ORIGINAL ARTICLE

DOI: 10.4274/hamidiyemedj.galenos.2024.87699

Hamidiye Med J 2025;6(1):16-23

Ear Anatomy from Galen's *De Usu Partium*, Avicenna's El-Kânûn Fi't-Tıbb, and Şemseddîn İtâkî's Works Titled Teşrîhu'l-Ebdân and Tercümân-ı Kıbâle-i Feylesûfân to the Present Day

Galen'in *De Usu Partium*'u, İbn Sina'nın El-Kânûn Fi't-Tıbb'ı ve Şemseddîn İtâkî'nin Teşrîhu'l-Ebdân ve Tercümân-ı Kıbâle-i Feylesûfân Eserlerinden Günümüze Kulak Anatomisi

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ABSTRACT

Background: Galen is considered the founder of anatomy and experimental physiology and is the author of the *De Usu Partium* (Περὶ χρείας μορίων). In the 11th century, Avicenna wrote El-Kânûn Fi't-Tıbb (Kânûn), one of the fundamental books of medicine, inspired by Galen's teachings. Teşrîhu'l-Ebdân ve Tercümân-ı Kıbâle-i Feylesûfân (Teşrîhu'l-Ebdân), an anatomy book written by physician Şemseddîn İtâkî in the 17th century. The primary purpose of our study was to compare the ear anatomy of works written in different centuries with each other and current anatomy information.

Materials and Methods: The Greek edition of *De Usu Partium* (Περὶ χρείας μορίων) and the Arabic edition of the Kânûn were obtained. Translations of the works into Turkish have been completed. One of the illustrated copies of Teşrîhu'l-Ebdân has been accessed. In this study, ear anatomy information obtained from three studies was compared with each other and with current anatomy. Additionally, the data in his Kânûn were compared with his first Turkish commentary, Tahbîzü'l-Mathûn.

Results: Some information familiar to all three physicians was obtained, such as the fifth cranial nerve providing hearing, second cervical spinal nerve reaching the outer ear layer, and carotid artery providing blood supply to the ear. However, no information was found regarding the middle ear ossicles, middle ear muscles, inner ear structures, or the function of the ear to maintain balance in the narratives of the three physicians.

Conclusion: Although some incorrect and incomplete information has been presented in the studies, the information given by the three physicians regarding ear anatomy is mainly similar to current ear anatomy. Our study shows that although they lived in different centuries, they were influenced by each other in terms of anatomy.

Keywords: Ear anatomy, Galen, Avicenna, Şemseddîn İtâkî, Tokadî Mustafa Efendi

ÖZ

Amaç: Galen, anatomi ve deneysel fizyolojinin kurucusu olarak kabul edilir ve *De Usu Partium* (Περὶ χρείας μορίων) adlı eserin yazarıdır. On birinci yüzyılda İbn Sînâ, Galen'in öğretilerinden ilham alarak tıbbın temel kitaplarından biri olan El-Kânûn Fi't-Tıbb (Kânûn) adlı eseri yazmıştır. Teşrîhu'l-Ebdân ve Tercümân-ı Kıbâle-i Feylesûfân (Teşrîhu'l-Ebdân), 17. yüzyılda hekim Şemseddîn İtâkî tarafından yazılmış bir anatomi kitabıdır. Çalışmamızın ana amacı, farklı yüzyıllarda yazılmış bu eserlerin kulak anatomisini birbirleriyle ve günümüz anatomisiyle karşılaştırmaktır.

Gereç ve Yöntemler: *De Usu Partium* (Περὶ χρείας μορίων) eserinin Yunanca baskısı ve Kânûn eserinin Arapça baskısına ulaşılmıştır. Eserlerin Türkçeye çevirileri tamamlanmıştır. Teşrîhu'l-Ebdân adlı eserin bir illüstrasyonlu kopyasına erişilmiştir. Çalışmada, üç

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Received: 11.11.2024 **Accepted:** 25.12.2024 **Publication Date:** 27.03.2025

Cite this article as: Karip B, Topçu İ, Salman Z, Cerrah F. Ear Anatomy from Galen's *De Usu Partium*, Avicenna's El-Kânûn Fi't-Tıbb, and Şemseddîn İtâkî's works titled Teşrîhu'l-Ebdân and Tercümân-ı Kıbâle-i Feylesûfân to the present day. Hamidiye Med J. 2025;6(1):16-23

ÖZ

eserden elde edilen kulak anatomisi bilgileri birbiriyle ve günümüz anatomisiyle karşılaştırılmıştır. Ayrıca, Kânûn eserindeki veriler, ilk Türkçe şerhi olan Tahbîzü'l-Mathûn ile karşılaştırılmıştır.

