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ORIGINAL ARTICLE

Endosteal blood supply of the mandible: anatomical study of nutrient vessels in the condylar neck accessory foramina

Matthieu Olivetto[1] · Jérémie Bettoni[1] · Jérôme Duisit[2,3] · Louis Chenin[4] · Jebrane Bouaoud[1] · Stéphanie Dakpé[1,5] · Bernard Devauchelle[1,5] · Benoît Lengelé[2,3]

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Abstract

Purpose In the mandible, the condylar neck vascularization is commonly described as mainly periosteal; while the endosteal contribution is still debated, with very limited anatomical studies. Previous works have shown the contribution of nutrient vessels through accessory foramina and their contribution in the blood supply of other parts of the mandible. Our aim was to study the condylar neck's blood supply from nutrient foramina.

Methods Six latex-injected heads were dissected and two hundred mandibular condyles were observed on dry mandibles searching for accessory bone foramina.

Results Latex-injected dissections showed a direct condylar medular arterial supply through foramina. On dry mandibles, these foramina were most frequently observed in the pterygoid fovea in 91% of cases. However, two other accessory foramina areas were identified on the lateral and medial sides of the mandibular condylar process, confirming the vascular contribution of transverse facial and maxillary arteries.

Conclusions The maxillary artery indeed provided both endosteal and periosteal blood supply to the condylar neck, with three different branches: an intramedullary ascending artery (arising from the inferior alveolar artery), a direct nutrient branch and some pterygoid osteomuscular branches.

Keywords Condylar neck · Mandibular condyle · Mandible blood supply · Arterial vascularization · Maxillary artery

Introduction

Condylar neck vascularization has a tremendous importance in many clinical situations, especially for traumatology, osteoradionecrosis or even allotransplantation. But the condylar neck blood supply is still debated and has been poorly studied. Indeed, perfusion of the mandible is usually divided in three main regions [5, 15]: 1) the angle and the horizontal branch, supplied by endosteal blood arising only from the inferior alveolar artery; 2) the symphysis, with a combined contribution of the periosteal and endosteal vascularization, through the submental artery (coming from the facial artery), the sublingual artery (coming from the lingual artery) and the incisive artery (coming from the inferior alveolar artery); and 3) the region up to the lingula mandibulae (ramus, condyle and coronoid process), also exhibiting a combined blood supply. Most of the experimental studies [5–7, 9, 10, 16, 20] have investigated the mandibular perfusion as a whole, without considering the specific topographic supply of the condylar neck. The endosteal blood supply is sometimes described as coming from an intraosseous ascending artery, arising from a division of the inferior alveolar artery, a few millimeters after penetrating the mandibular foramen [8]. Other authors have suggested that capillary networks from the temporomandibular joint

✉ Matthieu Olivetto
olivetto.matthieu@chu-amiens.fr

1 Department of Maxillofacial Surgery, University Hospital of Amiens-Picardy, Avenue René Laennec, 80000 Amiens, France

2 Department of Plastic and Reconstructive Surgery, Cliniques Universitaires Saint-Luc, Avenue Hippocrate 10, 1200 Brussels, Belgium

3 Department of Human Anatomy (MORF), UCLouvain, Avenue Mounier 52/B1.52.04, 1200 Brussels, Belgium

4 Laboratory of Anatomy and Morphogenesis, Université de Picardie Jules Verne, Chemin du Thil, 80025 Amiens, France

5 EA 7516 "CHIMERE" (UPJV), Facing Faces Institute, CHU SUD, Avenue Laennec, 80054 Amiens Cedex 1, France

capsule could also contribute to it [5]. Descriptive studies have shown the role of accessory foramina and their vascular contents in mandibular blood supply [2, 3, 13], especially for symphysis with lingual foramina [12, 14]. But no standardized descriptions are provided for this particular type of vascularization in the neck of the condylar region.

The aim of this study was then to provide a more extensive anatomical description of the condylar neck blood supply, emphasizing a possible direct perfusion through foramina, which were cautiously listed according to their location and frequency.

