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The Mandible – Natural History of a Bone Completely Different from All the Others

Żuchwa – naturalna historia specyficznej kości

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Abstract

The study of the developing human mandible was performed on more than a hundred subjects (fetuses, neonates and young children) by means of all the modern techniques used to study the histology of calcified tissues. Qualitative microradiographic analysis of 80 μm -thick undecalcified sections is the most suitable to underline all the particular aspects of this growing bone. The growing mandible was divided into three parts: the body, the symphyseal region and the ramus. The body develops alongside or in opposition to and within the Meckel's cartilage. It has been divided into a basilar part and an alveolar part, in close relation with the teeth buds. It is built of woven bone in which Haversian bone appears very soon; it also contains remnants of the condylar cartilage that are visible at least up to birth. During the fetal period, the symphyseal region contains several soft tissues including the chondriola symphysea which are the remnants of the Meckel's cartilage. They do not have any influence on the formation of the synostosis and they progressively disappear by a process very similar in this aspect to arthrotic cartilage unrelated in time to the development of the synostosis. The most striking feature corresponds to the fact that both hemimandibles are covered with chondroid tissue, a third class of tissue different from bone and cartilage. The presence of chondroid tissue clearly indicates the existence of a stretching process corresponding to the development of the tongue and explains the similarities between the mandibular symphysis and the metopic sutural area of a growing skull. From this observation, it appears very clearly that the growth of the tongue is determining the development of the mandible. The condylar cartilage is not an epiphyseal cartilage but a centre of endochondral ossification comparable to a growing epiphyseal nucleus or to the so-called unfertile extremity of a small long bone (Dent. Med. Probl. 2004, 41, 3, 395–402).

Key words: human mandible, microradiograph, chondroid tissue, condylar cartilage.

Streszczenie

Badania rozwoju ludzkiej żuchwy były prowadzone u ponad stu osób (płodów, noworodków i małych dzieci) za pomocą wszystkich nowoczesnych technik stosowanych w pracach histologicznych nad tkankami zmineralizowanymi. Mikroradiograficzna analiza jakościowa odwapnionych preparatów o grubości 80 μm jest najbardziej właściwa do wykazania wszystkich szczególnych aspektów wzrostu tej kości. Wzrastająca żuchwa została podzielona na trzy części: trzon, rejon spoiniowy i ramię. Trzon żuchwy rozwija się wewnątrz chrząstki Meckela i dzieli się na część podstawną i zębodołową, ściśle związaną z zawiązkami zębów. Jest zbudowany z kości spłotowatej, w której bardzo szybko pojawiają się kanały Haversa. Zawiera również pozostałości chrząstki kłykciowej widoczne przynajmniej do urodzenia. W okresie płodowym rejon spoinia żuchwy zawiera tkanki miękkie, w tym chrząstkę spoinia, która jest pozostałością chrząstki Meckela. Nie mają one wpływu na formowanie kośćca i zanikają stopniowo w wyniku bardzo zbliżonego w tym aspekcie do chrząstki stawowej procesu niezwiązanej w czasie z rozwojem kośćca. Najbardziej znaną cechą wynikającą z pokrycia połowy żuchwy tkanką chrząstkopodobną jest to, że trzecia kategoria tkanki różni się od kości i chrząstki. Obecność tkanki chrząstkopodobnej wskazuje na zachodzenie procesu rozciągania odpowiadającego rozwojowi języka i tłumaczy podobieństwa między spoinią żuchwy a obszarem szwu czołowego rosnącej czaszki. Z obserwacji tej wynika, że wzrost języka jest zdeterminowany rozwojem żuchwy. Chrząstka kłykciowa nie jest chrząstką nasadową, lecz ośrodkiem kostnienia wewnątrzchrząstkowego zbliżonym do rosnącego jądra nasadowego lub tzw. *unfertile extremity* małej kości długiej (Dent. Med. Probl. 2004, 41, 3, 395–402).

Słowa kluczowe: żuchwa ludzka, mikroradiografia, tkanka chrząstkopodobna, chrząstka kłykciowa.

