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Comparative anatomical studies on the otoliths (Ear stones) of some fishes

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Abstract
To fulfill this study, the otoliths (ear-stones or crystals) of four fish species were obtained to complete this comparative morphological study. Fifty Tilapia nilotica (*Oreochromis niloticus*), thirty flat head mullet (*Mugil cephalus*), thirty Nile catfishes (*Clarias lazera*) and forty herring fish species **(***Clupea harengus*) were used, where the ear-stones were extracted from the cranial cavity of the fishes, prepared, cleaned by H_2O_2 and examined anatomically. The results revealed that, there were clear differences between these stones in fish species under investigation. The shape of otolith is ovoid in tilapia, elongated in flat head mullet, rosette shape in catfish and bifid shape in herring fish. These suggest that the morphology of the skulls of different species of fishes could affect the otolithic shape.

Keywords: Anatomy, otoliths, tilapia, catfish, mullet, herring fish

1. Introduction
The otoliths are very solid stone-like structures (ear-stones or crystals) located inside the corresponding fossa in the cranial cavity, just lower to the brain. This otolith is an important part of stato-acoustic organ (organ of balance and hearing), which is intimately related to the internal ear of fishes, as well as, these crystals are considered as one of the higher sensory organs such as the lateral line nerve system [1].
The otoliths are strongly solid and relatively heavy stones or a mass of calcareous crystals present in the head region under the brain [2]. As well as the otoliths or statoliths may be used in determination of fish age by the marginal otolith increment, especially in marine fishes but rarely employed in fresh water fishes [3].
In addition to the otoliths are varied in its shapes and size between species of fish, where it may be oval, leaf shape or flat [4]. Also, the otolithic crystals in tilapia nilotica had an ovoid shape and their structure were formed mainly from calcium carbonate matrix and do not contain any collagenic fibers (organic materials) [5]. The authors added that, these crystals were located in a deep fossa under the brain and the otoliths (ear-stones) had a good role in the process of equilibrium and balance in fishes. The shape of otoliths (ear-stones) differed from species to another [6].
This otolith is an important part of stato-acoustic organ (organ of balance and hearing), which is intimately related to the internal ear of fishes, as well as, these crystals are considered as one of the higher sensory organs such as the lateral line nerve system [7]**.** The aforementioned author explained that, during the movement of the head and the body of the fish, the otoliths (ear-stones) move or slide across the surrounding sensory cilia to stimulate the sensory cells in the semicircular canals to perceive and register the changes in the position of the individual.
The present study was aimed to elucidate the anatomical difference in shape of otoliths in fishes under investigation in relation to different morphology of their skulls.

2. Materials and Methods
2.1. Animals
This research was conducted on the otoliths of 50 fishes of tilapia nilotica (*Oreochromis niloticus*), 30 of Nile catfish (*Clarias lazera*), 30 of flat head mullet (*Mugil cephalus*) and 40 of herring fish (*Clupea harengus*) to fulfill the morphological studies.

2.2. The otoliths extraction
The otolithic crystals of each species were extracted from the cranial cavity, treated by hydrogen peroxide, then washed by tape water and used for morphological studies.

2.3. The preparations of the skulls (syncranium)
As well as the preparations of the skulls (syncranium) of the examined fishes was carried out by maceration method according to Onwuama *et al*., [8].

2.4. Stereomicroscopic study
The otoliths of the fishes under investigation were examined and photographed under forced light by light stereomicroscope (Odrrect, Toko, Seiwa Optical No.6075000) by objective lens X15.

2.5. Photographing
The images of the specimens were photographed using Sony digital camera (DSC-W690)16.1 mega pixels then edited and labeled on Adobe Photoshop version 8.

3. Results
3.1. Tilapia nilotica (*Oreochromis niloticus*) Fig 1:
The otoliths of tilapia nilotica appeared as an ovoid, flat and heavy stone-like (or cloudy and milky stone crystal). It located in a deep fossa at the base of the cranial cavity, just ventral to the brain and anterior to the foramen magnum.