Bulgular: Üç hekimin de bildiği bazı bilgiler elde edilmiştir, örneğin beşinci kranial sinirin işitmeye katkı sağlaması, ikinci servikal spinal sinirin dış kulak katmanına ulaşması ve karotis arterinin kulağa kan sağlaması gibi. Ancak, üç hekimin anlatılarında orta kulak kemikçikleri, orta kulak kasları, iç kulak yapıları veya kulak dengeyi sağlama fonksiyonu hakkında bilgi bulunmamaktadır.

Sonuç: Eserlerde bazı yanlış ve eksik bilgiler olsa da, üç hekimin kulak anatomisi hakkındaki verdikleri bilgiler genel olarak günümüz kulak anatomisiyle benzerlik göstermektedir. Çalışmamız, farklı yüzyıllarda yaşamış olmalarına rağmen, bu hekimlerin anatomi alanında birbirlerinden etkilendiklerini göstermektedir.

Anahtar Kelimeler: Kulak anatomisi, Galen, İbn Sînâ, Şemseddîn İtâkî, Tokadî Mustafa Efendi

Introduction

The knowledge of mummification before writing illustrates the ancient origins of anatomy (1). The Ebers Papyrus (1550 BC) contains prescriptions for ear diseases (1,2). Hippocrates first described the eardrum as "a dry, finely woven network" and linked it to hearing (2). Although Aristotle (384-322 BC) did not add new insights into ear anatomy, he contributed to the field by defining animal dissection, coining the term "anatomy," and founding comparative anatomy (1,3,4).

Dissection freedom at the Alexandria Medical School advanced anatomy significantly, training famous anatomists like Galen (129-216 AD) (1). Galen, the father of anatomy and experimental physiology, wrote nearly 400 treatises, making him one of the most influential surgeons and philosophers of his time (5,6). His *De Usu Partium* was crucial for understanding his anatomical and physiological concepts (7). Ibn Sînâ quoted Galen over 300 times in his El-Kânun fit-Tıbb (the Canon of Medicine) (8).

Ibn Sînâ (980-1037), also known as Avicenna, was regarded as the "prince of physicians" and the author of the most influential medical texts ever written (8,9). He wrote 273 works, 43 of which focused on medicine (10). The Canon was written over ten years, starting in 1012, and it became the most printed book after the Bible (11-13). It comprises approximately one million Arabic words and is divided into five sections covering various medical topics (8,12,13).

Teşrîhu'l-Ebdân ve Tercümân-ı Kıbâle-i Feylesûfân (Teşrîhu'l-Ebdân), the first illustrated anatomy book in Ottoman Turkish, was written by Şemseddîn İtâkî in the 17th century, around 1632, and dedicated to Sultan Murad IV (14-17).

Comparing medical texts across time periods is valuable for understanding medical history. Few comparative anatomy studies have examined changes across four periods, including the present. Our study uniquely compares ear anatomy between Galen, Ibn Sînâ, Itâkî and modern knowledge, illustrating how medical knowledge evolves and influences practitioners. The aim of this study was to show how physicians influence each other and how information changes.

Materials and Methods

In this study, Galen's *De Usu Partium* was accessed through the Greek works of Georgius Helmreich *via* an open-source platform (Internet Archive) (18). The Greek texts served as the primary source for the study, and information about the ear sensory organ was translated from Greek to Turkish (19,20). The Canon was based on two volumes of the four-volume Arabic Kânûn available at the Islamic Research Center (21,22). Access was also provided to the illustrated copy of Teşrîhu'l-Ebdân from the Süleymaniye Manuscripts Library, Vehbi Efendi (Baghdad) Collection. This work, written in Ottoman Turkish, was translated into modern Turkish by the authors. Tahbîzü'l-Mathûn, the first Turkish commentary on the Canon in the 18th century, was examined.

Tokadî Mustafa Efendi prepared this commentary under the order of Sultan Mustafa III, referencing prior excellent Kânûn commentaries when necessary. The modern Turkish transcription of this work was accessed through an e-book application from the Turkish Manuscripts Institution (23,24). In this study, Tahbîzü'l-Mathûn was compared with the Arabic Kânûn, and any differences in ear anatomy within the Kânûn's particular commentary tradition were also examined.

Statistical Analysis

All the information is qualitative and obtained from ancient texts. Therefore, statistical analysis is unnecessary and should not be performed.