At the end of his book, still quoted today as a reference and dealing with the organization of bone, Lacroix [1] pointed out that the papers dealing with facial and skull growth were only descriptive. The sagacity of this illustrious author was such that he understood that classical sections, obtained after decalcification and paraffin embedding, were unable to detect and to highlight the peculiarities of a bone like the mandible. This also means that, at that time, the described types of ossification, intramembranous (dermal) and endochondral, were inadequate, as basic knowledge about calcified tissues, for understanding the ways in which the mandible and the other bones of the head are different from those of the appendicular skeleton.

Very soon after this, Amprino [2] described a X-ray procedure applicable to thick undecalcified bone sections furnishing radiographs detailed up to the level of cytology. For that reason, this procedure was called microradiography. It determines the level of calcification of the different constituents present in a section of bone.

The use of this very simple new technique was immediately combined with calcium⁴⁵ autoradiography [3] and with the staining with toluidine or methylene blue of the section allowing three different aspects of the same microscopic field to be observed. This new approach of the morphology of bone immediately led to the discovery of the preosseous layer in the depositing osteons [4] clearly indicating the existence of a gap between bone matrix deposition and its calcification. The author and co-workers also very soon applied these techniques to the growing skeleton [5] as well as studying the acute osteoporosis induced in the calcaneum by resection of the Achilles tendon [6].

When some time later on, it was obvious that the tetracyclines, visible under fluorescent light microscopy, were incorporated into the bones at the level of the calcification front following osteogenesis [7], it became easier to study bone and calcified tissues because other fluorescent markers, like uroporphyrin and alizarin red S, were rapidly identified, enabling more sophisticated research programmes. The author and co-workers used these markers to bring a new contribution to the growth of long bones [8] and to measure the rate of osteoclastic bone destruction during the production of Haversian canals in the compact bone of dogs [9, 10].

Meanwhile, while these techniques were leading to a complete renewal of the knowledge about bone and calcified tissues present in the appendicular skeleton, many papers dealing with the growing mandible appeared without reference to the recent progress in histology of calcified tissues

and without consideration of orthodontic problems. For example, a review of the literature [11], summarized knowledge about the growth of the condylar process as follows: "The contribution of the condylar cartilage to the growth of the mandible has been debated for a considerable length of time with very little progress being made towards a total concept, leaving many questions unanswered or debatable". Indeed, contradictory accounts have been written about the condylar cartilage and postulated even by the same author. Again as an example, let us take the overlong discussions about primary or secondary cartilages: in fact, they are of little importance in understanding mandibular growth. Let us also note the paper [12] that concludes, without any evident reason, that the growth behaviour of the human growing temporomandibular joint is analogous to a membranous suture.

In the present paper, the author shows how applying a modern morphological technique – microradiography of thick undecalcified sections embedded in methyl methacrylate – can bring a better understanding of the phenomena occurring in the growing mandible.

Material and Methods

About 120 human mandibles falling in four categories: embryonic, fetal, neonatal and young children were sampled. Fetal age was determined either by measuring the maximal length of the fetus or the cranial perimeter of the subjects according to the methods used in pediatrics [13].

The bones were dissected with care to preserve the periosteum and muscular insertions and were embedded in methyl methacrylate without previous decalcification [14]. The bones were sectioned in the three orthogonal planes, frontal, sagittal and transverse, into slices about 120 μm thick using an automatic saw (type 32, Safag, Bienne, Switzerland). The thickness was thereafter reduced to a uniform 80 μm by manual grinding on a ground glass plate under methanol.

A contact microradiograph was prepared for each section by placing it on a fine grain Kodak spectroscopic plate 649-0 and exposed to long wavelength X radiation produced by a Machlett tube connected to a Baltograph BF-50/20 generator* (Balteau, Liège, Belgium) at 13 kV and 18 mA. The exposure time was 15 or 45 minutes depending on the film-focus distance, which varies according to the dimensions of the section. After

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exposure, the sections were stained by a 1% aqueous solution of methylene blue buffered at pH 4.8 by 0.1 N potassium biphthalate according to the method the author published earlier [15].

Results

According to their embryological development, bones may be classified as large or small long bones, short bones and flat bones. The large long bones have two epiphyseal cartilages, the small long bones only one. Short bones are similar to an epiphyseal growth centre and flat bones have several ossification centres but no epiphyseal plate.

