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REVIEW

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The orobasal organ (of Ackerknecht): A bizarre structure of the mammalian oral cavity

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Abstract

Vestigial organs are considered to have lost most or all of their functions through evolution. However, these structures can give insights into the phylogenetic history of species. Additionally, vestigial organs can be of clinical importance, since these structures might be confused with pathologies. The orobasal organ of Ackerknecht was discovered by and named after the veterinary anatomist Eberhard Ackerknecht. In 1912, he described morphologically highly variable epithelial invaginations behind the lower medial incisors in different mammalian species. The orobasal organ is considered a rudimentary structure without physiological function, but the evolutionary history of the orobasal organ remains unknown, so far. In this review, we sum up the actual knowledge about the orobasal organ and discuss possible origins of this structure. With this review, we hope to increase awareness of this anatomical structure, and thereby decrease the risk of confusion with a pathological condition like oral cancer.

KEYWORDS
comparative anatomy, dentistry, evolution, oral mucosa, vestigial organs

1 | INTRODUCTION

Vestigial anatomical structures are considered to have lost much or all of their function through evolution. These structures (e.g., eyes in some subterrestrial animals, rugae palatinae in humans) can give insights into the phylogenetic history of species (Dhawan et al., 2023; Smith & Wright, 2018). Additionally, vestigial structures can be of clinical importance since these structures might be confused with or be the source of pathologies (e.g., hamartoma of the juxtaoral organ of Chievitz; Ide, 2003). The orobasal organ is a rudimentary organ of the oral floor in mammals. The name "organ of Ackerknecht" refers to the discoverer Eberhard Ludwig August Ackerknecht (1883–1968), a German and Swiss veterinary anatomist. In 1912 Ackerknecht found this "bizarre" organ during examination of horse jaws and described it as "regular presence of two peculiar, often symmetrical, often asymmetrical, often unequally formed openings in the lower jaw behind the medial incisors in the mucous membrane of the floor of the mouth" (Ackerknecht, 1912). Histologically, Ackerknecht found "a blind-ending duct with epithelium that is invaginated to varying degrees, which is developed in varying degrees and arches into the mucous membrane towards the tongue" (Figure 1; Ackerknecht, 1912). The main focus of this narrative review lied on the identification of all primary research performed on the orobasal organ. Since most literature about this structure is not accessible online we performed a manual literature search in academic libraries in Europe and Asia, to make this information accessible to the public.