Methods

Specimens

Six fresh heads (three men and three women) and one hundred dry mandibles were used, all from obtainer from body donation at the UCLouvain department of Human Anatomy (Brussels, Belgium), and the University Picardie Jules Verne department of Anatomy (Amiens, France), following local ethical rules. Human fresh heads were injected with red-dyed latex and used to describe the vascularization of the condylar neck. Dry mandibles were then used to record and characterize vascular foramina in the condylar neck.

Latex-injected arterial study

Fresh heads were injected with red latex in the two common carotid arteries, and with blue latex in the two internal jugular veins. They were then fixed in a formaldehyde bath for 4 weeks. The six heads formed twelve hemi-facial areas of interest.

We incised the skin through a facelift approach, performed a total parotidectomy and resected the facial nerve, to gain full access to the infratemporal fossa. The external carotid artery was dissected along its axis, up to the superficial temporal artery. All branch of the pericondylar region was meticulously dissected; at that point, if branches for the lateral, and posterior surfaces of the condylar neck were found, photographs were taken. Thereafter, an osteotomy is performed to continue dissection on the medial side.

The mandibular angle and the temporal bone were resected to clearly expose the condyle (Fig. 1). After infratemporal release, the medial aspect of the condylar process was freed. The presence or not of an arterial branch to the condylar neck was then recorded. Then, the whole condylar process was isolated from surrounding tissue and a periosteal stripping was performed. An inspection of the condylar cortical bone surface was then realized, with careful attention paid to the presence and the precise location of foramina. Moreover, to detect any intramedullary ascending artery, transillumination and cross-sectional examination of the condyles were performed.

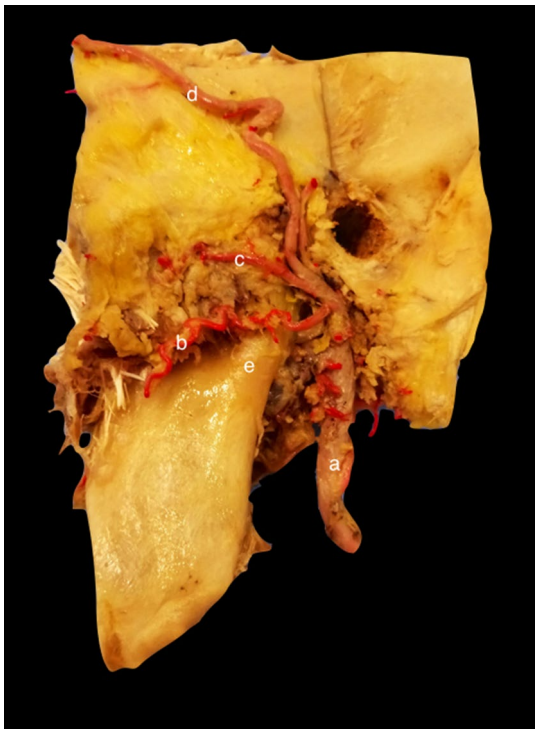

Fig. 1 Lateral view of a temporomandibular specimen after vascular dissection and osteotomy. a: External carotid artery, b: transverse facial artery, c: zygomatic-orbital artery, d: superficial temporal artery and e: condylar process

Dry mandibles study

The hundred mandibles procured two-hundred condylar processes for carefull inspection. The neck of the condylar process of the mandible was anatomically defined as the region under the articular surface of head of the mandible, descending to the mandibular notch. Four main regions of interest were distinguished: (1) the pterygoid fovea, corresponding to the surface of the lateral pterygoid muscle insertion, (2) the subcapital space, under the anterior joint capsule insertion, (3) the medial and (4) the lateral surfaces of the condylar process.

Foramina's location was determined by the distance from the basilar border of the mandible, in height and width. The distances between each foramen, the angle basilar border (h), and the total mandibular height (H) were measured. A ratio "h/H" was subsequently determined.

The distance (in millimeters) of the foramen from a tangent to the basilar border (l) was also determined (Fig. 2). In the pterygoid fovea, we documented only the number of foramina, when present.

