



# Arterial vascularization of the mandible and soft tissues. Anatomic study

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## Abstract

**Purpose** The literature has for too long described the arterial supply of the mandible as coming from a single artery, the inferior alveolar artery, and being of the terminal type. Rather, it appears to come from an extensive and complex arterial network dependent on the lingual, facial, and maxillary arteries and their collateral branches. Our study aims to confirm and demonstrate the arterial vascular richness of the mandible and to establish arterial mapping.

**Methods** The arterial vascularization of the mandible was revealed in six anatomic specimens after performing selective injections of the lingual, facial, and maxillary arteries with different dyes. A specimen was injected intra-arterially with colored latex at the level of the maxillary artery for a morphometric study.

**Results** Eighteen selective arterial injections were performed on six anatomic specimens. The mucocutaneous, musculoperiosteal, and intramedullary vascularizations were analyzed. Each of the arteries has a defined and delimited cutaneo-mucous vascular territory. The facial and maxillary arteries supply the musculoperiosteal vascularization of the mandible from the condyle to the symphysis. The lingual artery supplies only the inner cortex of the parasymphyseal and symphyseal regions. The facial and maxillary arteries provide intramedullary vascularization from the angle of the mandible to the parasymphysis. The vascularization of the symphysis depends on the facial artery. No staining was found in the condyle region. Neoprene latex injection was performed on an anatomic specimen, revealing a permeable anastomosis between the inferior alveolar and facial arteries.

**Conclusion** The arterial vascularization of the mandible is dependent on the maxillary, facial, and lingual arteries. This is a network vasculature. This study makes it possible to establish an arterial map of the mandible. The presence of an anastomosis between the inferior alveolar artery and the facial artery confirms the existence of dynamic and borrowed vascularization. Knowledge of this arterial system makes it possible to adapt maxillofacial surgical care and to anticipate possible intraoperative complications.

**Keywords** Mandible · Lingual artery · Facial artery · Maxillary artery · Arterial map

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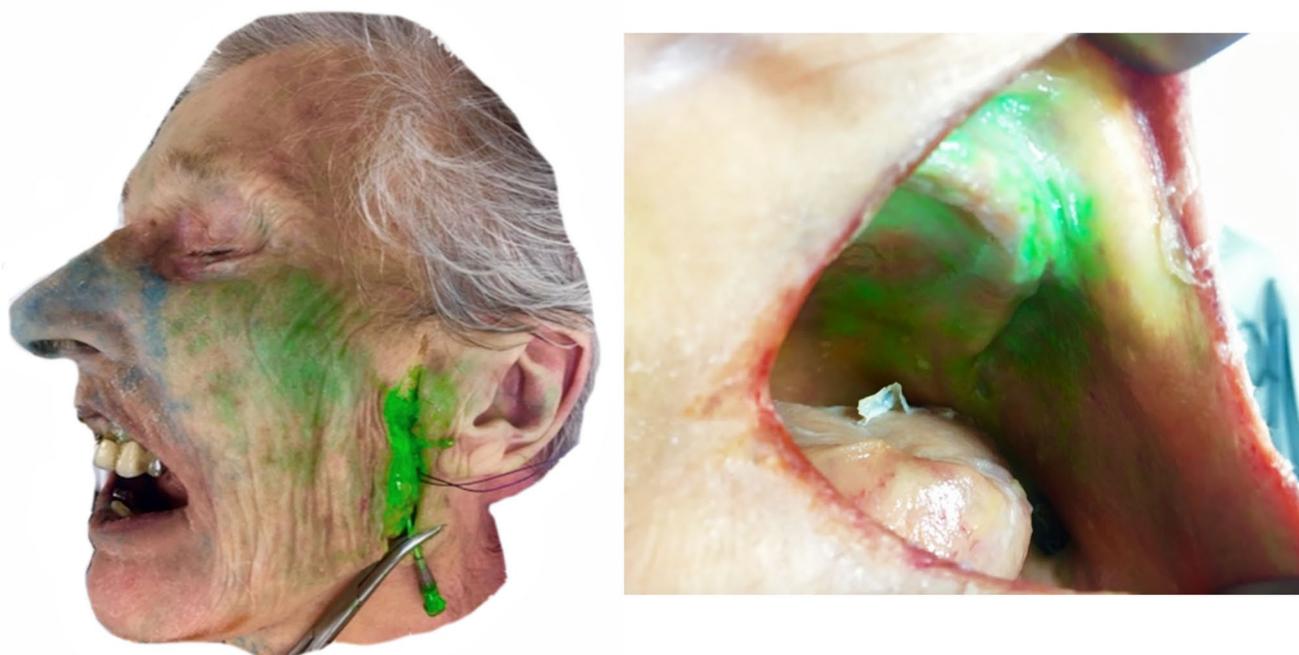
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**Fig. 1** Mucocutaneous mapping of the maxillary artery after arterial injection of a green dye (colour figure online)

## Introduction

The arterial vascularization of the mandible remains an underdeveloped subject in the literature, [4, 9, 14] in which it seemed to be exclusively dependent on the inferior alveolar artery from the maxillary artery [1, 3, 7, 12, 17, 18]. Thus, this facial bone would have an arterial vascularization of the terminal type, which seems inconceivable on the anatomophysiological level. Indeed, the mandible seems to benefit from a more complex and more extensive arterial network, depending on the lingual, facial, and maxillary arteries and their collaterals in an example of borrowed vascularization [10].

