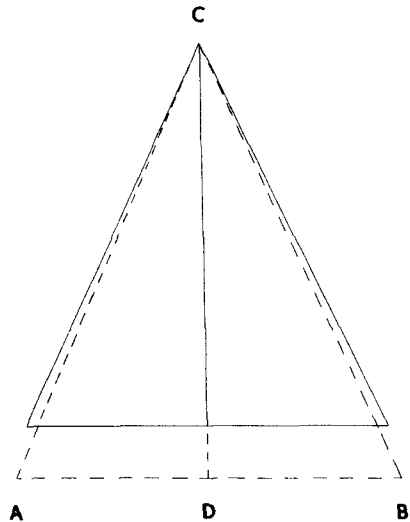


Fig. 2. Changes in form of the rat mandible between 14 and 30 days (dorsal view).

Serial sections were made in horizontal, transversal, sagittal and several oblique directions.

RESULTS

Roentgenocephalometry

Error of method

The error of the method was for linear measurements between 0,08 and 0,20 mm. For angular data the error was 0.84 degrees.

The growth study

Data on length and angular values at 14 and at 30 days are given in Table 1. Increases in length and changes in angular value between 14 and 30 days are given in Table 2. Length and breadth of the mandible increase during growth, length, however, twice as much as breadth. The angle between the two halves of the mandible becomes slightly more acute (Fig. 2).

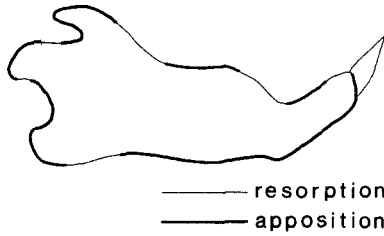


Fig. 3. Surface activities in antero-posterior and supero-inferior directions at 14 days.

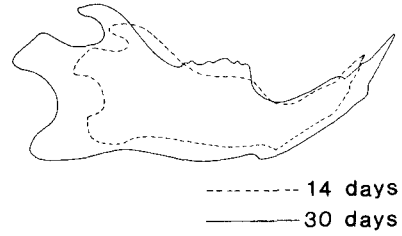


Fig. 4. The growth in height and length of the rat mandible between 14 and 30 days.

Table 1. Means (\bar{x}) and standard deviations (sx) of length (mm) and angular measurements at 14 and 30 days

		BC		AC		AB		CD		< ACB	
		F	M	F	M	F	M	F	M	F	M
14 days	\bar{x}	15,89	15,98	16,19	16,00	13,81	13,70	14,53	14,47	51,2	50,8
	sx	0,51	0,59	0,43	0,53	0,27	0,51	0,40	0,51	1,2	2,4
30 days	\bar{x}	18,06	18,02	18,02	18,26	14,94	14,81	16,47	16,74	49,5	48,5
	sx	0,85	0,79	0,85	0,74	0,30	0,45	0,74	0,60	2,7	2,3

Table 2. Mean differences (\bar{x}) and standard deviations of changes in length and angular values between 14 and 30 days

		BC		AC		AB		CD		< ACB	
		F	M	F	M	F	M	F	M	F	M
14-30 days	\bar{x}	2,17	2,04	1,85	2,23	1,18	1,10	1,94	2,28	-1,7	-2,3
	sx	0,89	0,94	0,83	0,98	0,36	0,66	0,77	0,74	2,4	2,8

All mean values differ significantly from 0

Vital staining

The results from this part of the study show that the processes of surface apposition and resorption on the rat mandible are very complicated. To facilitate a systematical description of these processes, growth in the supero-inferior and antero-posterior directions and in the medio-lateral direction is described separately.

Supero-inferior and antero-posterior dimensions

14 days. The lower border of the mandible is

appositional. However, a limited resorptive area is found anterior to the root of the angular process. The superior surface of the incisal process is resorptive in the anterior and posterior parts whereas the central part and the anterior end are appositional. The crests surrounding the molars are appositional. The anterior surface of the ramus is resorptive whereas the coronoid process is appositional.

The condylar process is appositional with the exception of limited areas superiorly and inferiorly. The angular process is appositional (Fig. 3).

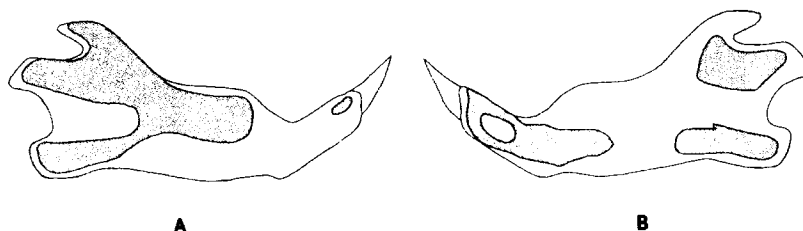


Fig. 5. The patterns of surface activities on medially and laterally facing surfaces at 14 days.

hatched areas – resorption

white areas – apposition

A. lateral view

B. medial view

14–30 days. Most new bone is laid down in the posterior parts of the mandible. A marked bone formation is also seen on the lower border with more new bone laid down in the posterior and central parts than in the anterior part. The anterior end of the incisal process shows only slight bone formation.