From this point of view, the mandible occupies an unique situation for several reasons. This bone consists of two bodies united anteriorly by soft tissues at in the symphyseal area and separated posteriorly where they continue into a ramus. Moreover, the body of the mandible is divided into a base and an alveolar one containing the teeth buds. The ramus mandibulae has also two processes: the condylar process and the coronoid process. Up to now, it has not been established whether or not an angular cartilage exists at the level of the gonion in the human fetuses as observed in some other mammals [16].

Microradiographic analysis alone is able to characterize the different calcified tissues observed in a growing mandible. They are represented, at the same magnification, in Figure 1. Woven bone is presented in A; it is made of irregular trabeculae, having a very uniform mineral content. They are separated by vascular spaces. Calcified cartilage is visible in B (asterisk); it is incorporated into lamellar bone (L). Its degree of calcification is always higher than that of bone [5] and except enamel, always the highest in a microradiograph of a section containing calcified tissues [17, 18]. The half of the figure located at the right hand side (C) contains only chondroid tissue.

The Body of the Mandible

As opposed to the long bones of the appendicular skeleton, which are formed by the transformation into bone of a cartilaginous model, the body of the mandible develops alongside and not within the Meckel's cartilage. Endochondral ossification occurs only in the condylar cartilage (Fig. 3), producing cartilaginous pillars which are incorporated in the posterior part of the mandibular body. These pillars are easy to identify in microradiographs owing to their calcium content [5] always higher than that of bone (Fig. 1B). They are still present in neonates.

The Base

The base of the mandible is less transparent to X-rays than the alveolar part [16]. In the early stage of its development, the mandibular body has an U-shaped configuration with a groove dividing in two superposed compartments: the alveolus and the mandibular canal. The different calcified tissues present in the base of the mandible during fetal life were illustrated by a combination of histological and microradiographic techniques [17]. The author's observations showed that in addition to the classical description of the mandibular body [19], where only intramembranous ossification is mentioned, the participation of endochondral ossification in condylar cartilage is also taking place.

The trabeculae of woven bone are easy to recognize; they have a random arrangement and irregular osteocytic lacunae, sometimes confluent. Lamellar bone was also observed under the periosteum in two aspects, described by [20], as slow and rapid subperiosteal apposition. Moreover, the presence of typical osteons originating from true Haversian bone remodelling were observed as early as 5th month of fetal life [17].

The Alveolar Part

As known for a long time [21], the existence and the development of the alveolar part of the mandible is closely related with the presence and growth of dental germs. As perfectly summarized by [22]: "l'os alvéolaire naît et meurt avec la dent".

At first, alveolar bone is only built of woven bone which is then used as a support for lamellar bone apposition [23]. There is a close relation between alveolar bone growth and the increase in volume of tooth germs. This may be compared with the effects of cerebral growth on the development of the skull [24].

Later, during premolar eruption, as the author and co-workers have shown in an experimental study on the mandible of the dog [25, 26], the growing body of the mandible has the same characteristics as the diaphysis of a growing long bone: periosteal activity varies, at any time, from place to place, stopping or shifting from osteoclastic resorption to osteogenesis leading to bone deposit either by a slow or rapid process, as early described by Lea and Ponlot [20], for the diaphysis of a growing long bone.

The Symphyseal Region

During fetal life, the gap between the two hemimandibles is filled by soft tissues, not visible in the microradiographs. They mainly consist of fibrous tissues in which the so-called "chondriola