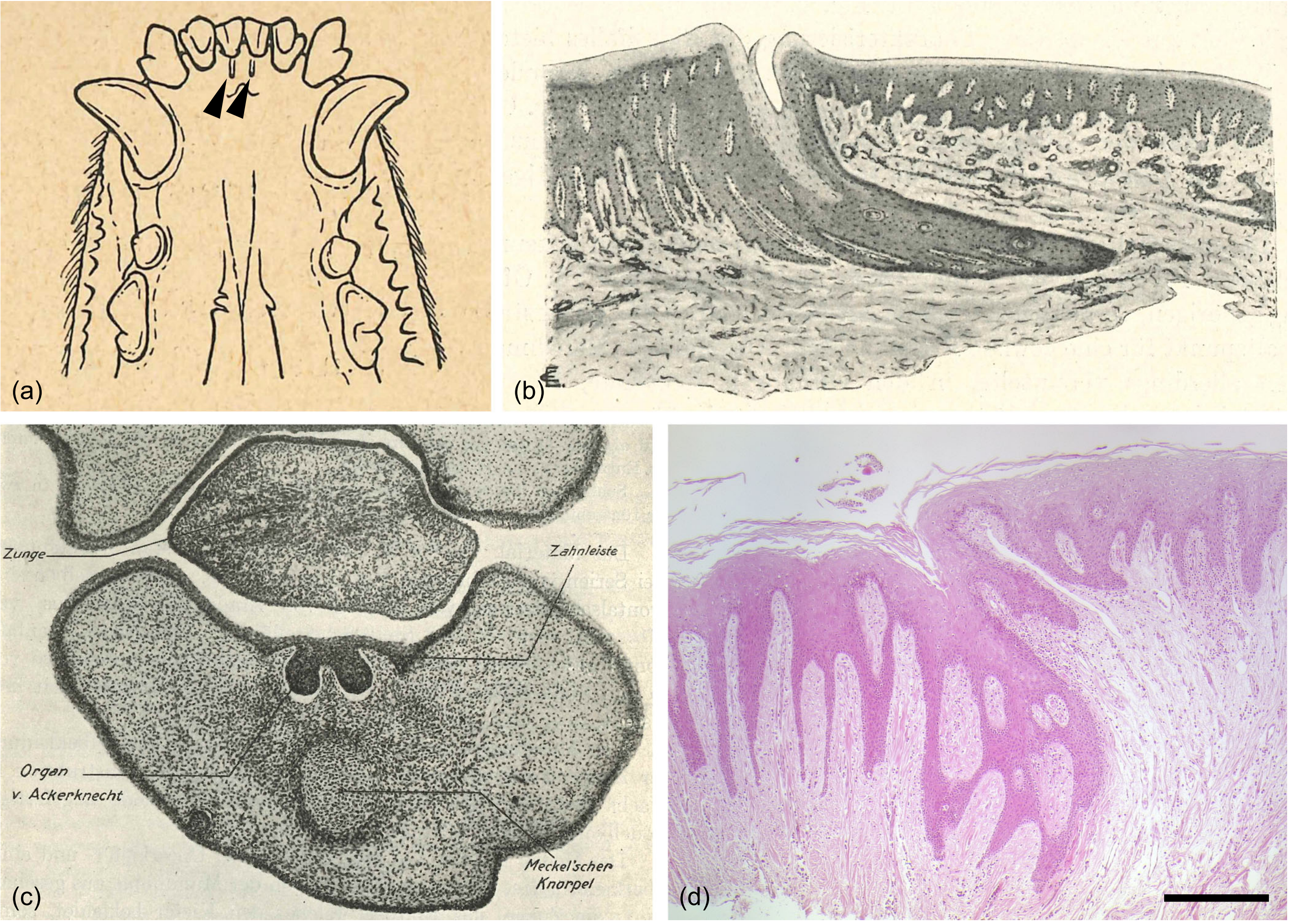

FIGURE 1 (a) Macroscopical drawing of the lower jaw of a dog. The orobasal organ is visible as two parallel ridges (arrowheads) behind the lower incisors (Keller, 1922). (b) Drawing of the orobasal organ of a stallion from the first publication of Ackerknecht on this topic (Ackerknecht, 1912). On the left side, the lingual gingiva is shown, on the right side, the oral mucosa. The orobasal organ impresses as an epithelial cone with a small pit on the surface. (c) Frontal section of the head of a pale-throated sloth. Tongue (Zunge), dental ridge (Zahnleiste), Meckel's cartilage (Meckel'scher Knorpel) and orobasal organ (Organ v. Ackerknecht) are labeled (Coebergh, 1930). (d) Microscopic photograph of a human orobasal organ. On the left side, the lingual gingiva is shown, on the right side the oral mucosa (Hematoxylin and eosin staining, bar = 250 µm).

2 | PUBLICATIONS ABOUT THE OROBASAL ORGAN

We were able to identify 23 primary research articles about the orobasal organ (Table 1). We defined an article as primary research article when the authors presented original macroscopic and/or microscopic investigations. Seventeen of the twenty-three papers on the orobasal organ were published in German language (74%), one in Italian, one in Japanese, and one in Russian. The first and only study in English was published by our group in 2022. The dominance of German articles might explain the poor international recognition of the orobasal organ. Ackerknecht himself published three papers related to "his" organ (Ackerknecht, 1912, 1913a, 1913b). As a supervisor, Ackerknecht assigned four doctoral theses on the orobasal organ to German speaking doctoral students leading to publications (Ackermann, 1924; Eberle, 1925; Keller, 1922; Tanner, 1926). Another doctoral student and later collaborator of Ackerknecht, Erich Künzel, dedicated a publication on this topic to an anniversary of his mentor (Künzel, 1953). Thus, eight works about the orobasal organ are directly related to the discoverer Eberhard Ackerknecht.