The main objective of this study was to define a map of the arterial territories of the mandible in the form of arterial subunits, revealing the complex origin of the arterial contributions. This study offers a functional and dynamic analysis useful in daily clinical practice.

## Methods

This monocentric anatomic study was performed at the anatomy laboratory of the Toulouse Medical Faculty from December 2019 to March 2020, using seven fresh cadavers from Paul Sabatier University's body donation program. The average post-mortem time before dissection was 7 days. The

studied population was the white inhabitants of Southern France. The main exclusion criterion was a scar in the cervicofacial region or any intervention, as this can compromise and invalidate dissections and intra-arterial injections. The other usual exclusion criteria are possible risks of viral contamination.

## Dissection technique

The corpses were placed in the prone position, and a slight cervical extension was made to expose the carotid sheath and facilitate the dissection of the lingual and facial arteries.

In the preauricular region, the maxillary artery is found and the superficial temporal artery exposed. By extending the incision in the cervical region, this allows access to the bifurcation of the external carotid artery in its two terminal branches.

The maxillary artery was injected on one side of each dissected mandible, and the facial and lingual arteries were injected selectively on the other. Each branch was catheterized with a 20–24 gauge catheter and injected with a mixture of sodium chloride and concentrated watercolor ink (Pebeo Colorex) at a pressure of 110 mmHg with a pressure infusion bag. On average, 20 ml of dye was injected to define an arterial territory. Dissections were made after cold storage for 48 h. The arterial vascularization of the mandible was studied according to three approaches: the



**Fig. 2** Mucocutaneous mapping of the facial artery after arterial injection of a blue dye (colour figure online)

mucocutaneous, musculoperiosteal, and intramedullary bone vascularization's.

The mucocutaneous vascularization was revealed by the definition of an arterial territory obtained immediately after injection of one or another artery (Figs. 1, 2, 3). This territory corresponds to a real angiosome.

The musculoperiosteal vascularization was studied after disarticulating the mandible, taking care to leave a muscular and, therefore, periosteal layer (Figs. 4, 5, 6, 7).

The intramedullary bone vascularization was studied with osteotomies performed on different mandibular regions: the subcondylar region (Sect. Introduction), the mandibular angle (Sect. Methods), and the parasymphysis region (Sect. Dissection technique) (Fig. 8).