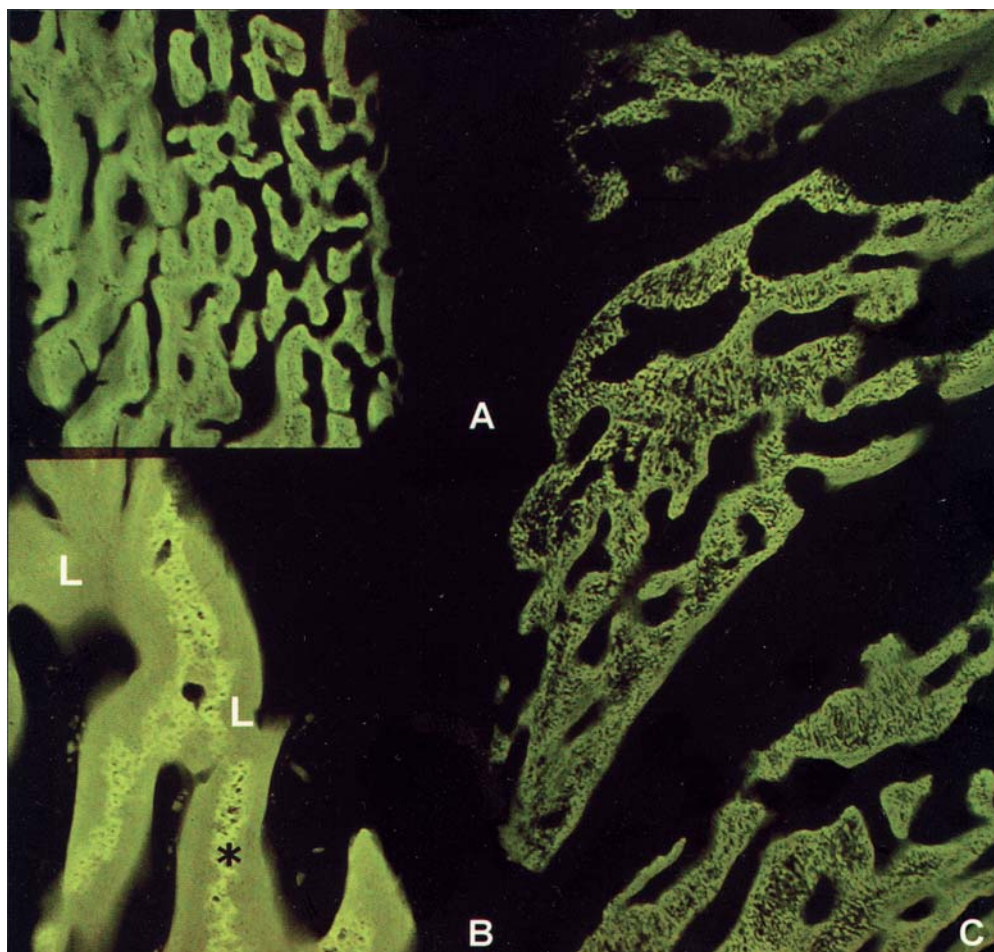


Fig. 1. Microradiographic aspects of the calcified tissues observed in a human growing mandible ($\times 24$): A – woven bone, B – calcified cartilage, L – lamellar bone, C – chondroid tissue

Ryc. 1. Obraz mikroradiograficzny tkanek zmineralizowanych w rosnącej żuchwie ludzkiej ($\times 24$): A – kość spłotowata, B – chrząstka zmineralizowana, L – kość blaszkowata, C – tkanka chrzęstna

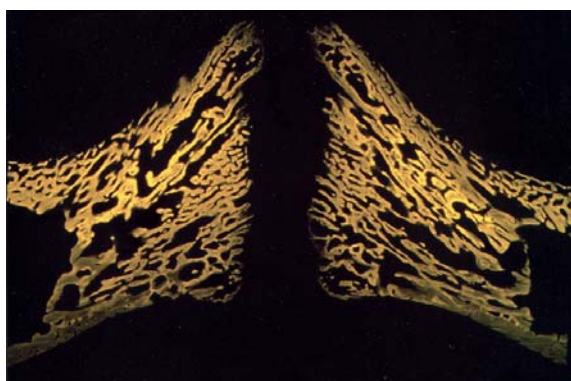


Fig. 2. Microradiograph of a transverse section in the symphyseal region, at the end of fetal life ($\times 8,2$)

Ryc. 2. Mikroradiografia preparatu z obrazu spojenia żuchwy w końcu okresu płodowego ($\times 8,2$)



Fig. 3. Microradiograph of a sagittal section in the ramus of the mandible of a newborn child ($\times 5$). The dotted line surrounds the osteocartilaginous pillars originating from the endochondral ossification taking place in the condylar process

Ryc. 3. Mikroradiografia preparatu z ramienia żuchwy noworodka ($\times 5$). Linia kropkowana otacza filary kostno-chrząstne pochodzące z kostnienia wewnątrzchrząstkowego przebiegającego w procesie kłykciowym

symphysea” [27] or meckelian islets [28] and secondary cartilages are included. Author’s previous observations [29] confirm that they really originate from the ventral extremity of the Meckel’s cartilage. They disappear very soon by resembling

the degenerative arthrotic cartilage. They have no physiological significance, being only remnants.