2.1 | The orobasal organ in mammals

Interestingly, only mammals were investigated regarding the occurrence of the orobasal organ. We were able to identify a number of more than 568 investigated individuals (Figure 2). Unfortunately, no number of investigated cases was given for the Syrian hamster (*Mesocricetus auratus*; Künzel, 1953), cattle (*Bos taurus*; Callegari & Sagri, 1964), sheep embryos (Ackerknecht, 1912) and humans (Nishiyama, 1933). Hence, no absolute number of investigated individuals could be determined from primary literature.

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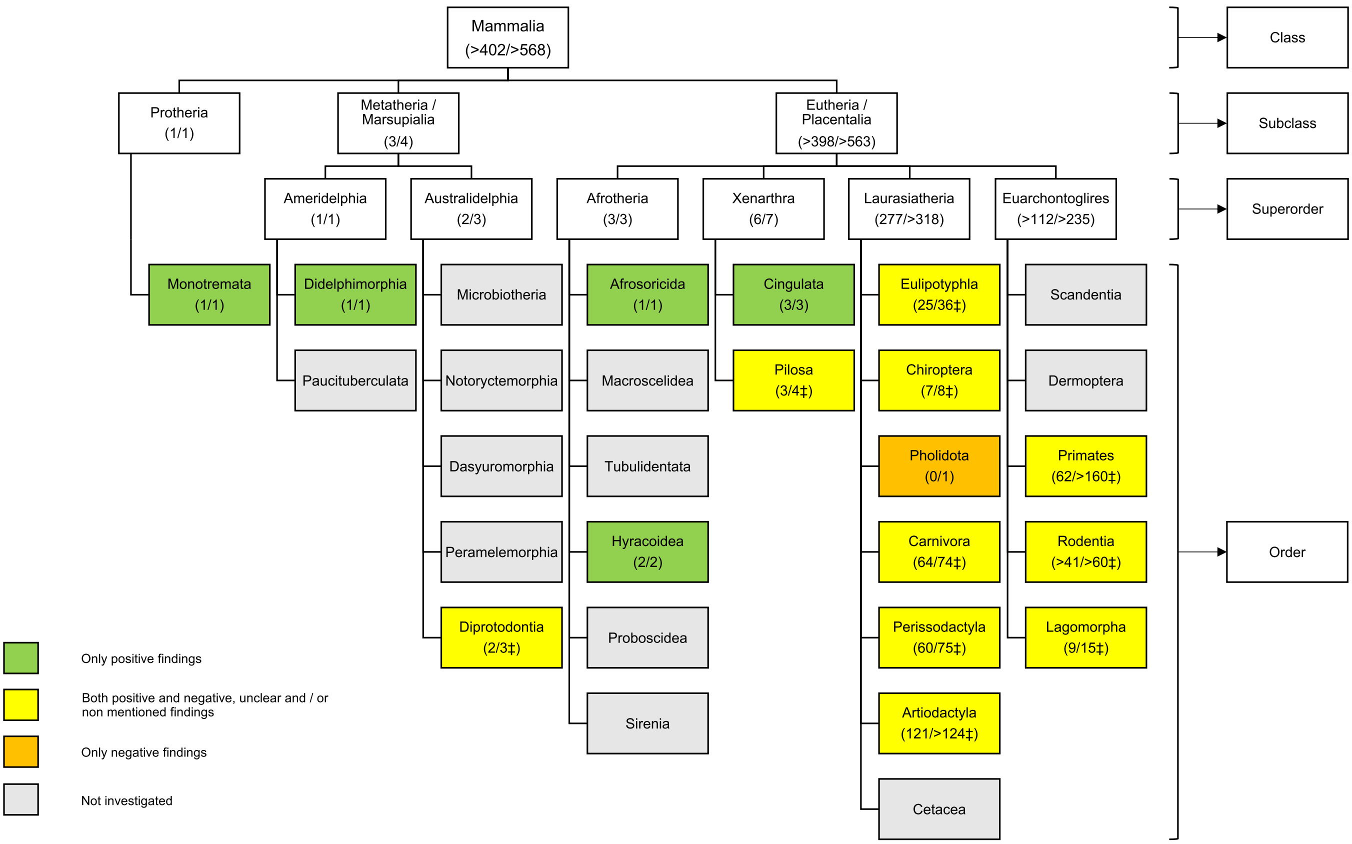

FIGURE 2 Cladogram of subclasses, superorders, and orders of the class Mammalia. The colors represent findings of orobasal organs. Orders in green showed only positive findings, orders in orange only negative. Orders in yellow showed both positive and negative, unclear and/or nonmentioned findings and gray orders were not investigated. The first number in brackets indicates the positive findings, the second number is the investigated individuals. If the number of cases (positive findings and/or investigated individuals) was not mentioned in a publication, a > was added. ‡Indicates that more than one species was investigated.