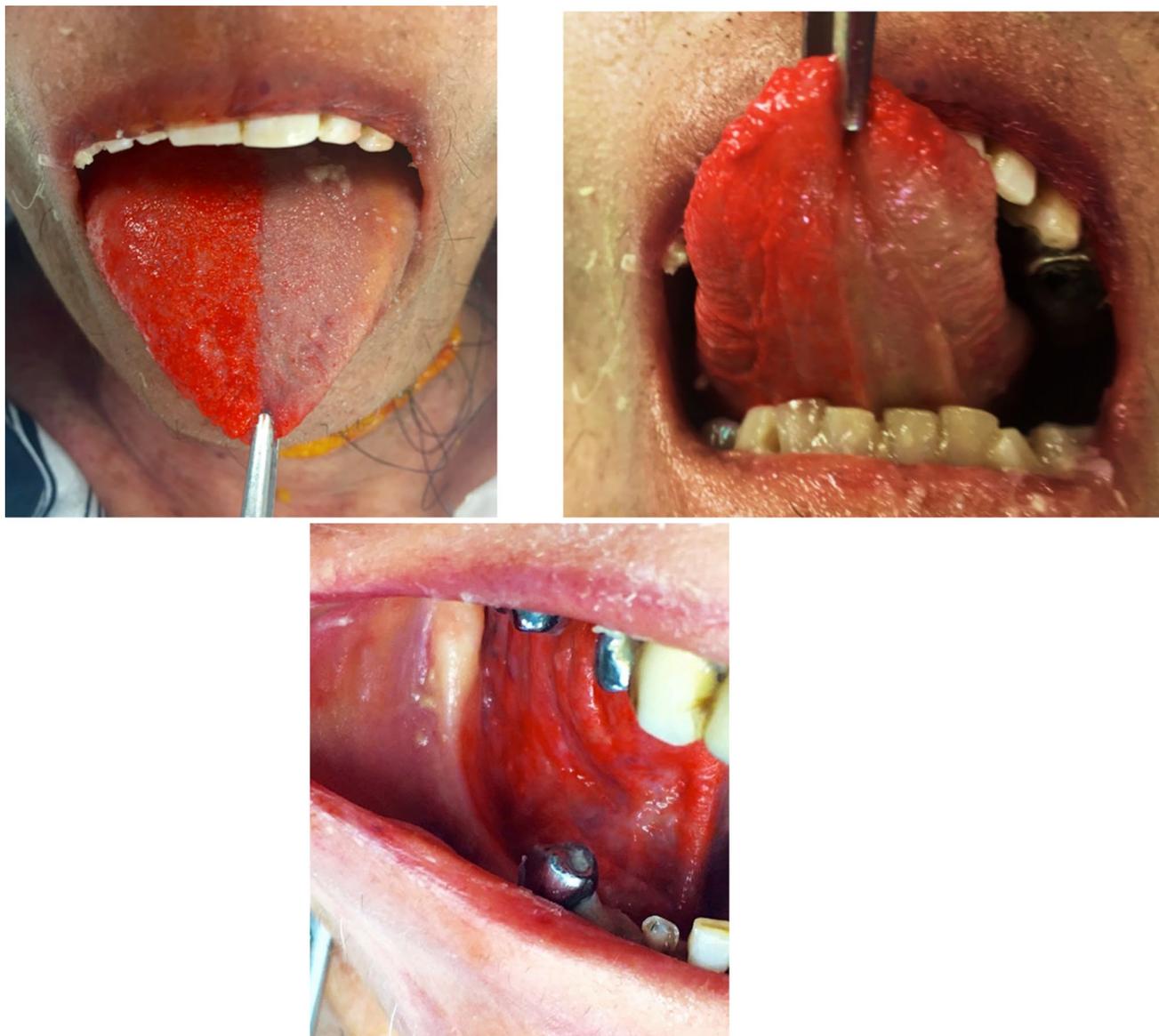
Figures 9, 10, 11, 12 show the revealed osseous territory after each injection.

One mandible was studied after injection of the maxillary arteries with colored Neoprene Latex 671 (UK, Dupont Limited®), which consists of 50% latex diluted in acetone, giving a milky-white suspension. It is colored

with a special dye, such as Biodur AC 50 red dye (Biodur® Heidelberg, Germany). This type of injection makes it possible to define the mandibular intramedullary vascularization on the one hand and, on the other, its diffusion at the level of other arteries, reflecting the existence of an anastomotic network. Moreover, the injection of colored latex allows a morphometric evaluation (Figs. 13, 14).

## Results

Seven anatomic dissections were performed. The subjects were all adult, Caucasian, and female, with an average age of 90 years. Six dissections were made after injection by different dyes in the maxillary, lingual, and facial arteries (18 injections in total). One dissection was made after injection into the inferior alveolar arteries with pink-colored latex.



**Fig. 3** Mucocutaneous mapping of the lingual artery after arterial injection of a orange dye (colour figure online)

The different approaches of this vascular study lead us to present the results in two forms:

- A description of the mucocutaneous territory, which depends on the maxillary, facial, and lingual arteries defining potential angiosomes (Figs. 1, 2, 3).
- Descriptions of the musculo-periosteal territory and the intramedullary bone vascularization in the different anatomical regions of the mandible (Figs. 4, 5, 6, 7).

### Selective arterial injections by dyes

#### Mucocutaneous territory

Injection of the maxillary artery leads to staining the zygomatic region's entire skin covering, including the infra-orbital region and the cheek. The revealed mucosal territory extends over the ipsilateral hemi-hard palate and hemi-soft palate, the ipsilateral upper vestibule to the maxillary tuberosity, and finally, the upper part of the cheek.

Unilateral injection of the facial artery stains the skin of the nasal, cheek, and perioral regions bilaterally, demonstrating the richness of the anastomoses between the right and left facial arteries. The mucosal territory of the facial artery



**Fig. 4** Musculoperiosteal mapping of the maxillary, facial and lingual arteries after the following arterial dye injections. Green for maxillary artery. Blue for facial artery. Orange for lingual artery (colour figure online)

is very wide and includes the whole cheek, the vestibules, and the mandibular gingiva up to the alveolar crest.

No cutaneous territory was observed after injection of the lingual artery in any of the dissections. Its mucous territory includes the ipsilateral tongue base, the ventral and dorsal surfaces of the hemitongue up to the tip and the ipsilateral pelvi-lingual furrow, and the ipsilateral mandibular gingiva.

#### Musculoperiosteal territory (Table 1)

The condyle is vascularized only by the maxillary artery. Indeed, in all the dissections, the condyle (on its external and internal cortices) and the inferior alveolar nerve, at the level of the mandibular foramen, were stained after injection of the maxillary artery. The musculoperiosteal vascularization of the angle and the body of the mandible was dependent

on the maxillary and the facial arteries (on the internal and external cortices) in all dissections.