At the end of fetal life, around the 8th month [30], mental ossicles are also present. They are seen in the basal level of the symphyseal mesenchyme, their disposition dorsoventrally varying from one case to another. Their constitution is similar to the adjacent hemimandible, i.e., woven bone, chondroid tissue and cartilage [29, 30]. Because of their location and structure, they certainly do not originate from the chondriola symphysea [29, 30, 32]. They fuse with the adjacent hemimandible soon after birth.

But the most striking feature to mention about the symphyseal region concerns the extremities of the mandible bone adjacent to the gap. Each hemimandible is characterized by a cover of a very peculiar tissue that the author decided to call “chondroid tissue”. Chondroid tissue differs from all the other calcified tissues by the composition of its matrix. As shown by immunofluorescence techniques, it contains collagen type I, like bone, and collagen type II, like cartilage [33]. However, its histological appearance is fundamentally different from both of them; it also differs from fibrocartilage [32]. Electron microscopic examination also shows that chondroid tissue is clearly different from cartilage [34]. This is also true for the way in which it calcifies. While the calcification starts elsewhere at the immediate periphery of the chondrocyte lacunae [5], in chondroid tissue it starts away from the lacunae as revealed by methylene blue staining of thick undecalcified sections [31].

The Ramus of the Mandible

Three different parts have to be considered separately in the ramus of the mandible, according to their ontogenesis and evolution: the condylar process, the coronoid process and the gonion. As mentioned earlier, no angular cartilage has yet been detected in the fetal human mandible.

The Condylar Process

Among the regions constituting the mandible, the condylar process is certainly the most studied and the results published the most debatable [11] and subject to discussion. However, by comparing the microradiographic appearance of the condylar cartilage (Fig. 3) with the results observed during appendicular bone development [1, 8], it is very obvious that the condylar cartilage can never be compared with an epiphyseal plate [35].

The osteocartilaginous pillars originating from the growth activity occurring at the level of the condylar cartilage are isolated by a dotted line in Figure 3 which represents the microradiograph of a sagittal section in the ramus of a newborn child. As

the author and co-workers have shown [35], the features observed are not those of an epiphyseal cartilage but rather to a growing epiphyseal nucleus or to the so-called infertile extremity of a small long bone.

Appeared after the Meckel's cartilage, the condylar cartilage is considered as a secondary one. But this is not important as discussed later.

The Coronoid Process

The coronoid process also originates from a secondary cartilage, which appears soon after the condylar one. As shown earlier [36–38], the coronoid process is mainly constituted of chondroid tissue, arranged to correspond to the tractions exerted by the temporal muscle. The influence of the forces exerted by this muscle are well documented. The height of the coronoid process is indeed reduced by the section of this muscle [39] or by the section of the motor root of the trigeminal nerve [40].

As in other parts of the mandible where chondroid tissue is present at first, this tissue is progressively replaced by woven bone and lamellar bone.

Discussion

The previously-quoted remarks of Durkin et al. [11] about the condylar cartilage are also valid for the symphyseal region.

The microradiographic aspects of the fetal mandibular symphyseal region are very similar to a fracture callus in the diaphysis of a long bone a few weeks after trauma. However, when a fracture callus is at this stage of development, fusion occurs in a very short time, about two weeks, unlike the symphyseal region which persists for at least one year or even more. This clearly indicates that the hemimandibles are unable to fuse because they are distracted by the development of the tongue. This also explains the great similarity between the mandibular symphyseal region and the growing metopic suture [24] where the parts of the frontal bone are kept away from each other by the growth of the brain.

All the data published about chondroid tissue clearly indicate that this tissue represents a third type of hard tissue, differing from bone and cartilage. From a physiological point of view, the presence of chondroid tissue always coincides with the existence of a tractive effort. This is the case not only for the symphyseal region of the growing mandible but also for the cranial sutures as shown for the metopic one [24] or the cranial vault [41].

The significance of the presence of chondroid tissue is very obvious today [42]. It always develops when bone fragments are stretched whereas cartilage is laid down when they are compressed.

Previously given more than 30 different names [43], this tissue, very difficult to identify in classical paraffin sections, was clearly identified by microradiographic analysis combined with methylene blue staining of thick undecalcified sections [31]. It has also been characterized by electron microscopic study [34] and by immunofluorescence, which detects different collagen types [33].