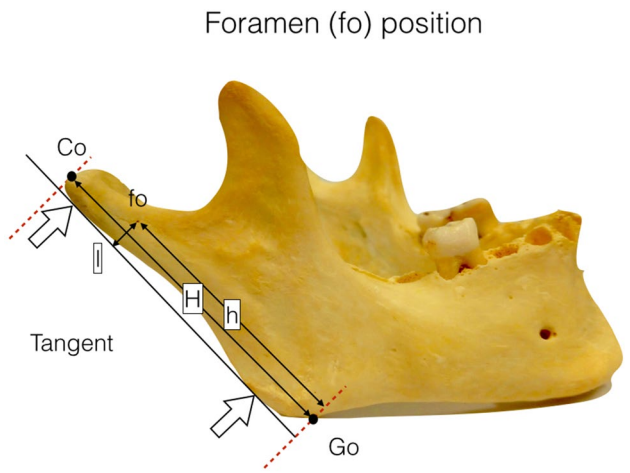

Fig. 2 Measuring methodology to determine foramina's location on the condylar neck. The height is determined by the ratio (*h*/*H*) with the distances between the foramina and the angular basilar border (*h*), and the total mandibular height (*H*) = distance between the gonion (Go) and the condyle apex (Co)

Statistical analysis

A statistical analysis of the foramina's position determined the 95% confidence interval of the ratio « *h*/*H* » and width (l) using Excel® (Office 2016). The correlation between the right and left side of a given mandible regarding the number and position of foramen has been calculated using the spearman's rank correlation coefficient. The numbers of foramina recorded in the fovea were calculated as minimum, maximum, mean, standard deviation and median.

Results

Vascular dissection

Among the 12 dissected hemi-facial regions, a condylar neck artery was found in one case, branching directly from the maxillary artery, half-way between its origin and the inferior alveolar artery origin; it penetrated the cortex through its medial face of the neck, at middle height, through a foramen which permitted to this branch to continue its route down into the medulla (Fig. 3).

By transillumination, we found in another specimen the existence of obvious endosteal blood supply, arising from an ascending intraosseous branch at the level of the mandibula foramen, from the main stem of the inferior alveolar artery (Fig. 4).

Dry mandible inspection

Foramina were found in four main regions: (1) on the pterygoid fovea (91% of cases, 182/200); (2) on the medial aspect of the condylar neck (6%, 12/200); (3) on the lateral aspect of the condylar neck (8%, 16/200); (4) along the "sub-capital" area (6.5%, 13/200) (Fig. 5). In the fovea, there was an average of 3.4 foramina/condyle (Table 1).