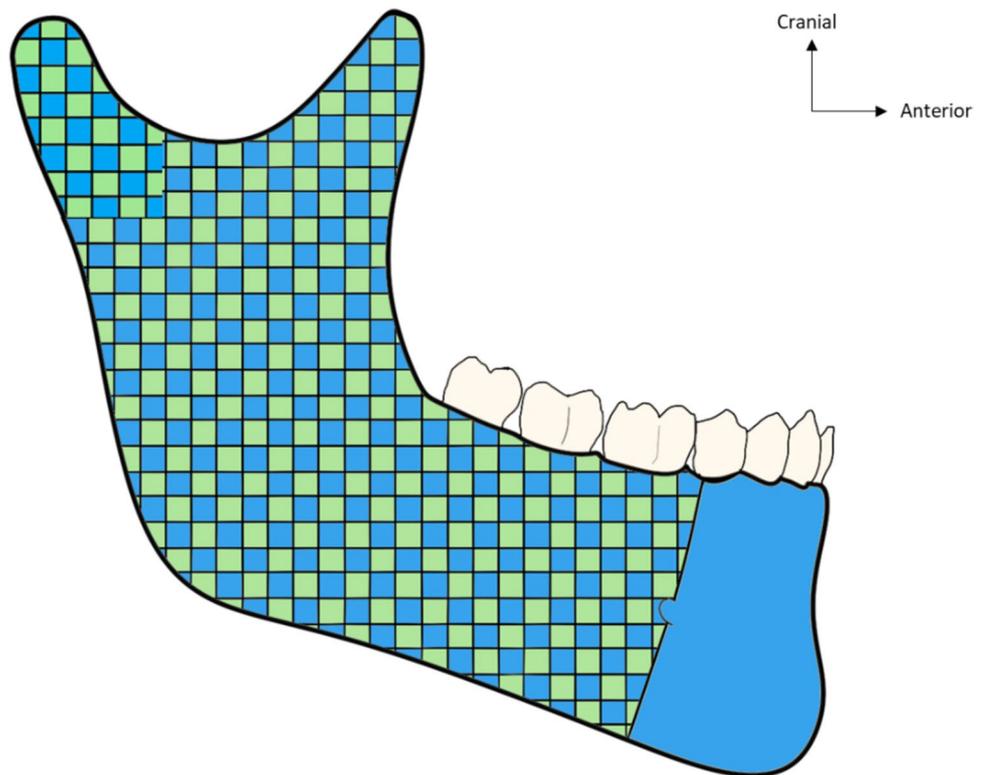
The musculoperiosteal vascularization of the parasymphysis is dependent on the maxillary, facial, and lingual arteries. The maxillary and facial arteries provide ipsilateral musculoperiosteal vascularization on the external cortical bone. The facial and lingual arteries provide ipsilateral musculoperiosteal vascularization on the internal cortical bone (Fig. 7).

The musculoperiosteal vascularization of the symphysis is dependent on the facial and lingual arteries. The facial artery provides blood supply to the external and internal cortices bone, while the lingual artery only supplies the internal cortical bone.