The early occurrence of Haversian remodelling [44] in the body of the mandible has to be related to the fact already pointed out by Enlow [45] that the mandible is submitted to mechanical activity primarily resulting from sucking and swallowing. However, more recently, the author and co-workers have shown that typical osteons, which are formed of concentric lamellae circumscribed by a cementing line, appeared prior to osteoclastic resorption of old bone, being present in the long bones of the appendicular skeleton as well as in the ribs of the human fetuses aged between 23–30 weeks [46].

The absence of Haversian bone remodelling in the skeleton of the normal rat [10, 47] is an additional reason to avoid this animal as experimental model when the aim of the study is to understand human clinical problems.

The condylar cartilage is obviously not an epiphyseal cartilage as stated earlier by several authors [48–51]. However, the results of an accident of the nature in which the answer is very clearly indicated seem to have been ignored: whereas the anatomical aspects and shapes of the long appendicular bones are deeply and tremendously altered by achondroplasia, no apparent deformity of the mandible is observed in this congenital disorder due to absence of activity because of epiphyseal cartilage. As the author stated a long time ago, the microradiographic and histological aspects of the condylar cartilage are more similar to the so-called unfertile extremity of a small long bone, like a phalanx, or to a growing epiphyseal nucleus [35]. It appears after the Meckel's cartilage and is considered as secondary for this reason. But this is not really important as indicated by the following comparison. According to its position

into the cartilaginous bud of a long bone, a chondrocyte would disappear very soon to make place for the bone marrow cavity or after acting for some time in the epiphyseal cartilage or persisting all the life in the region of the articular cartilage.

By analysing the effects of the cutting of the rat lateral pterygoid muscle by counting the number of mitoses, identified by tritiated thymidine labelling administered one hour before sacrifice, Petrovic and Stutzmann [52] concluded, from the reduction of the number of mitoses, that the section of the muscle results in a decreased of the growth of the condylar cartilage. On the basis of their experiment, these authors also concluded that the condylar cartilage is incapable of spontaneous activity.

However, when the growth rate is measured, like the author and co-workers did [53, 54], by means of double labelling technique under fluorescence microscopy, it clearly appeared that the section of the lateral pterygoid muscle does not correspond to an inhibition of the condylar activity. The values measured in the central part of the condylar cartilage are similar for both operated and control sides. Moreover, an excess of growth has been found in the posterior part of the condyle. The cybernetic model [52] of the mandibular growth based on this experiment is thus not valid.

Conclusion

The way in which mandible develops is completely different from that of any other bone.

When the end result is to be a mandible without any orthodontic problems, attention must also be drawn not only to the condylar cartilage but also to the symphyseal region. Chondroid tissue there results from the existence of a stretching process due to the development of the tongue and exercise has to be undertaken in order to stimulate the growth of this muscular mass [55]. Since the symphyseal region ossifies very soon, around one year of postnatal age, due to the developing teeth buds, the way to promote development of the tongue is to favour breast feeding instead of bottle feeding.