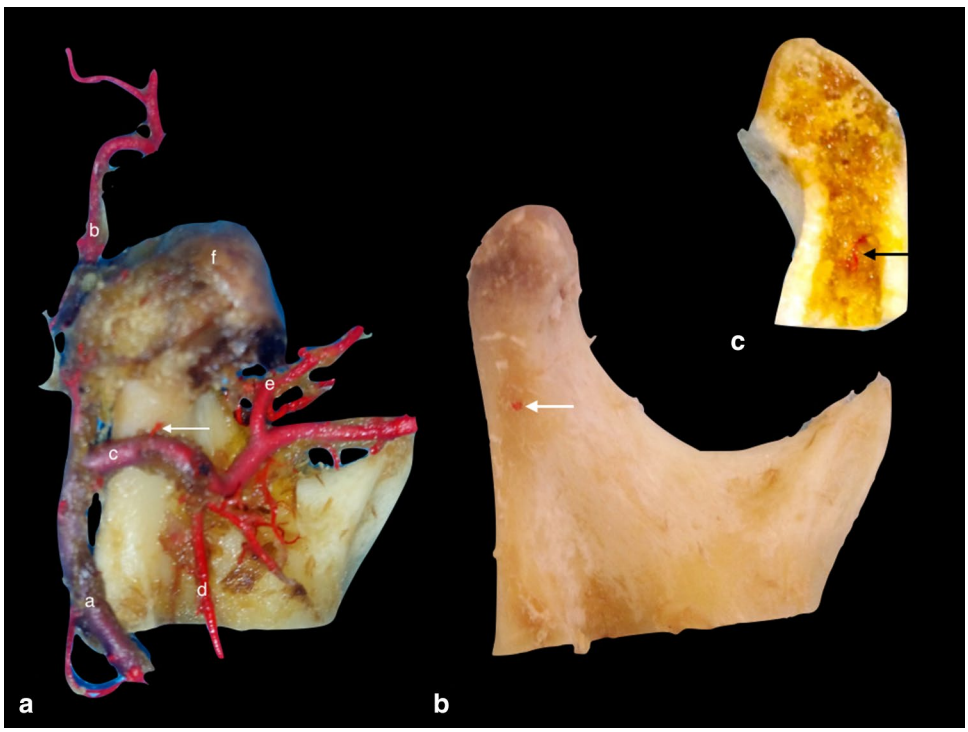

Fig. 3 **a** Medial view of a left condylar process with vascular dissection. a: External carotid artery, b: superficial temporal artery, c: maxillary artery giving a direct branch (←) for an accessory foramen located at the medial side of the condylar neck, d: the maxillary artery gives off the inferior alveolar artery, e: pterygoid muscular branches. **b** After periosteal stripping, the accessory foramen is located on the medial side of the condylar neck, and shows an obvious an arterial content. **c** Longitudinal section of the condylar process, in which the nutrient vessel is found

Fig. 4 Left medial side after mandibular periosteal stripping and latex vascular injection. a: Condylar process, b: coronoid process, c: lingula, →: ascending branch of the inferior alveolar artery to the condyle

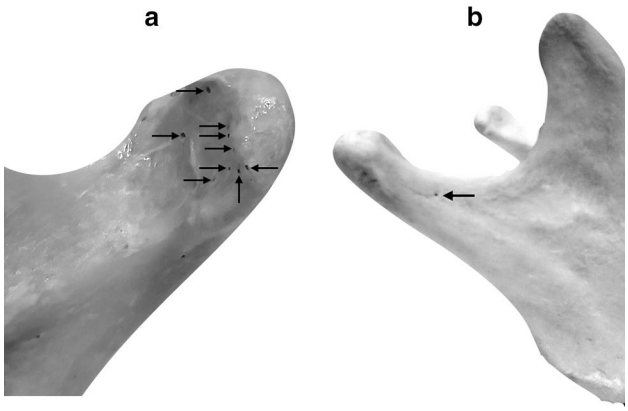

Fig. 5 Right medial view of a dry mandible condylar process **a** fovea with nine accessory foramina (→). Lateral view of a dry mandible **b** showing a single accessory foramen on the condylar neck

No correlation between the right and left sides, for a same mandible, was found ($r_s = 0.22$).The main locations of foramina on the medial side, lateral side and sub-capital area is summarized in Table 2 and Fig. 6. Depending on their location, the origin of the arterial content of the foramina was considered according to the results of vascular dissection (Fig. 7).

Table 1 Number of foramen into the pterygoid fovea (=200)

	Number of foramen into the fovea (=200)	Right condyle ($n=100$)	Left condyle ($n=100$)
Minimum	0	0	0
Maximum	14	14	9
Average	3.44	3.28	3.6
Standard deviation	2.67	3.08	2.25
Median	3.5	3	4

Discussion

This study has been completed by observing the presence of foramina at the level of the condylar neck that contain vascular elements. In the literature, between none and thirty-six accessory foramina could be identified for each whole mandible, with an average of eight [17]. Regarding their vascular content, an analogy may be drawn with the well-established anatomical work on mandibular lingual foramina. Careful dissections [14] have highlighted the presence of a neurovascular bundle, associated with each foramen considered. Other studies [11, 12, 19] have clarified the location of the lingual mandibular foramen, working on a large number of human dry mandibles.