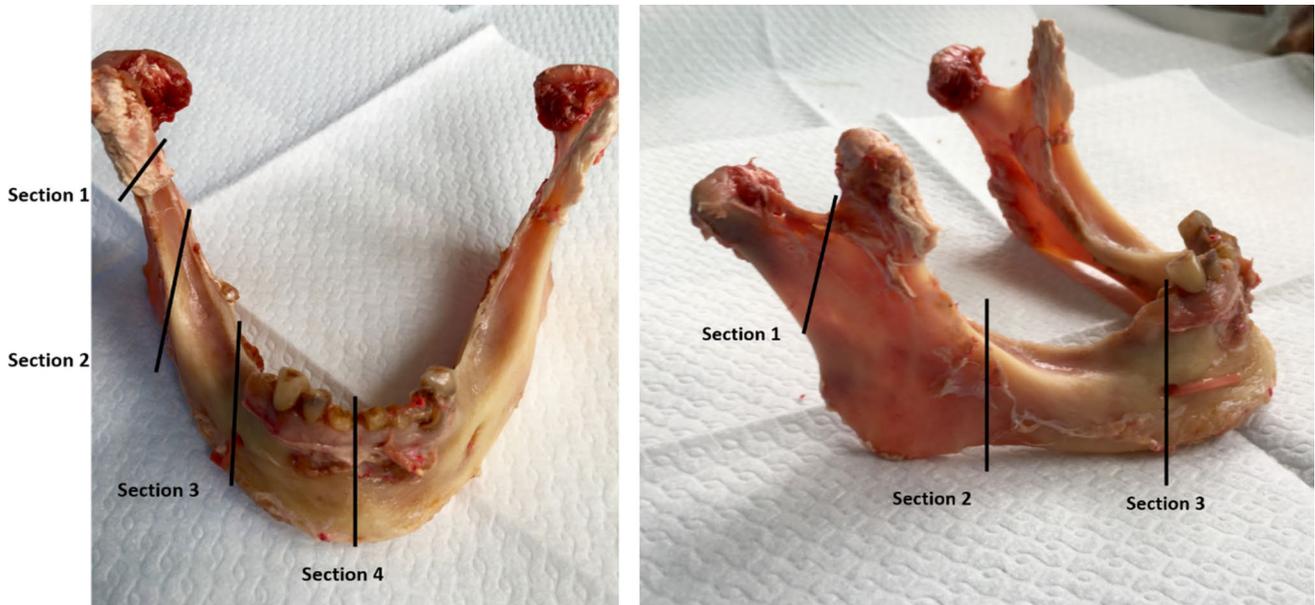
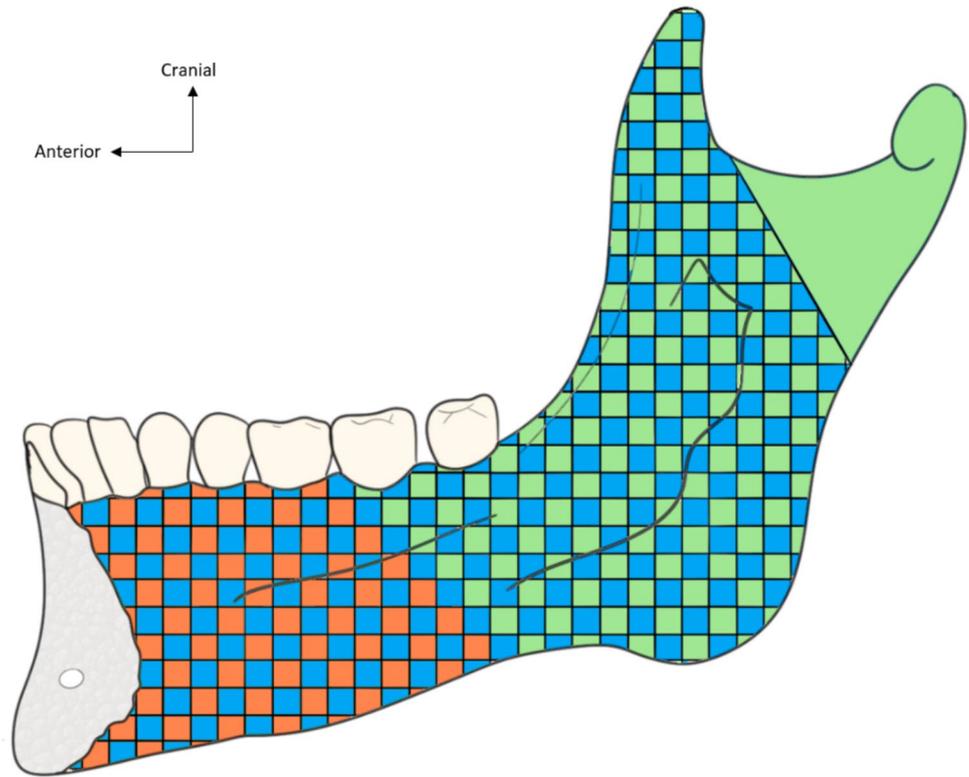


**Fig. 5** Musculoperiosteal mapping of the lingual artery outlined in red for better visualization (orange dye used) (colour figure online)

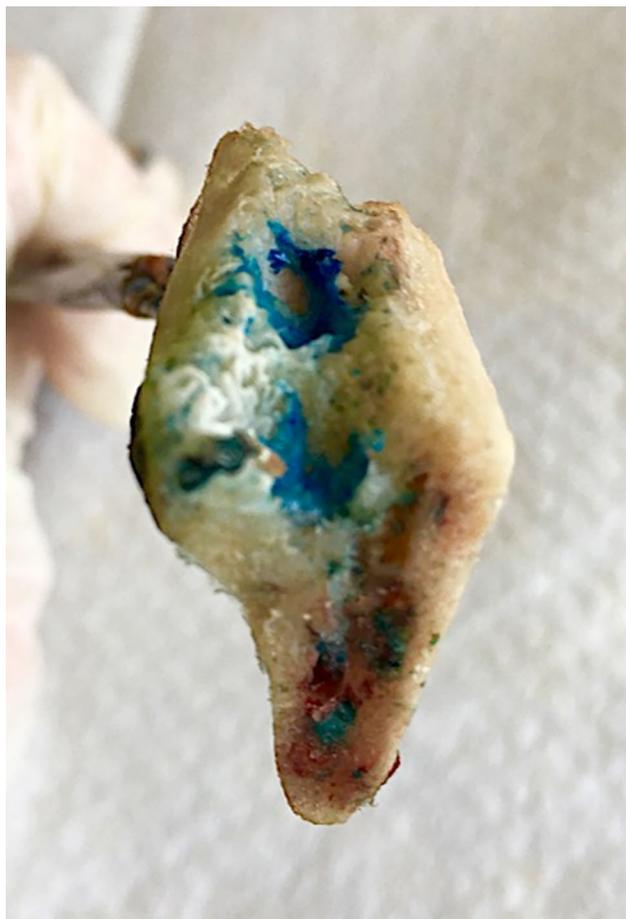
**Fig. 6** Musculoperiosteal arterial territories of the external cortical of the mandible (maxillary artery in green, facial artery in blue) (colour figure online)