Both right and left otolithic fossae appeared deep and oval, diverge anteriorly and converge posteriorly in front the foramen magnum. The otolith of tilapia nilotica had two surfaces, two borders and two extremities. The lateral surface appeared concave with rough appearance, while the medial one was convex with a branched vascular groove or furrow (Sulcus acusticus) Figs 2, 3 and 4. Each individual had two milky white otoliths (right and left), each of them was lodged in its corresponding deep fossa. The two fossae were separated from each other via a sagittal bony plate in syncranium at mid line of the floor of the cranial cavity in front of the foramen magnum Fig 5. The dorsal and ventral borders appeared convex and serrated, the dorsal one was truncated anteriorly to make a pointed anterior end, while the posterior end had a rounded appearance Figs 2 and 3.

Fig 1: A photomicrograph of tilapia nilotica

Fig 2: A photomicrograph of the otolith of tilapia nilotica (digital camera).

Fig 3: A photomicrograph of the otolith of tilapia nilotica magnified by (x15 Stereomicroscope) medial surface**.**

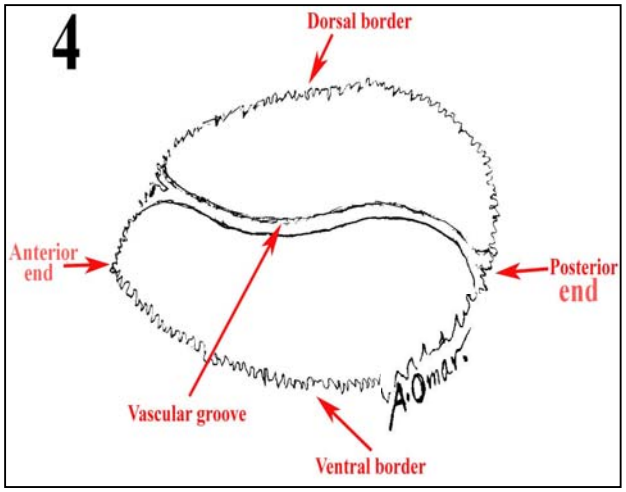

Fig 4: A schematic diagram of the otolith of tilapia nilotica (medial view).

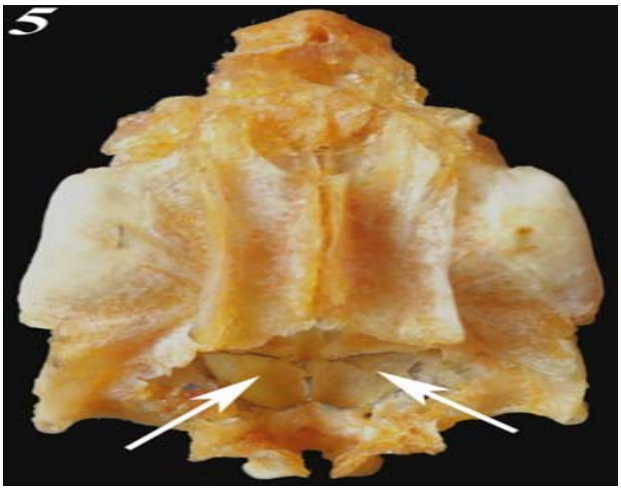

Fig 5: A photomicrograph of the skull (syncranium) tilapia nilotica (white arrows refer to otolithic fossae).

3.2. Flat head mullet (*Mugil cephalus*) Fig 6:

The otolith of this fish species appeared as an elongated oval stone like structure. Also it had two surfaces, two borders and two extremities. The lateral surface was somewhat concave and smooth, while the medial one appeared gently convex with a clear vascular furrow or groove which ran near or parallel to the dorsal border Figs 7, 8 and 9. This groove reached the anterior end of the otolith and did not reach the posterior one. The ventral border was faintly concave and serrated, while the dorsal one had a straight appearance. The anterior end appeared pointed while the posterior one had a rounded shape Figs 7 and 8. The two otoliths were located in elongated otolithic fossae close to each other Fig 10.

Fig 6: A photomicrograph of flat head mullet.

Fig 7: A photomicrograph of the otolith of flat head mullet (digital camera).