We found foramina on the lateral side in 8% of cases: due to the vascular proximity along its course, we can consider that the transverse facial artery was involved. Foramina at the medial side (6% of cases) may contain branches directly arising from the maxillary arteries. The frequently observed foramina in the pterygoid fovea may contain muscular pterygoid vessels penetrating the cortex. Lateral pterygoidal muscle provides besides the well-described periosteal vascularization and endosteal blood supply to the condylar process [18]. Including the hypothesis of an ascending intramedullary artery, originating from the inferior alveolar artery, it can be established that the maxillary artery is the source of three types of endosteal vascularization of the neck of the mandibular condylar process. For the sub-capital region, it is more difficult to propose a systematic arterial source description, which seems to be originating from the joint capsule. Like any cadaveric studies, our specimens were very predominantly procured from elderly people: this could lead to an underestimation of the importance of endosteal blood supply to the mandibular condylar neck [1].

Traditionally, two main arterial sources for the condylar process are described [5], from articular and muscular origins: the first one originates from the vascular network of the temporomandibular capsule; the second one, from the lateral pterygoid muscle arteries. Authors report an endosteal blood supply by a branch of the inferior alveolar artery ascending forwards the condylar process [4, 8], not

Table 2 Location of foramen in the medial face, lateral face and sub-capital area

Number of observed cases	Lateral side foramens		Medial side foramens		Sub-capital area foramens	
	16/200 (8%)		12/200 (6%)		13/200 (6.5%)	
	Height (*h*/*H*)	Width (mm)	Height (*h*/*H*)	Width (mm)	Height (*h*/*H*)	Width (mm)
Average	0.752	11.43	0.752	10.36	0.845	11.41
Standard deviation	0.04	2.06	0.07	3.85	0.05	2.75
Coefficient of variation (%)	5.61	18.07	9.35	37.19	6.26	24.05
95% confidence interval	0.729; 0.774	10.3; 12.51	0.710; 0.793	8.1; 12.6	0.81; 0.87	9.86; 12.96

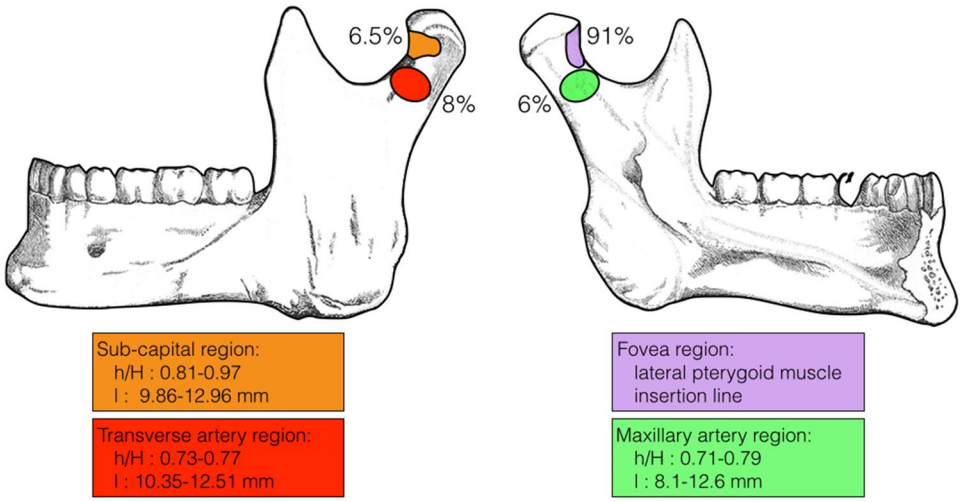

Fig. 6 Results summary of the dry mandibles inspections, providing the percentage of accessory foramina found for each of the four main regions; and their location (anatomical landmark for the fovea; 95% confidence interval for height and width, in the three other areas: lateral side, medial side and « sub-capital »)