**Fig. 7** Musculoperiosteal arterial territories of the internal cortical of the mandible (maxillary artery in green, facial artery in blue, lingual artery in orange) (colour figure online)



**Fig. 8** Different osteotomies used to study the intramedullary bone vascularization



**Fig. 9** Illustration of the intramedullary vascularization of the horizontal branch and the angle of the mandible on a posterosuperior view after injection of a blue dye in the maxillary artery (colour figure online)

#### Intramedullary bone vascularization (Table 2)

In all cases, the osteotomy performed at the level of the angle or the horizontal branch of the mandible found intramedullary staining after injection of the maxillary artery. The inferior alveolar artery, collateral to the maxillary artery, therefore ensures the intramedullary vascularization of this region by traversing the mandibular canal (Figs. 9, 10, 11, 12).

The medulla of the subcondylar segment did not appear stained in the six mandibles studied. The intramedullary vascularization of the mandibular condyle seemed poor and essentially dependent on a musculoperiosteal supply (Fig. 10). In most cases, the intramedullary staining depended on the maxillary artery at the level of the basilar edge of the angle of the mandible (Fig. 11).

The intramedullary vascularization of the parasymphysis is dependent on the maxillary and facial arteries. Indeed, whether after injection of the maxillary artery or the facial

artery, the intramedullary portion of the parasymphysis takes on the coloration of the respective injected arteries (Fig. 12). The lingual artery did not participate in the intramedullary vascularization of the mandible. Finally, the intramedullary vascularization of the symphysis solely depended on the facial artery in all our dissections (Fig. 12).

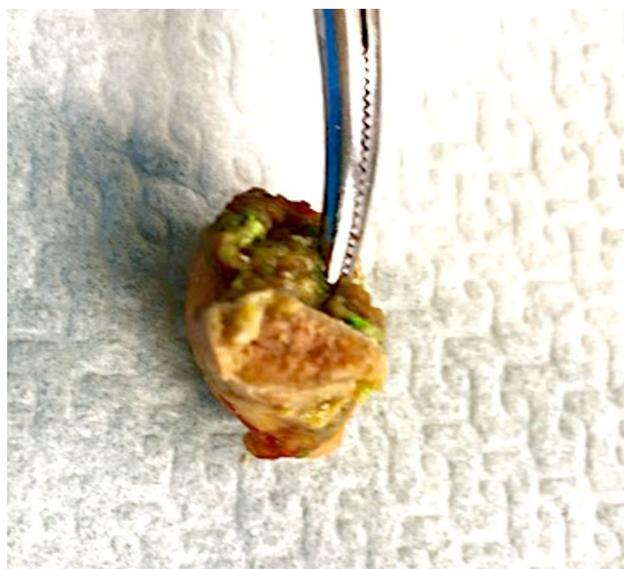
#### Neoprene latex injections

Intra-arterial injection with neoprene latex was performed in the two maxillary arteries of the studied mandibles. The inferior alveolar artery was stained at its origin (mandibular foramen) within the mandibular canal and at its emergence at the level of the mental foramen (mental artery). The inferior alveolar artery has an average caliber of 1 mm within its channel in the body. This injection confirms the arterial supply of the inferior alveolar artery in the intramedullary bone vascularization (Fig. 13).

The most relevant finding of this injection was the retrograde staining of the two facial arteries, which showed patent anastomoses between the inferior alveolar arteries and the facial arteries (Fig. 14).