Marked resorption is seen on the anteriorly facing surface of the molar process and the ramus (Fig. 4).

described appositional areas (Fig. 5B) show deposition of bone, with most bone formed in the area posterior to the molars.

The new bone laid down on the articular surfaces of the incisal process seems to be evenly distributed (Fig. 6F). With increasing age, a tendency of slight bone formation on former resorptive areas is of significance.

Medio-lateral dimensions

14 days. The lateral surface of the mandible is appositional in its anterior and infero-central parts. Well-defined areas of apposition are also found in the posterior part and at the molar alveolar crest. The rest of the surface is resorptive (Fig. 5A).

The medial surface is appositional in its central and most of its posterior parts. The resorptive areas are situated anteriorly and at certain well-defined areas in the posterior part (Fig. 5B).

14–30 days. On the lateral surface of the mandible bone formation in the anterior and infero-central parts is of significance, with most new bone laid down anteriorly and inferiorly. The described appositional area in the posterior part (Fig. 5A) shows slight bone formation. On the medial surface the

DISCUSSION

Roentgenocephalometry

Studies of growth in length of the rat mandible (7, 14) show that it grows rapidly but at a decreasing rate; dimensions in the interval between 14 and 30 days agree with the dimensions measured in the present study.

The increase in breadth and in acuteness of the angle between the mandibular halves observed in this study agree with the common view of developmental changes of the mandible (7). However, metrical expressions of these changes in the rat have not been presented before.

Vital staining

Earlier descriptions of the processes of apposition and resorption on the rat mandible (2, 3, 7) in the period between 14 and 30 days

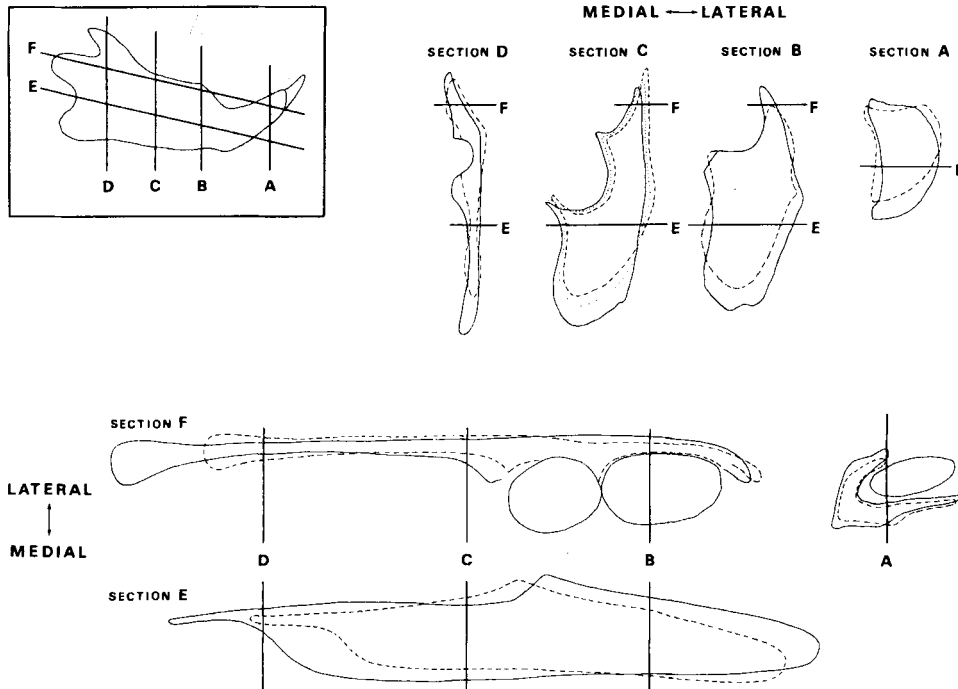


Fig. 6. The growth pattern of the rat mandible between 14 and 30 days as observed in sections at various levels. (Levels indicated in left top illustration.)

- 30 days
- - - 14 days
- 21 days

do not deviate much from the description of the present study. In this period the mandibular halves increase in supero-inferior and antero-posterior dimensions by marked bone formation on their lower borders and on their posteriorly facing surfaces. An anteriorly directed growth, taking place at the anterior end of the incisal process has also been reported (7). However, in the present study bone formation at this site was found to be limited.