The class Mammalia (mammals) divides into the subclasses Protheria, Metatheria/Marsupialia (marsupials) and Eutheria/Placentalia (higher mammals) (Westheide & Rieger, 2015). The subclass Protheria with the only recent order Monotremata was examined and diagnosed positive for the occurrence of an orobasal organ in only one case of a platypus (*Ornithorhynchus anatinus*) (Ackerknecht, 1912). In the subclass Marsupialia, four animals were examined. One case belonged to the order Didelphimorphia and three cases to the order Diprotodontia. In the case of Didelphimorphia a common opossum (*Didelphis marsupialis*) was diagnosed positive. One case of Diprodontia, a bridled nail-tail wallaby (*Onychogalea fraenata*), did not show an orobasal organ. However, it was found in a red kangaroo (*Osphranter rufus*) and a black-striped wallaby (*Notamacropus dorsalis*) (Ackermann, 1924). While a singular case does not finally prove the existence of the orobasal organ in Protheria, it is most likely that the orobasal organ is a normal structure in Metatheria.

The subclass of Eutheria subdivides into the superorders Afrotheria, Xenarthra, Eucharchontoglires, and Laurasiatheria (Westheide & Rieger, 2015). The huge differences in the number of investigated individuals in the different superorders (three in Afrotheria, seven in Xenarthra, more than 234 in Eucharchontoglires, and more than 319 in Laurasiatheria) might be explained by the natural habitat of Afrotheria (mainly located in Africa; Westheide & Rieger, 2015) and Xenarthra (in America; Kraft, 1995), which make them not easy accessible for European researchers. From the Afrotheria, one case of Afrosoricida (*Tenrec ecaudatus*) and two cases of Hyracoidea (hyraxes) (*Procavia syriaca* and *Procavia habessinica*) were analyzed and found positive. Both orders of Xenarthra (Cingulata and Pilosa) (*Dasypus peba* for Cingulata; *Tamandua tetradactyla*, *Bradypus tridactylus* and *Choloepus* spec. for Pilosa) were analyzed (seven individuals) and the orobasal organ was found in both.

The superorder Laurasiatheria can be divided into the orders Eulipotyphla (insectivores), Chiroptera (bats), Pholidota (pangolins), Carnivora (predators), Perissodactyla (odd-toed ungulates), Artiodactyla (even-toed ungulates) and Cetacea (whales; Westheide & Rieger, 2015). Whilst for most orders several cases were analyzed, only one case of Pholidota, a Chinese pangolin (*Manis pentadactyla*), was studied and diagnosed negative. Fahrenholz wrote in the textbook of comparative anatomy of vertebrates (Bolk et al., 1937), that a structure corresponding to an orobasal organ was already described by Pouchet and Beauregard in sperm whales in 1892 (Pouchet & Beauregard, 1892), 20 years before the first description by Ackerknecht. Additionally, he wrote that he was able to find an orobasal organ in porpoises. Unfortunately, we were not able to identify an original publication on this topic by Fahrenholz, so the situation in Cetacea remains obscure.

The superorder of Euarchontoglires divide into the orders Scandentia (shrews), Dermoptera (giant gliders), Rodentia (rodents), Lagomorpha (hare-like species), and Primates (Westheide & Rieger, 2015). Since rodents and rabbits are important animals in basic medical research, the fact that the orobasal organ is present in Rodentia and Lagomorpha might help to clarify a potential function of this structure. There is no information about the orobasal organ in Scandentia and Dermoptera.