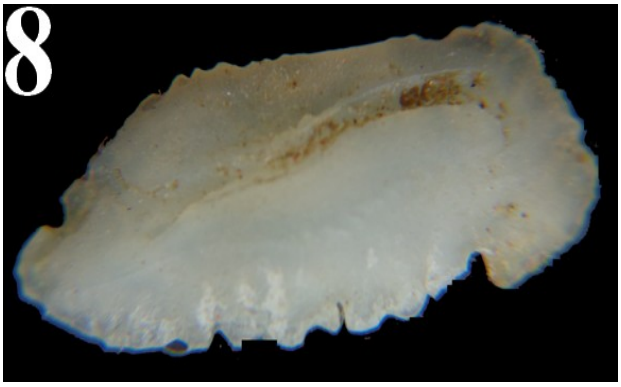

Fig 8: A photomicrograph of the otolith of flat head mullet magnified by (x15 Stereomicroscope) medial surface.

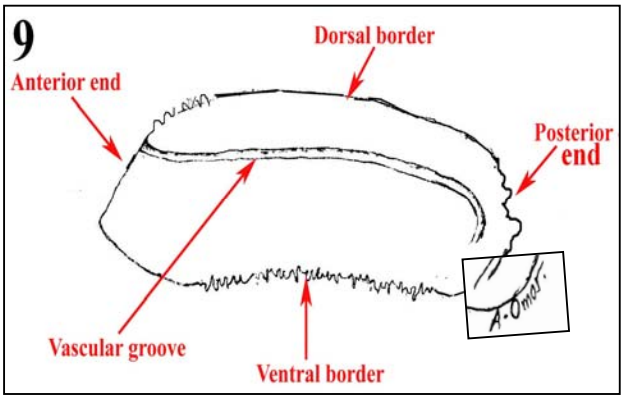

Fig 9: A schematic diagram of the otolith of flat head mullet (medial view).

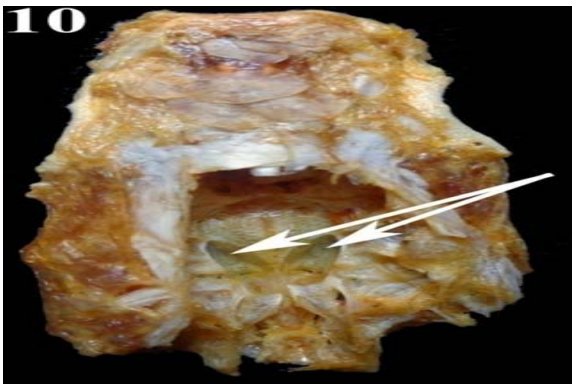

Fig 10: A photomicrograph of the skull (syncranium) of flat head mullet (white arrows refer to fossae).

3.3. Nile catfish (*Clarias lazera*) Fig 11:
The ear-stone of the cat fish had a triangular rosette shape or lotus flower appearance Figs 12 and 13. This otolith had two surfaces and three borders, the medial surface appeared flat glistening and smooth, while the lateral one gave the stone its rosette shape due to the presence of three portions which were clearly demarcated by presence of two grooves, as well as the middle one of these portions was somewhat elevated than the anterior and posterior ones Figs 12, 13and 14. The anterior border appeared convex while the posterior one was straight, the dorsal border appeared dentated due to the presence of the three portions which gave the stone its rosette-shape appearance Figs 12, 13and 14. It lodged inside a rounded shallow fossa on the corresponding side of the floor of the cranial cavity just lower to the brain, these two fossae located on both sides of cranial cavity and faraway from each other Fig 15.