#### Discussion

In the literature, the arterial vascularization of the mandible is commonly described by taking into account three main anatomical regions [3, 11–13, 15, 16, 19]:



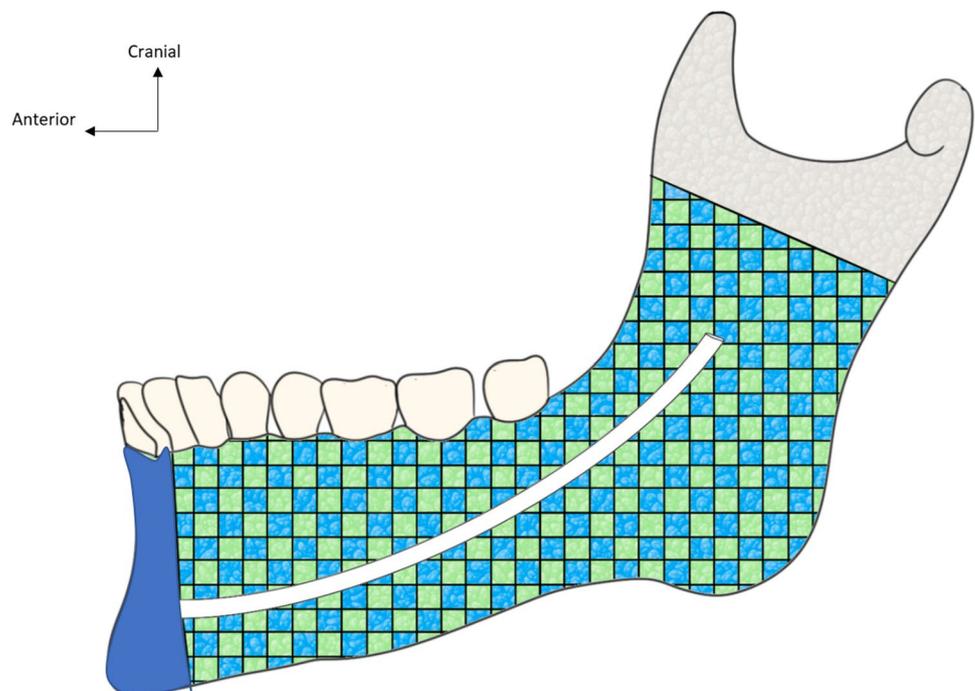
**Fig. 10** Subcondylar region showing the absence of coloring of the spongy bone, despite the injection of a green dye in the maxillary artery (colour figure online)



**Fig. 11** Illustration of the intramedullary vascularization of an angle of the mandible on an anterosuperior view after injection of an orange dye in the facial artery (colour figure online)

- The angle and the body are preferentially vascularized by an intramedullary supply from the inferior alveolar artery.

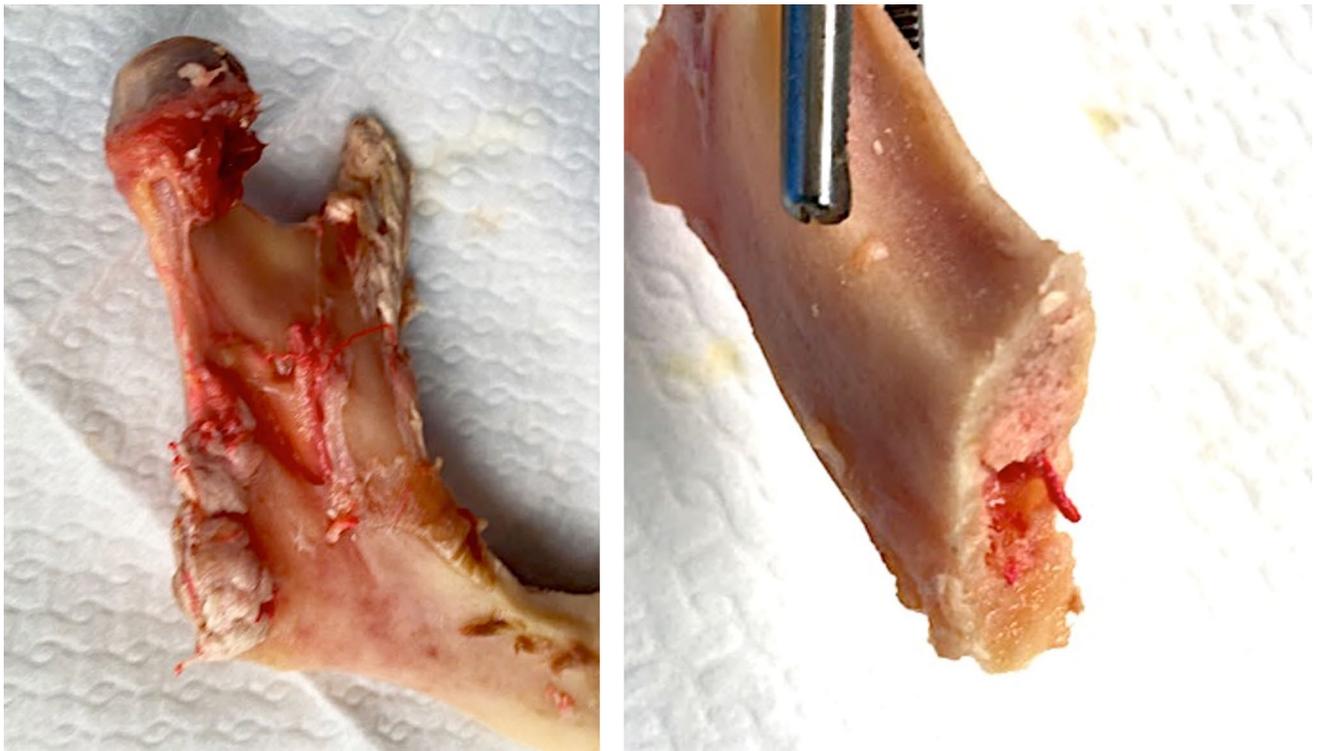
**Fig. 12** Intramedullary arterial territories of the mandible (maxillary artery in green; facial artery in blue) (colour figure online)