Results

Galen and Ear Anatomy

In *De Usu Partium* (Chapter 7, Volume 2, 750-755), Galen explains that the skull is made of multiple bones to prevent

fractures from spreading in case of impact. The petrous bone, described as "stone-hard" (τὸ λιθώδης ὀστέον), contains the auditory nerve. However, his descriptions do not mention the middle ear bones. In Chapter 7, Volume 1 (622-623), Galen states that the encephalon originates from nerves, which transmit sensations from sensory organs. The encephalon is softer than the nerves it generates, facilitating sensory processing. Sensory nerves are smoother and shorter to reduce the risk of external damage, which is why sensory organs are close to the encephalon.

Chapter 7, Volume 2 (270-271) further differentiates soft nerves for sensation and hard nerves for voluntary movement. Sensory organs, such as the eye, ear (οὖς), and tongue, contain both types of nerves.

Galen identified seven cranial nerves, with the fifth pair being responsible for hearing. This pair passes through a petrous bone and divides into two branches: one leads to the ear canal. At the same time, the other opens into the stylomastoid foramen, which he clarifies is curved and not "blind," as previously thought. The fifth pair also has a temporal branch from the stylomastoid foramen.

Finally, according to Chapter 7, Volume 2 (295-297), animals with large temporal muscles and ears have larger nerves and can move their ears, whereas smaller animals like humans and monkeys cannot. Galen described the fifth cranial pair as being relatively soft and protected as it enters the ears near the meninges. To facilitate hearing, the nerve is shielded from external factors by being housed in a rigid bone and passing through curved spirals, which lengthen its path, protect it from cold, and reduce humidity, thus hardening the nerve. According to Galen, sensory organs typically exist in pairs to ensure proper functioning even in the presence of damage. Nature also protects exposed organs such as ears to prevent injury. The auricle's cartilage (χονδρώδης) structure prevents it from being too brittle or too soft, with its convex outer and concave inner shapes protecting the ear canal from damage. Galen emphasized that the ear's design is not rough or disproportionate but an elegant natural ornament for humans. (19,20).

In Chapter 7, Volume 2 (97-99), Galen explains that the cervical spinal nerves innervate the neck muscles and control head movement. The second pair of spinal nerves extend to the area around the ears, the top of the head, and the front of the head (bregma). In Chapter 7, Volume 2 (266-267), he describes the artery leaving the heart, which divides into two branches: the larger branch descends to the lower body, while the smaller branch supplies the upper body. In Chapter 7, Volume 2 (332-336), Galen details the carotid artery (καρωτίδες), which divides into two branches- one going toward the back and the other toward the front, each branching again. The front branch supplies the tongue and inner muscles of the lower jaw, while the other branches supply the temporal muscle near the ear. Galen states that there are no veins reaching the ear.

Avicenna and Ear Anatomy

In the title of Bone Anatomy of the Lower Side of the Skull in the first volume of the Canon, it is explained that two of the skull bones serve as walls on the right and left, that the two bones are called temporal bones (الحجرتين) because they are as hard as a stone, and that they contain the ears.

In the Canon, Avicenna described the temporal bones as walls for the skull containing the ears, but provided no details about the middle ear bones (21). The cheek muscles, which have four fibers, involve a fiber that extends from the cervical vertebrae to the cheeks and, in some individuals, allows ear movement (21). Regarding the cerebral nerves, Avicenna explains that the fifth cranial nerve, which is responsible for hearing, passes through the temporal bone, which curves and merges with the third cranial nerve to reach the temporal muscles (21).

Avicenna identified eight pairs of cervical spinal nerves, with the second pair reaching the ears and supplying the sensory feedback. He also discussed arterial pathways, noting that the vein leaving the heart splits, with the giant branch forming the carotid artery, which supplies blood to the neck, head, and ears. In vein anatomy, the external jugular vein is mentioned, which branches into two parts and serves areas near the head and ears (21).

In the third volume of the Canon, Avicenna details the ear's anatomy, describing its shell-like structure, auditory canal, and role in sound vibration. The ear's design, with its long, curved canal, regulates the temperature and protects the auditory nerve. The cartilage auricle maintains its shape and is protected from impacts. He noted the strategic positioning of the ears for optimal hearing and vision and noted that ear diseases can cause severe pain and fever (22).

Avicenna's descriptions align with Tokadî's Tahbîzü'l-Mathûn in terms of ear anatomy. However, Tokadî only mentioned the auditory nerve entering the area near the ear canal without referencing the involvement of the seventh cranial nerve.