2.2 | The orobasal organ in primates

With more than 160 individuals, the order Primates is the most intensively examined order of mammals. This is quite easy to understand since this order includes our own species. The order Primates is subdivided into the suborders Strepsirrhini (wet-nosed primates) and Haplorhini (dry-nosed primates; Figure 3). The Strepsirrhini are further subdivided into the suborders Lemuriformes (lemurs) and Lorisiformes (loris-like). No representatives of Strepsirrhini were analyzed. Since these animals are endangered species, access to material is problematic. This may explain why the suborder Strepsirrhini was not examined.

The suborder Haplorhini can be subdivided into the infraorders Tarsiiformes, Platyrrhini (New World monkeys), and Catarrhini (Old World monkeys). As representatives of the Tarsiiformes, eight individuals of the only family of this suborder, the Tarsiidae (tarsiers), were examined and the orobasal organ was found in two of them. In the infraorder Platyrrhini, only two representatives of Atelidae (spider monkeys) and one representative each of Callitrichidae (marmosets) and Cebidae (capuchin monkeys) was examined. An orobasal organ was found in all four cases. The infraorder Catarrhini divides into the superfamilies Cercopithecoidea (tailed Old World monkeys) and Hominidea (humanoids). In Cercopithecoidea, the orobasal organ was found in seven out of nine animals. In Hominidea other than human, there was one positive case of an orangutan (*Pongo pygmaeus*) and one positive case of a Chimpanzee (*Pan troglodytes*).

2.3 | The orobasal organs of humans

From the 23 original publications, eight authors describe the occurrence of the orobasal organ in *Homo sapiens*. Eberle carried out the first study on *Homo sapiens* in 1925–1926 (Eberle, 1925), but Schückher (1937) was the first who indeed found a human orobasal organ (Table 1).