- The symphysis has both periosteal and intramedullary vascularization provided by the submental artery (collateral to the facial artery), the sublingual artery (collateral to the lingual artery), and the incisor artery (collateral to the inferior alveolar artery).
- The region above the lingula (ramus, condyle, and coronoid process) has dual vascularization, periosteal and intramedullary, provided by the maxillary artery and its collaterals.

In our study, this musculoperiosteal and intramedullary vascularization were very similar. Nevertheless, we did not detect any intramedullary arterial supply within the condyle and the subcondylar region, thus testifying to a preferential musculoperiosteal vascularization. However, in all the dissections carried out, we found that the lingual artery does not participate in the intramedullary vascularization of the mandible. This artery participates in the mandibular blood supply through its musculoperiosteal supply. This supply constitutes part of the mucosal territory of the lingual artery (via the sublingual artery) described by Lopez et al. [8].

Bhattacharya et al.'s [1] cadaver specimen study highlights a single anastomosis between the facial artery and the inferior alveolar artery. This aberrant anastomosis, with a diameter of 1.1 mm at its origin, is located at the level of the facial artery facing the basilar edge of the mandible, goes up the ramus inside the masseter muscle, then crosses the body through a foramen before joining the inferior alveolar artery. This anastomosis could not be formally demonstrated in our study. However, during our



**Fig. 13** Intramedullary arterial supply of the inferior alveolar artery after injection of Neoprene Latex in the maxillary artery

**Fig. 14** Illustration of Neoprene Latex staining of the facial artery after injection of the maxillary artery



dissections, the study of the intramedullary vascularization of the angle and the body revealed the involvement of the facial artery on two hemimandibles. This observation, already mentioned by Kawai et al. [6], suggests

the existence of a patent anastomosis between the inferior alveolar artery and the facial artery near the corpus of the mandible.

**Table 1** Participation of the maxillary, facial, and lingual arteries in the musculo-periosteal vascularization of the six dissected mandibles

	Maxillary artery	Facial artery	Lingual artery
Condyle	6	0	0
Angle and body	6	6	0
Parasymphysis	6 (external cortical bone)	6 (external and internal cortices bone)	6 (internal cortical bone)
Symphysis	0	6 (external and internal cortices bone)	6 (internal cortical bone)

**Table 2** Participation of the maxillary, facial, and lingual arteries in the intramedullary vascularization of the mandible according to the different levels of osteotomies on the six dissected mandibles

	Maxillary artery	Facial artery	Lingual artery
Condyle	0	0	0
Angle and body	6	2	0
Parasymphysis	6	6	0
Symphysis	0	6	0

The rich arterial vascularization of the mandibular condyle is known and demonstrated [2, 5, 16]. It comes from several arteries including the maxillary artery (and its lateral pterygoid, masseteric branches), the superficial temporal artery, the facial transverse artery which form a true condylar arterial circle [16].

The risks of necrosis of the mandibular condyle, during a displaced fracture, remain moderate if the insertion of the lateral pterygoid muscle is preserved [16]. During invasive surgery of the condylar region, these risks of necrosis are greater [11].

## Conclusion

Our study makes it possible to determine the arterial territories of the mandible. The presence of an anastomosis between the inferior alveolar artery and the facial artery confirms the existence of dynamic and borrowed vascularization. Knowledge of this arterial system makes it possible to adapt maxillofacial surgical care and to anticipate possible intraoperative complications.

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**Author contributions** P Jeanneton and R Lopez contributed to the study conception and design. Material preparation, data collection and analysis were performed by P Jeanneton. The first draft of the manuscript was written by the first author and all authors commented

on previous versions of the manuscript. All authors read and approved the final manuscript.

**Data availability** The corresponding author and other authors of this article declare the availability of the data to the publisher of this journal.

## Declarations

**Conflict of interest** The authors have no conflicts of interest to declare regarding the materials or methods used in this study or the findings presented in this paper.

**Ethical approval** All procedures in this study were performed in accordance with the ethical standards of the institutional research committee, and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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