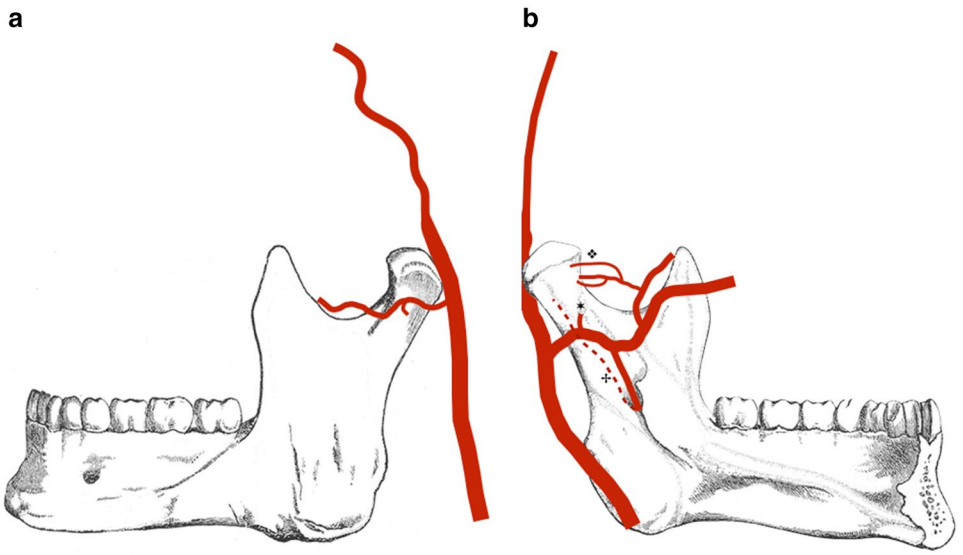

Fig. 7 Schema of endosteal vascular contributions: The transverse facial artery **a** giving a direct nutrient branch in an accessory foramen on the lateral face (8% of cases), the maxillary artery **b** providing a direct nutrient branch by an accessory foramen (✶), 6% of cases; after its division into pterygoid musclar branches and a course into the lateral pterygoid muscle through a foramen located in the fovea (❖), in 91% of cases; and along the inferior alveolar artery, by an intramedullary ascending branch destined to the condyle (✣), in 1 case out of 12 observed

unanimously recognized however. Literature also suggests a mixed condylar neck vascularization, with possibly a predominance of periosteal vascularization without quantifiable evidence [5, 18, 20, 21]. Toure [18] clarified the contribution of each arterial branch to the periosteal vascularization of the condyle. He retained three constant sources for the condyle: the superficial temporal artery, the posterior deep temporal artery and the arterial branches to the lateral pterygoid muscle arising from the maxillary artery. Wysocki [21] argued that the most reliable and consistent source of

condyle vascularization is the intramedullary ascending branch from the inferior alveolar artery. Emphasizing the role of the joint capsule, it is also the unique reference in the literature to report an endosteal blood supply of the condylar neck by nutrient vessels penetrating directly into the bone. Nevertheless, the very upper location of these arteries placed them quasi in the condylar head.

Conclusions

In this study, the existence of an endosteal blood supply of the neck of the mandibular condyle by nutrient arteries directly penetrating into the medullary by foramina has been proven. Vascular dissections have confirmed the vascular content of the foramina recorded in this region.

Foramina are most common in the pterygoid fovea. We highlight the predominant role of the maxillary artery. The maxillary artery has a role in the endosteal vascularization of the condylar neck: by direct nutrient branches (in its first portion), by various pterygoid muscular branches for the fovea (in its second portion) and by the intraosseous ascending artery branch of the inferior alveolar artery. The transverse facial artery also has a role that must be mentioned.

This study provides a systematic approach to the endosteal blood supply of the condylar neck, and provides arguments in favor of the vascular independence of this region compared to the rest of the mandible, explaining that it is rarely affected by post-radiotherapy or post-traumatic necrosis.

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Author contribution MO: data collection and analysis/manuscript writing. JB: data analysis/manuscript writing. JD: protocol development; data management; data analysis; manuscript writing/editing. LC: data collection and management. JB: data analysis/manuscript writing. SD: project development. BD: protocol/project development. BL: protocol/project development/data collection or management/manuscript writing/editing

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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