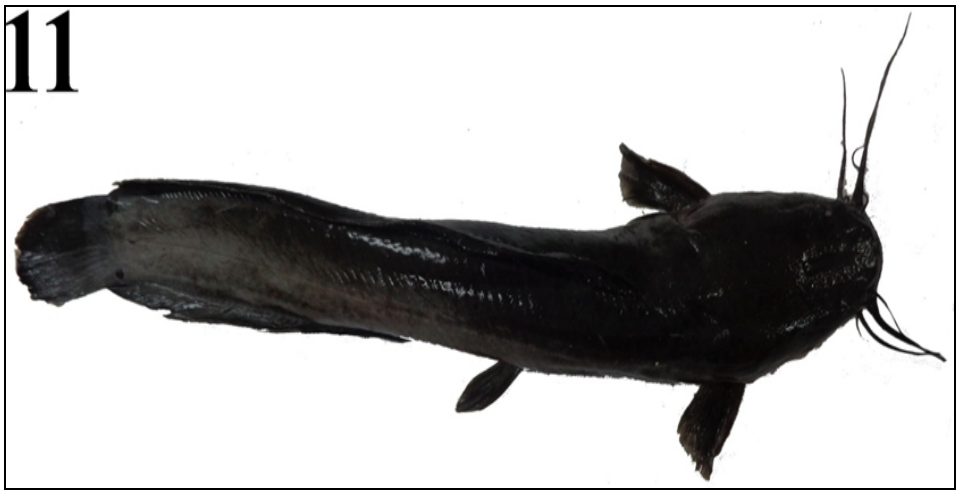

Fig 11: A photomicrograph of sharp tooth cat fish

Fig 12: A photomicrograph of the otolith of Nile catfish (digital camera).

Fig 13: A photomicrograph of the otolith of Nile catfish magnified by(x15 Stereomicroscope) medial surface.

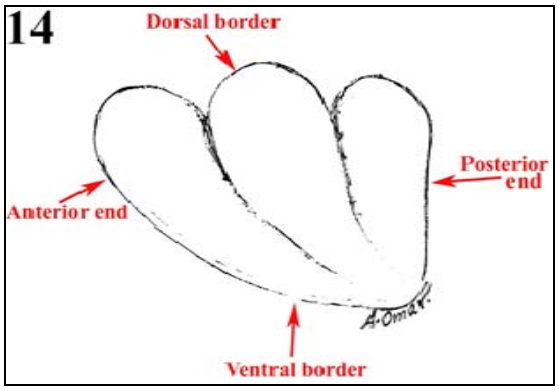

Fig 14: A schematic diagram of the otolith Nile cat fish (medial view).

Fig 15: A photomicrograph of the skull (syncranium) of Nile catfish (white arrows refer to fossae).

3.4. Herring fish (*Clupea harengus* L.) Fig 16:
The otolith (ear-stone) of herring fish had a characteristic shape where it was formed of completely fused two unequal portions (small dorsal part and another larger ventral one) Figs 17 and 18. This ear-stone had two surfaces, two borders and two extremities, the lateral surface appeared flat, smooth and glistening. The medial surface appeared flat or faintly concave with a longitudinal groove or furrow on the ventral long portion. Also there was a deep fissure between the two portions medially Figs 17, 18 and 19. Both dorsal and ventral borders appeared straight. The anterior end of dorsal and ventral portions was pointed while the caudal one appeared rounded with a faint notch at its midpoint Figs 17, 18 and 19. The otoliths were situated in its corresponding deep fossa, the two fossae were separated from each other by a thick sagittal bony plate Fig 20.

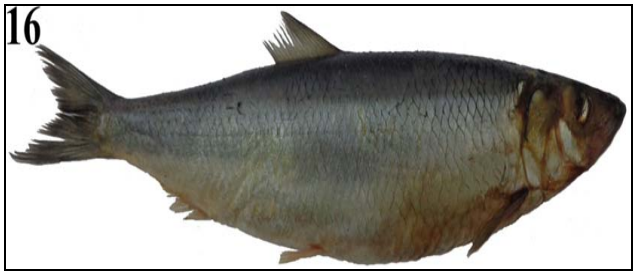

Fig 16: A photomicrograph of herring fish.