The dimensional increase in the transversal plane seems to take place by a combination of apposition on one surface while the contra-lateral or -medial surface shows either apposition or resorption.

During growth, bones undergo complex surface changes in order to maintain proportionate positions of their parts.

Descriptions of such changes have been given by Enlow and co-workers (e.g. 4).

These complex patterns of resorption and apposition are also found during growth of the rat mandible. The pattern of surface changes in the posterior part of the mandible is an excellent expression of such conditions.

In this part, the mandible grows in a medio-posterior direction with the result that original posterior parts become relocated into more anteriorly situated parts of the bone. This relocation involves marked processes of remodelling – appositional or resorptive – according to the configuration of the parts involved (Fig. 7).

In the same way patterns of apposition or resorption on other surfaces may be explained. For instance, the deposition at the anterior end of the incisal process may in part

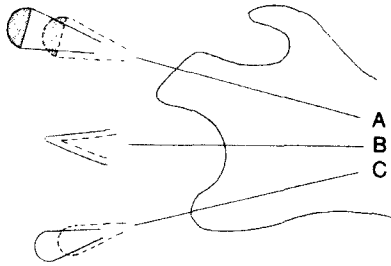


Fig. 7. Schematized patterns of surface changes during posteriorly directed growth of the rat mandible.

- A. The condylar process. The condylar neck shows periosteal resorption according to the V-principle (5). See also Fig. 9A.
- B. This free ending edge grows by strong apposition on posterior and medially directed surfaces and slight apposition on lateral surfaces. See also Fig. 9B.
- C. The growth pattern of the angular process is comparable to that of the condylar process. Remodeling follows the V-principle (5). See also Fig. 9C.

be related to the increase in diameter of the erupting incisor. Thus, as a means of lengthening of the mandible this deposition has a limited significance. Also, the slight bone formation on the surfaces facing toward the intermandibular articulation may, together with a lateral migration of the incisal process, express a growth pattern which serves to compensate for the converging direction of the mandibular halves and the erupting incisors (7).

However, additional patterns of apposition and resorption are regularly found on surfaces of growing bones. These patterns of growth often result in rotations of the bones in relation to themselves (11). Such surface changes are also found in the present study. According to the observed patterns the mandibular halves rotate medially in their posterior parts and laterally in their anterior parts. The center of the rotation is situated at the root of the incisal process (Fig. 8).

The combination

As shown in the roentgenocephalometric part

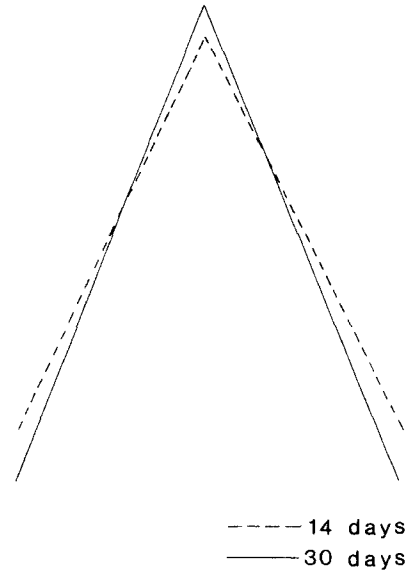


Fig. 8. The growth of the rat mandible between 14 and 30 days. The contours of the original bone (----) is found in a rotated position in the new bone (—).

of the study the rat mandible increases both in antero-posterior and in transversal dimensions in the 14–30 days period, while the angle between the two halves decreases. Such metrically expressed changes are referred to as translative growth movements (8). They result in transformative growth movements i.e. processes of apposition and resorption on the periosteal and articulating surfaces of the bones involved.

In previous publications (12, 13) it has been shown that changes in angulation between neighbouring bones in the rat skull are due to a combination of differential growth on bone surfaces towards articulations (synchondroses and sutures) and differential apposition and resorption on periosteal surfaces. The latter seems in some way to regulate and adjust the effects of the former, or vice versa. According to this, the measured decrease in angular obtuseness between the mandibular halves might be expected to be a result of a combination of differential growth towards the intermandibular articulation (the symphysis) leading to an angular decrease and