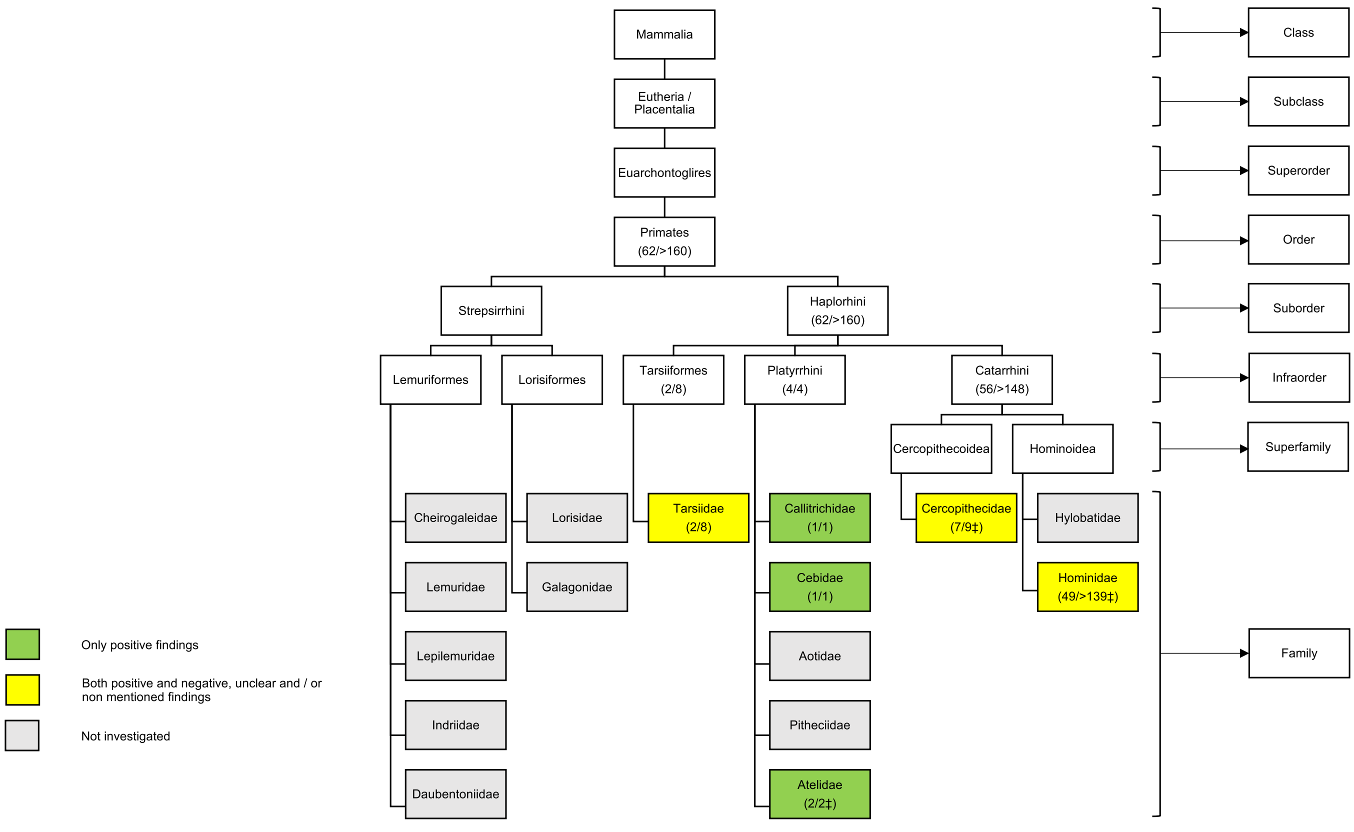

FIGURE 3 Cladogram of suborders, infraorders, superfamilies, and families of the order primates. The colors represent findings of orobasal organs. Families in green showed only positive findings, families in yellow showed both positive and negative, unclear and/or nonmentioned findings. Families in gray were not investigated. The first number in brackets indicates the positive findings, the second number is the investigated individuals. Since the exact number of investigated Hominidae is not mentioned in one publication (Nishiyama, 1933), a > was added. ‡Indicates that more than one species was investigated.

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TABLE 1 Primary research articles (authors present original macroscopic and/or microscopic investigations) about the orobasal organ (of Ackerknecht).

Study	Title	Journal	Language
Ackerknecht (1912)	Ein eigenartiges Organ im Mundhöhlenboden der Säugetiere	Anatomischer Anzeiger	German
Arnbäck-Christie-Linde (1912)	Der Bau der Soriciden und ihre Beziehungen zu den Säugetieren	Morphologisches Jahrbuch	German
Ackerknecht (1913a)	Neue Beobachtungen im präfrenularen Mundabschnitt von Säugetieren	Berliner tierärztliche Wochenschrift	German
Ackerknecht (1913b)	Zur Topographie des präfrenularen Mundhöhlenbodens vom Pferde; zugleich Feststellungen über das regelrechte Vorkommen parakarunkulären Tonsillengewebes (Tonsilla sublingualis) und einer Glandula paracaruncularis beim Pferde	Archiv für Anatomie und Physiologie	German
Sicher (1917)	Die Entwicklung des Gebisses vom Talpa europea	Anatomische Hefte	German
Keller (1922)	Über ein rudimentäres Epithelorgan im präfrenularen Mundboden der Säugetiere	Anatomischer Anzeiger	German
Ackermann (1924)	Neues über das Vorkommen des Ackerknecht'schen Organs in der Säugetierreihe	Anatomischer Anzeiger	German
Eberle (1925)	Zur Entwicklung des Ackerknecht'schen Organs	Anatomischer Anzeiger	German
Tanner (1926)	Die Entwicklung des Ackerknecht'schen Organs beim Schaf	Anatomischer Anzeiger	German
Ivanov and Hbahob (1927)	The development of the organ of Ackerknecht in large horned cattle	Repts Siberian Vet Inst Omsk Ussr	Russian
Greiner (1929)	Zur Entwicklungsgeschichte des Gebisses von Tarsius spectrum	Zeitschrift für anatomische Entwicklungsgeschichte	German
Coebergh (1930)	Das Organ von Ackerknecht bei Bradypodidae	Anatomischer Anzeiger	German
Gubler (1933)	Die Mundbodenorgane des Wildschweines	Anatomischer Anzeiger	German
Nishiyama (1933)	Beiträge zur Kenntnis der Morphologie und Entwicklung des Ackerknecht'schen Organs	Keizyo Journal of Medicine	German
Schückher (1937)	Embryologische Untersuchung über das Ackerknechtsche Organ bei Ratte und Mensch	Zeitschrift für mikroskopisch-anatomische Forschung	German
Herre and Metzdorff (1938)	Über das Ackerknechtsche Organ einiger Primaten	Zoologischer Anzeiger	German
Künzel (1953)	Das Ackerknecht'sche Organ beim Syrischen Goldhamster	Berliner und Münchner tierärztliche Wochenschrift	German
Kato (1953)	Embryological studies on the development of the tooth in human embryo, with special reference to the formation of the tooth band and the lip furrow band	Shigaku	Japanese (with an English abstract)
De Risky (1954)	Rilievi sull'organo di Ackerknecht nella specie umana	Rassegna odontotecnica	Italian
Zorzoli (1954)	Contributo allo studio dell'organo di Ackerknecht negli animali e nell'uomo	Biologica Latina	Italian
Kagawa (1956)	Über das früheste Stadium der Entwicklung der Zähne des Menschen	Archivum histologicum japonicum	German (with a Japanese title and summary)
Callegari and Sagri (1964)	Sullo svolgimento dell'Organo di Ackerknecht in *Bos taurus*	Archivio Italiano di Anatomia e di Embriologia	Italian
Staeber and Schumann (2022)	The orobasal organ of Ackerknecht in a male body donor: A case report	European Journal of Anatomy	English