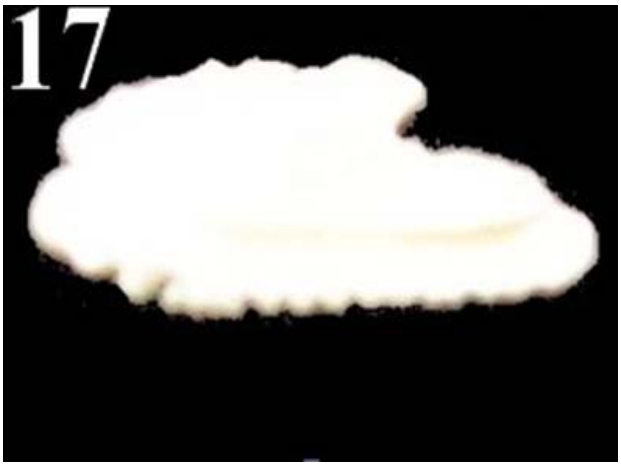

Fig 17: A photomicrograph of the otolith of herring fish

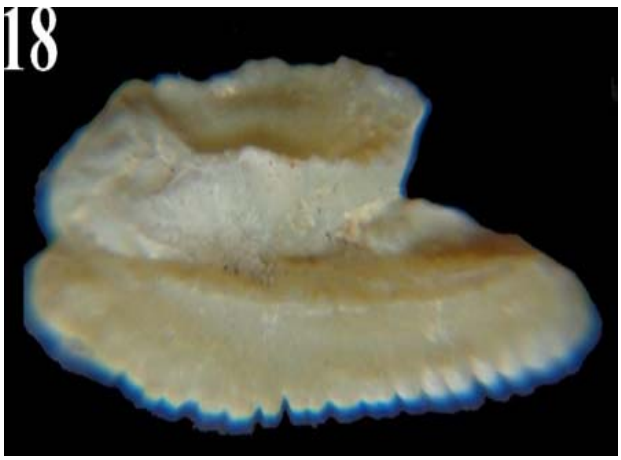

Fig 18: A photomicrograph of the otolith of herring fish magnified by (x15 Stereomicroscope) medial surface.

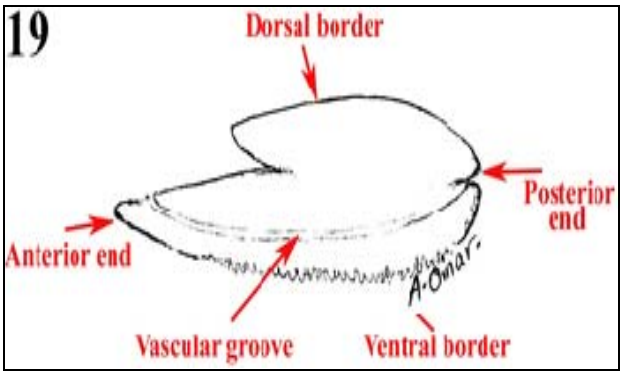

Fig 19: A schematic diagram of the otolith of herring fish (medial view).

Fig 20: A photomicrograph of the skull (syncranium) of herring fish (white arrows refer to fossae).

4. Discussion

Regarding the shape of otoliths, in fishes, it differed from fish species to another [6]. Moreover, the morphological characteristics of fish otoliths were highly variable between fish species, where their shape ranging from a relatively simple disc in some flat fishes to irregular shape in others as red fish [9]. A result which came in a line with the present findings.

The Sulcus acusticus (vascular groove or furrow) which was observed on the medial surface of otoliths in the present study was also recorded in the teleosts fishes [10].

The blue-fin tuna had otoliths of elongated form in larger fishes (tuna) and squared in small ones [11], the results which completely differed from the current findings in all species under investigation.

An oval, leaf shape, oblong or flat shapes of otoliths in some fresh –water fishes in addition to the serrated edge in eel [4]. These differences in shapes of otoliths were comparable to the present investigation. Furthermore, the shape of otoliths may aid in identification of the species [12]. The finding which could be supported by the present work where each studied species had characteristic otolithic shape.

With reference to the position of otoliths, they were observed inside the cranial cavity just lower to the brain where they were considered as a part of the main compartments of the internal ear. Certainly, this is in line with findings in the investigations conducted by other scholars [2, 4, 5, 7, 10, 13, 14].

The present research revealed that, the size and length of otoliths were in a good relation with the size, weight and length of the fishes, a result which coincided with authors [4, 5, 9, 11, 12].

In regard to the numbers of otoliths, the present study clarified one pair of otoliths (right and left one) in each studied species, which agreed with scientists [11, 13, 15]. On the contrary there are (three pairs of otoliths), three on each side of the head inside the cranial cavity, arranged in an anterior, middle and posterior positions [4, 10, 16].

Concerning, the structure of the otoliths, the present research manifested that, they were consisted from precipitation of calcium carbonate (Ca co3), that was similar to several authors [5, 7, 10, 14].

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6. Disclosure

The authors declare no conflicts of interest, financial or otherwise.

7. References

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