Şemseddin Itâkî and Ear Anatomy

Itâkî mentions skull bones in the title of the Lower Side of the Skull Bone Anatomy Section. In this section, the ears' bones are called haceriyân (temporal bone) because they are as solid as stone. (25).

In the Cheek Muscle Anatomy section, it is seen that the muscles in the lower jaw, lip, and each cheek achieve the

movement of the cheek. The cheek muscles consist of four fibers. The fourth fiber comes to the cheek. In some people, this fiber passes through the immediate area of the ear and allows ear movement. No information about middle ear muscles was detected in other muscle descriptions. (25).

In the Anatomy of Nerves Section title, Itâkî states that seven pairs of nerves emerge from the brain, supporting this narrative through drawings. According to Itâkî, the fifth pair of heads emerges from both sides of the brain and is found in multiple pairs within itself. A branch of the pair distributes to the membrane inside the ear, and the sensation of hearing occurs with this branch (see Figure 1). The other branch of the pair leaves the blind hole in the temporal bone and joins the third pair of nerves. Most of it reaches the face and flat muscles, while some reaches the temporal muscles (25).

Under the Cervical Nerves and Tracts Anatomy Section heading, eight pairs of nerves emerge from the cervical vertebrae. The second pair of these nerves emerges from the hole between the first and second vertebrae and reaches the head. From this area, it turns toward the front and distributes to the outer skin of the ear and its surroundings (see Figure 2) (25).

Itâkî provides information about non-beating veins. In the section explaining the superior vena cava, one of these veins, Itâkî states that the superior vena cava, which reaches the neck circle, is divided into two branches, and the outer branch is called vidāc-ı ẓāhir (external jugular vein). The vein divides into two branches again in this region, and one branch of the separated branches is distributed around the ear and head (25).

The last information shared about the vein is the carotid artery. According to this information, the arteries leaving the heart consist of ascending and descending sections. The vein ascending from the heart is divided into large and small. The more prominent vein came to the chest and split into three branches, two of which formed the carotid artery. When the carotid artery reaches the neck region, it is divided into two parts, one going to the front and the other to the back of the head. The vein coming to the front again divides into two branches. The second branch of these branches reaches the outer region and reaches the front of the ear and temple muscles, while the remaining branches reach the head region (25).

In the Ear Anatomy Section, the ear of each birthing animal is visible, but the ear of the egg-laying animal is not visible, and fish are against this rule. The ear has a shell structure like a sail made of cartilage, nerves, and flesh. This region is where a force activates the air, gathers in the sheath, and vibrates. The ear hole bends obliquely inside the temporal bone. This structure extends the path when hot and cold winds enter the ear. Thus, the hot and cold effects of the wind are broken and become moderate. A tree-like bone is in front of the ear hole, which opens into it. The air remains in this bone, and the auditory nerve is located there. The nerve is resistant to exposure to air and sound. The importance of this nerve in the ear is similar to the crystalline humor in the eye. Just as all other parts of the eye exist to protect and serve this structure, so does the duty of other ear parts on the auditory nerve. The benefit of the ear hole is likened to the iris layer in the eye (25).

Figure 1. Drawing of the fifth pair of heads in the work of Şemseddîn-i İtâkî [Taken from the Süleymaniye Manuscript Library, Vehbi Efendi (from the Baghdad) Collection, copy number 1476]

Discussion

When all the information obtained from the investigations is evaluated, although the works of Galen,

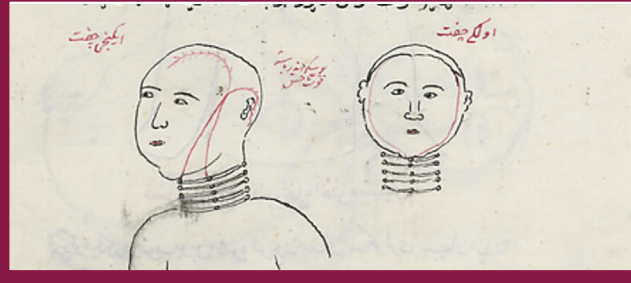

Figure 2. Drawing about the second cervical nerve in the work of Şemseddîn-i Itâkî [Taken from the Süleymaniye Manuscript Library, Vehbi Efendi (from the Baghdad) Collection, copy number 1476]