TABLE 2 Primary research articles about the occurrence of the orobasal organ in humans.

Study	Total number of investigated cases	Number of prenatal individuals	Number of positive cases/prenatal individuals	Number of postnatal individuals	Number of positive cases/postnatal individuals
Eberle (1925)	15	15	0/15	0	0/0
Schückher (1937)	46	46	6/46	0	0/0
Kato (1953)	31	31	20/31	0	0/0
De Risky (1954)	15	0	0/0	15	13/15
Zorzoli (1954)	19	13	1/13	6	1/6
Kagawa (1956)	10	10	5/10	0	0/0
Staeber and Schumann (2022)	1	0	0/0	1	1/1
Σ =	137	115	32/115 (27.8%)	22	15/22 (68.2%)

Note: The table shows the number of investigated and positive cases in prenatal and postnatal individuals.

More than 137 humans were examined (Table 2) in eight primary studies. Unfortunately, Nishiyama (1933) wrote that he did not find an orobasal organ in his adult human material but did not give the number of investigated individuals and is therefore excluded from Table 2. The seven remaining studies include 115 prenatal (embryos and fetuses) and 22 postnatal human samples. All examinations were carried out microscopically. Interestingly, the prevalence of the orobasal organ seems to be higher in postnatal humans (68.2%) than in prenatal humans (27.8%). Possible explanations are a late development or the misinterpretation of the orobasal organ with the primordia of a salivary gland. Additionally, the shaping of the orobasal organ might be influenced by mechanical stimulation of this region. Taken together, the orobasal organ must be considered as a nonpathological structure of the floor of the human oral cavity. In human dissection courses the anatomy of the oral cavity is often studied after median sagittal section of the head (Tillmann & Hirt, 2022). This way of dissection might destroy the orobasal organ and can be an additional factor why this structure is rarely recognized in human anatomy.

3 | EVOLUTION OF THE OROBASAL ORGAN

Since the orobasal organ was found in all three subclasses of mammals, an early evolutionary origin of this structure is most likely. Keller hypothesized, that the orobasal organ is a remnant of an anterior sublingual gland found in reptilian sauropsids (Keller, 1922). However, there is no experimental evidence supporting this theory. The orobasal organ does not show any histological signs of secretory activity and the absence of an orobasal organ in reptilian sauropsids has not been proven, yet. The anterior sublingual gland is described as a serous gland which lies close behind the teeth of the lower jaw in Lacertidae (true lizards; Oppel, 1900). In humans, there is a minor salivary gland in the same localization, the incisive gland. In contrast to the orobasal organ the incisive gland shows well-developed glandular parenchyma. Opening of the excretory ducts can be easily identified by the prismatic epithelium. Thus, the evolutionary origin of the orobasal organ remains unknown, so far.