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References

- [1] LACROIX P.: L'organisation des os. Éditions Desoer, Liège 1949.
- [2] AMPRINO R.: Rapporti fra processi di ricostruzione e distribuzione dei minerali nelle ossa. I. Ricerche eseguite col metodo di studio dell'assorbimento dei raggi Roentgen. *Zeitschr. Zellforsch.* 1952, 37, 144–183.
- [3] LACROIX P.: Sur le métabolisme du calcium dans l'os compact du chien adulte. *Bull. Acad. Roy. Méd. Belg.* 1953, VI^e érie, 18, 489–496.
- [4] VINCENT J.: Recherches sur la constitution du tissu osseux compact. *Arch. Biol.* 1954, 65, 531–569.
- [5] VINCENT J., DHEM A.: Étude microradiographique de l'ossification endochondrale. *Acta Anat.* 1960, 40, 121–129.
- [6] DHEM A.: Recherches expérimentales sur l'ostéoporose aiguë. *Ann. Anat. Pathol.* 1961, 6, 497–501.
- [7] GHOSEZ J. P.: La microscopie de fluorescence dans l'étude du remaniement haversien. *Arch. Biol.* 1959, 70, 169–178.
- [8] COUTELIER L., DHEM A., VINCENT A.: La microscopie de fluorescence dans l'étude de l'ossification endochondrale. *Bull. Acad. Roy. Méd. Belg.* 1963, VII^e série, 3, 675–689.
- [9] DHEM A.: Le forage des canaux de Havers. *Rev. Chir. Orthop.* 1965, 51, 583–593.
- [10] DHEM A.: Le remaniement de l'os adulte. Thesis Univ. Louvain, Bruxelles, Éd. Arscia, Paris, Maloine 1967.
- [11] DURKIN J., HEELEY J., IRVING J.: Cartilage of the mandibular condyle. In: *Temporomandibular joint function and dysfunction*. Eds.: Zarb G. A., Carlsson G. E., Munksgaard, Copenhagen 1979, 43–100.
- [12] COULY G.: Structure fonctionnelle du condyle mandibulaire humain en croissance. *Rev. Stom. Chir. Maxillofac.* 1980, 81, 152–163.
- [13] BABSON S. G.: Growth of low birth weight infants. *J. Pediatr.* 1970, 77, 11–18.
- [14] VINCENT J.: Recherches sur la constitution de l'os adulte. Thesis Univ. Louvain, Éd. Arscia, Bruxelles 1955.
- [15] DHEM A., PIRET N.: Remarques à propos de la résorption ostéoclastique. *Bull. Assoc. Anat.* 1975, 59, 157–162.
- [16] GORET-NICAISE M.: La croissance de la mandibule humaine: conception actuelle. Thesis Univ. Louvain, Leuven, Nauwelaerts 1986.
- [17] GORET-NICAISE M., DHEM A.: The mandibular body of the human fetus. Histologic analysis of the basilar part. *Anat. Embryol.* 1984, 169, 231–236.
- [18] GORET-NICAISE M., DHEM A.: Comparison of the calcium content of different tissues present in the human mandible. *Acta Anat.* 1985, 124, 167–172.
- [19] SCOTT J. H., DIXON A. D.: *Anatomy for students of dentistry*. 4th edition. Churchill Livingstone, Edinburgh–London–New York 1978.
- [20] LEA L., PONLOT R.: Sur les autoradiographies au calcium⁴⁵ des os longs en croissance. Les mécanismes de l'apposition osseuse sous-périostée. *Arch. Biol.* 1958, 69, 455–465.
- [21] HUNTER J.: *The natural history of human teeth*. J. Johnson, London 1778.
- [22] GASPARD M.: *L'appareil manducateur*. Prélart, Paris 1978.
- [23] GORET-NICAISE M., MALDAGUE P., DHEM A.: Die histologische und mikroradiographische Untersuchung des alveolären Knochens am Unterkiefer. Abstracts Deutsche Gesellschaft für Kieferorthopädie. Wissenschaftliche Jahrestagung: Brüssel 1984, 8.
- [24] DHEM A., DAMBRAIN R., THAUVOY C., STRICKER M.: Contribution to the histological and microradiographic study of the craniostenosis. *Acta Neurochir.* 1983, 69, 259–272.
- [25] PILIPILI C. M., GORET-NICAISE M., DHEM A.: Microradiographic aspects of the growing mandibular body during permanent premolars eruption in dogs. *Eur. J. Oral Sci.* 1998, 106, Suppl. 1, 429–436.
- [26] PILIPILI C. M., GORET-NICAISE M., DHEM A.: Transversal mandibular body growth during prefunctional intraosseous eruption of permanent premolars in dogs (In press).
- [27] BERTOLINI R., WENDLER D., HARTMANN E.: Die Entwicklung der Symphysis mentis beim Menschen. *Anat. Anz.* 1967, 121, 55–71.
- [28] BOLENDER C.: Étude comparative du développement mandibulaire chez le fœtus de rat et chez le fœtus humain. Thèse Univ. Strasbourg 1972.
- [29] GORET-NICAISE M., DHEM A.: Les chondriola symphysea ou îlots meckéliens. *Arch. Biol.* 1983, 94, 207–220.
- [30] GORET-NICAISE M.: La symphyse mandibulaire du nouveau-né. Étude histologique et microradiographique. *Rev. Stom. Chir. Maxillofac.* 1982, 83, 266–272.
- [31] GORET-NICAISE M., DHEM A.: Presence of chondroid tissue in the symphyseal region of the growing human mandible. *Acta Anat.* 1982, 113, 189–195.
- [32] GORET-NICAISE M.: Die Symphysis menti beim menschlichen Feten. *Anat. Anz.* 1984, 156, 217–224.
- [33] GORET-NICAISE M.: Identification of collagen type I and II in chondroid tissue. *Calcif. Tissue Int.* 1984, 36, 682–689.
- [34] GORET-NICAISE M., DHEM A.: Electron microscopic study of chondroid tissue in the cat mandible. *Calcif. Tissue Int.* 1987, 40, 219–223.
- [35] DHEM A., GORET-NICAISE M.: Rôle du cartilage condylien dans la croissance mandibulaire. *Arch. Histol. Embryol.* 1979, 62, 95–102.
- [36] GORET-NICAISE M.: Influence des insertions des muscles masticateurs sur la structure mandibulaire du nouveau-né. *Bull. Assoc. Anat.* 1981, 65, 287–296.
- [37] GORET-NICAISE M.: Ueber das Wachstum des Unterkiefers beim Menschen. *Fortschr. Kieferorthop.* 1981, 42, 405–427.
- [38] GORET-NICAISE M.: Tierexperimentelle Vergleichuntersuchung mittels zweier extraoraler mandibulärer Kräfte. *Fortschr. Kieferorthop.* 1981, 42, 429–440.