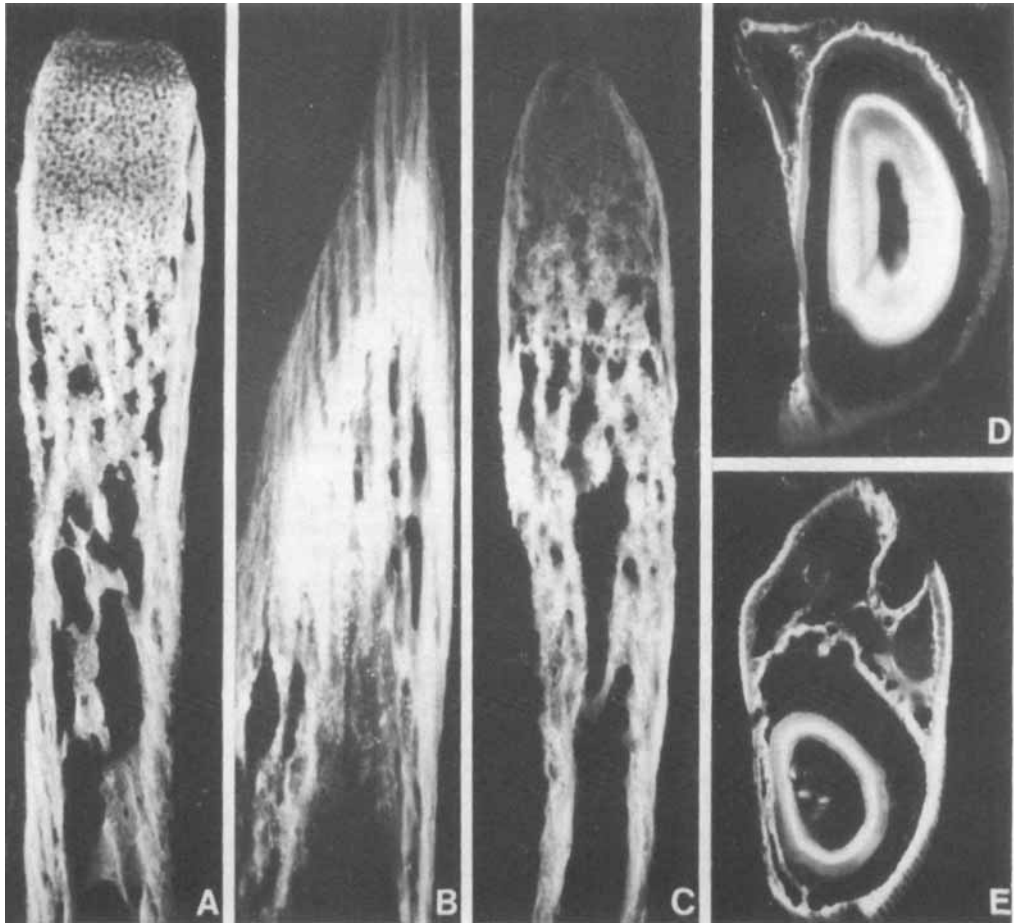


Fig. 9. Micro-photographs of sections of alizarinated bone of rat mandibles.

Fig. 9A. Section through the condylar process. Plane of section indicated in Fig. 7 (A). Note the periosteal resorption on lateral (left) and medial (right) surfaces of the condylar neck. Age 15 days, alizarin injection at 14 days.

Fig. 9B. Section through the free ending posterior part. Plane of section indicated in Fig. 7 (B). Note the great amount of bone formed at the medial and posterior surfaces (left and top) compared to the lateral surface (right). Age 21 days, alizarin injection at 14 days.

Fig. 9C. Section through the angular process. Plane of section indicated in Fig. 7 (C). Note the periosteal resorption areas and compare with 9A. Age 18 days, alizarin injection at 14 days.

Fig. 9D. Frontal section through the incisal process. Approximately section A Fig. 6. Note the limited growth at the medial surface (left) and the remarkable remodeling at the lateral surface (right). The inferior periosteal surfaces are resorptive. Age 30 days, injection at 14 days.

Fig. 9E. Frontal section through the area of the mental foramen M. Apposition at the infero lateral surfaces (right). Resorption at the medial surface (left). Compare with Figs. 5 A and B.

a laterally directed growth of the periosteal surface.

This is, however, not the case. The decrease in angular obtuseness is obviously not influenced by the growth of the intermandibular articular surfaces, as the bone formation here seems to be evenly distributed. The decrease seems solely to be due to a medially directed growth of the periosteal surfaces.

A plausible explanation of this is that the intermandibular articulation in contrast to other articulations between skull bones (sutures, synchondroses) in the studied age interval primarily serves as a device for functional movements between the halves during chewing and biting (9, 15). As already stated, the slight bone formation on the articulating surfaces only serves as a means to compensate for the converging direction of the mandibular halves and the erupting incisors.

The lack of importance of this articulation for the angular changes of the mandible during growth is further demonstrated by the fact that the transformative growth movements of the rat mandible are directly comparable to that of mandibles from species with ossified symphysis (1, 5, 7).

Acknowledgements. The authors acknowledge the technical assistance of Dr. H.W.B. Jansen, Laboratory for Craniofacial Growth and Development, University of Groningen, and Mrs. Helle Meile, Royal Dental College, Copenhagen. Drawings are made by Chris Lingemans; the manuscript was prepared by Marga van Dijken.

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