4 | VARIABILITY AND SEXUAL DIMORPHISM

The orobasal organ is highly variable in shape, size, and symmetry, even within one species (Ackerknecht, 1912), but no general differences between species are known so far. Comparative morphometric studies must clarify if there are species-dependent differences in morphology and prevalence. In cases where the existence of the orobasal organ was confirmed or denied, sexes were mentioned for 46 individuals. Twenty-eight males (*Rattus norvegicus*, *Canis lupus*, *Equus caballus*, *Pongo* spec., and *Homo sapiens*) and 18 females (*Rattus norvegicus*, *Canis lupus*, and *Equus caballus*). The orobasal organ could be detected in 19 of 28 male individuals (67.9%) and could not be detected in at least nine male individuals examined (32.1%) (Figure 4a). In 18 of the 18 female individuals (100%), the orobasal organ could be detected (Figure 4b). So, the prevalence of the orobasal organ seems to be higher in females. While Ackerknecht, without showing any data, said that he did not observe a sexual dimorphism of the orobasal organ (Ackerknecht, 1912), Schückher (1937) noted that he observed the orobasal organ only in female rat embryos. Further research is necessary to prove or reject a sexual dimorphic behavior of the orobasal organ.

5 | FUNCTIONAL AND CLINICAL ASPECTS

Most researchers assume that the orobasal organ does not have any physiological function, since it does not show any histological signs of secretory or sensory activity (Malinovsky et al., 1996). However, no

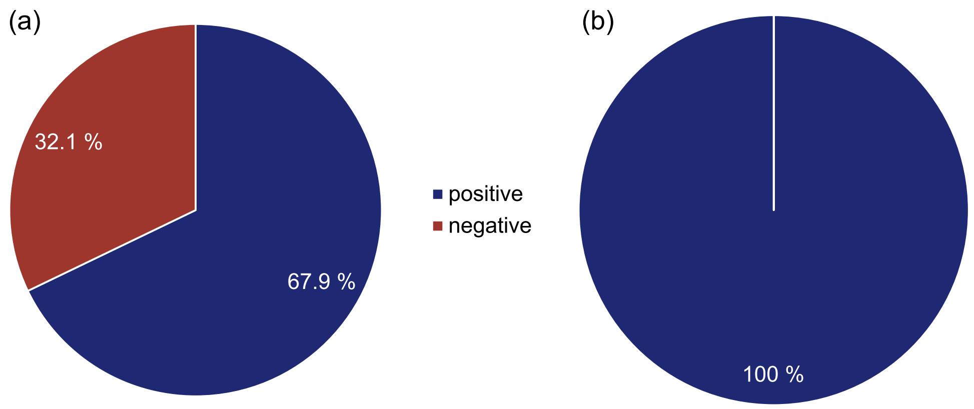

FIGURE 4 Occurrence of the orobasal organ in male (a) and female (b) individuals. Blue gives the percentage of positive finding, red of negative.

ultrastructural or immunohistochemical data were published so far. The orobasal organ must not be confused with pathological conditions like oral precancerous lesions (e.g., oral leucoplakia) or oral cancer (e.g., oral squamous cell carcinoma; Danforth & Baughman, 1979). Ungerecht (1951) assumed, that the orobasal organ can serve as a possible origin of dermoid cysts of the oral floor, but clinical data supporting this theory are still missing.

6 | TERMINOLOGICAL DISCUSSION

The term "organ" for this epithelial building was used by Ackerknecht himself (Ackerknecht, 1913a) and was adopted by later authors. Nevertheless, might be considered whether the term "organ" is appropriate for this structure. An organ is commonly defined as a part of the body that performs a special function (Neumann, 2017). Additionally, it may consist out of different tissues. Since the orobasal organ is an epithelial structure without a function, it does not fulfill these criteria. As mentioned above, vestigial organs are considered to have lost most or all of their functions through evolution. Since it is unclear if the orobasal organ developed from a functional precursor structure, its classification as a vestigial or rudimentary structure is speculative.

7 | CONCLUSION

Taken together, the orobasal organ (of Ackerknecht) might be an evolutionary conserved structure in the wall of the oral cavity of mammals including humans. We hope that this review will increase awareness of this anatomical structure, and thereby decrease the risk of confusion with pathological conditions like oral precancerous lesions or oral cancer. More research is desirable to better understand the evolution, prevalence, development, and function of this structure.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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PEER REVIEW

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