- [39] AVIS V.: The relation of temporal muscle to the form of the coronoid process. *Am. J. Phys. Anthropol.* 1959, 17, 99–104.
- [40] SARNAT B. G., FEIGENBAUM J. A., KROGMAN W. F.: Adult monkeys coronoid process after resection of trigeminal nerve motor root. *Am. J. Anat.* 1977, 150, 129–138.
- [41] GORET-NICAISE M., MANZANARES M. C., BULPA P., NOLMANS E., DHEM A.: Calcified tissues involved in the ontogenesis of the human cranial vault. *Anat Embryol.* 1988, 178, 399–406.
- [42] DHEM A.: A propos du tissu chondroïde. *Bull. Acad. Natle. Méd.* 2001, 185, 81–89.
- [43] BERESFORD W. A.: Chondroid bone, secondary cartilage and metaplasia. Urban & Schwarzenberg, Baltimore–Munich 1981.
- [44] SANTONE P.: Transformazioni nella struttura della mandibola dell'uomo nelle varie eta. *Arch. Ital. Anat. Embriol.* 1939, 42, 234–337
- [45] ENLOW D. H.: Handbook of facial growth. Saunders, Philadelphia–London–Toronto 1975.
- [46] BURTON P., NYSSSEN-BEHETS C., DHEM A.: Haversian bone remodelling in human fetus. *Acta Anat.* 1989, 135, 171–175
- [47] DHEM A.: Le rat comme modèle expérimental en orthodontie. *Rev. Orthop. Dento-Faciale*, 1983, 40, 219–224.
- [48] CRAVEN A. H.: Growth in width of the head of the *Macaca Rhesus* monkey as revealed by vital staining. *AM. J. Orthod.* 1956, 42, 341.
- [49] SARNAT B. G.: Facial and neurocranial growth after removal of the mandibular condyle in the *Macaca Rhesus* monkey. *Am. J. Surg.* 1957, 94, 19.
- [50] BLACKWOOD H. J. J.: Vascularization of the condylar cartilage of the human mandible. *J. Anat.* 1965, 99, 551–563.
- [51] BAUME L. J.: Differential response of condylar, epiphyseal, synchondrotic and articular cartilages of the rat to varying levels of vitamin A. *Am. J. Orthod.* 1970, 58, 537–551.
- [52] PETROVIC A., STUTZMAN J.: Le muscle ptérygoïdien externe et la croissance du condyle mandibulaire. *Recherches expérimentales chez le jeune rat.* *Orthop. Fr.* 1972, 43, 271–283.
- [53] GORET-NICAISE M., DHEM A.: The morphological effects on the rat mandibular condyle of section of the lateral pterygoid muscle. *Eur. J. Orthod.* 1983, 5, 315–321.
- [54] AWIN M., GORET-NICAISE M., DHEM A.: Unilateral section of the lateral pterygoid muscle in the growing rat does not alter condylar growth. *Eur. J. Orthod.* 1987, 9, 122–128.
- [55] BOURGE A.: Quelques aspects de l'influence de la langue dans l'étiologie des malformations maxillo-faciales. *Acta Stomatol. Belg.* 1963, 60, 107–117.

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