Table 1. Ear anatomy

	Galen (*De Usu Partium*) (Περὶ χρείας μορίων)	Ibn Sînâ (Al-Kânûn fi't-Tıbb)	Şemseddin Itâkî (Teşrîhu'l-Ebdân ve Tercümân-ı Kıbâle-i Feylesûfân)	Modern anatomy
The bone at which the sensory organ is located	Hard bone as a stone "τὸ λιθώδης ὀστέον"	A "harten" bone is a wall on the right and left side, with an ear sensory organ inside	The one on the right and left is a bone called "haceriyân" that contains ears	Temporal bone
Total number of cranial nerves emerging from the brain	Seven pairs	Seven pairs	Seven pairs	Twelve pairs
The cranial nerve provides hearing	Fifth cranial nerve	Fifth cranial nerve	Fifth cranial nerve	The eighth cranial nerve
The course of the auditory nerve	After the nerve progresses through the petrous bone, it comes to a crossroads. Some of it entered the ear canal, and some entered the blind hole section	After the nerve progresses through the petrous bone, it comes to a crossroads. Some of it entered the ear canal, and some entered the blind hole section	After the nerve progresses through the petrous bone, it comes to a crossroads. Some of it entered the ear canal, and some entered the blind hole section.	After nerve progression through the petrous bone, the transverse crest is located within the Internal acoustic canal, where the fundus of the internal acoustic meatus is located. Known as the auditory nerve, the cochlear nerve reaches the cochlea by passing through the canal in the lower front of the crest
Number of cervical spinal nerve pairs	Eight pairs	Eight pairs	Eight pairs	Eight pairs
The cervical spinal nerve reaches the outer layer of the ear	The second spinal nerve	The second spinal nerve	The second spinal nerve	Greater auricular nerve (C2-C3), lower occipital nerve (C2)
The artery that reached the ear	Carotid artery	Carotid artery	Carotid artery	Carotid artery
The vein accessing the ear	No direct ear vein was detected.	External jugular vein	External jugular vein	Posterior auricular vein à External jugular vein
Middle ear bones	Not detected	Not detected	Not detected	There are three bones in the middle ear: the malleus, incus, and stapes
Middle ear muscles	Not detected	Not detected	Not detected	There are tensor tympani and stapedius muscles in the middle ear
Hearing mechanism	The fifth cranial nerve, which has both hard and soft nerve types, reaches the ear next to the membranes and provides a sense of hearing. No information was provided regarding the inner ear	The sound penetrates the hole in the temporal bone and hits the complex fifth cranial nerve, and the nerve perceives that sound. No information was provided regarding the inner ear	The air reaches the ear, where the branch of the fifth head pair, located in one eardrum, detects the vibration. No information was provided regarding the inner ear	The cochlea structure in the inner ear transforms sound waves into electrochemical stimuli through inner and outer hair cells
The inner ear's relationship with balance	Not detected	Not detected	Not detected	The inner ear contains the otolith and semicircular organs, which are part of the peripheral vestibular system
Structure of the Auricula	Cartilage	Cartilage	Cartilage	Cartilage
Do you have an eardrum?	Yes	Yes	Yes	Yes

Avicenna, and Itâkî seem to have progressed in parallel, they contain some differences from today's modern medicine. The primary among these differences is the number of head pairs, as stated by Avicenna and Itâkî, inspired by Galen, which is seven. However, modern medicine has the opposite. It is observed that the current version of the cranial nerves was created by Samuel Sömmering (1755-1830 AD) in the 18th century (26,27).

Depending on the field of study, ear innervation is provided by many cranial nerves. While hearing and balance occur with the innervation of the eighth cranial pair (vestibulocochlear nerve), as defined today, many cranial nerves are involved in the section from the muscles in the middle ear to the external auditory canal and auricula (28). In the descriptions of Galen, Avicenna, and Şemsettin Itâkî, the fifth cranial nerve includes its modern counterparts, the facial nerve (7th cranial pair), and the vestibulocochlear nerve (8th cranial pair). Since these two nerves emerge with the same course and enter the same place (meatus acusticus internus) in the pons section of the brainstem, they were considered a single nerve by Galen and many subsequent scientists. They are referred to as the 5th cranial pair (26). Differences in the exact exit locations of the mentioned nerves in the brainstem and the nuclei where their fibers originate, as well as differences in their course and branching after the meatus acoustics internet, have shown that they are different nerves and have enabled them to be referred to as two separate skull pairs as used today. While Galen defined the two cranial nerves as a single nerve, he stated that they were divided into two branches after entering the inner ear canal. It states that while the auditory nerve moves from the larger side, the other branch enters another canal called the blind hole. By definition, this canal is thought to represent the facial canal where the facial nerve enters, and it can be said that these definitions are roughly similar to today's information based on the distribution of the vestibulocochlear and facial nerve within the internal acoustic meatus (29).

The descriptions of the ear by Galen, Avicenna, and Itâkî closely align with modern anatomical knowledge. Galen and Avicenna, who referred to the ear as made of cartilage, likely meant the auricula, which is the outer, curved part of the ear. Ibn Sînâ also noted that the auditory nerve (5th cranial pair), which enters the inner ear, is structurally rigid to protect it from damage due to air and impact. Sound perception occurs when sound waves stimulate a nerve (22). The first statement contradicts current anatomical knowledge. The auditory nerve, one of the eight cranial nerves, is the only nerve that does not emerge from the skull; thus, it cannot be influenced by weather or external factors. While the second statement was a logical explanation based on knowledge of the time, modern understanding of hearing involves sound waves reaching the eardrum. The eardrum's vibrations are transmitted to the inner ear *via* the ossicles (malleus, incus, stapes), and the vibration is then passed to the cochlea. The fluid movement stimulates the outer hair cells, activating the auditory nerve (30,31).

Galen and Avicenna stated that it would be more appropriate to separate the visual part of the front portion of the brain from hearing to another part (22). Although a precise localization is not given regarding hearing, the hypothesis regarding the visual aspect does not coincide with current knowledge of brain anatomy. The visual center of the brain is generally located in the posterior portion of the brain (occipital lobe) (28,32). Based on Galen's texts, the issue of hard and soft motor and sensory nerves cannot be clarified with today's knowledge. The most necessary observations in this context are that while motor neurons have a multipolar structure, their axons are long, and they must form a motor unit, sensory neurons have a unipolar structure, and their axons are shorter.

In Teşrîhu'l-Ebdân, Itâkî mentions a group of muscle fibers that enable the movement of the cheek and the lips coming together and provides information that these fibers also pass close to the ear in humans and allow the movement of the ear (25). If the variations in facial muscles are ignored, then the structure is unknown. Although the internal and external muscles that move the ear and the muscles that enable cheek and lip movement are generally considered mimic muscles, they can affect each other through the fascial system due to the layer in which they are located. From another perspective, the fact that a movement starting from the cheek area extends to the ear and its surroundings indicates the possibility of a connection between the buccinator and superior constrictor muscles, which have common attachment points in this region. Some studies have demonstrated the existence of this connection by revealing the possibility of two muscles acting as a single muscle (33). It is predicted that the fiber group mentioned above is based on these connections.

In all three works, the descriptions of the course and branching of arteries and veins although they lack detailed information, align with modern anatomical knowledge. The "tree-like bone" near the ear, described in different sources, is the temporal bone, which contains the ear's bony structures. The definitions of sensory branches from spinal nerves to the auricula and veins that drain the region are accurate despite the changes in modern nomenclature. These structures

include the greater auricular nerve (C2-C3), lesser occipital nerve (C2), and posterior auricular vein (34).

The dissection of the ear, including the inner and middle ear, was likely incomplete in earlier anatomical studies, as the petrous bone's delicate structure required foresight and proper tools for detailed examination. The facial canal curve highlights challenges in understanding the region. The comparison of the Canon commentary with the original Arabic text revealed similar descriptions of ear anatomy. Tokadî's version, however, states that only the auditory nerve enters the medial surface of the ear region. In contrast, the Arabic text indicates that both the auditory nerve and the fiber of the seventh cranial nerve are present. This differs from modern understanding because the seventh cranial nerve is the facial nerve, which has no direct relation to the ear during its course.

Conclusion

In our study, we tried to understand the interaction and change of the science of anatomy through the sensory organ of the ear by referencing the works of three different physicians who lived to varying dates for approximately 15 centuries, starting from the 2nd century. Subsequently, classical medical anatomy information was analyzed in light of contemporary modern anatomy information. The findings and inferences presented are expected to guide further medical history research on comparative anatomy.

Ethics

Ethics Committee Approval: Not applicable.
Informed Consent: Not applicable.

Footnotes

Authorship Contributions

Surgical and Medical Practices: B.K., İ.T., Concept: B.K., İ.T., Design: B.K., İ.T., Data Collection or Processing: B.K., İ.T., Z.S., F.C., Analysis or Interpretation: B.K., İ.T., Z.S., F.C., Literature Search: B.K., İ.T., Z.S., Writing: B.K., İ.T., Z.S., F.C.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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