The Functional Morphology of the Hagfish Feeding Apparatus Dental Plate Complex

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Abstract

Hagfish are deep-sea craniates that have not evolved opposable jaws. Despite this, hagfish power a “bite” forceful enough to allow them to utilize food sources ranging from marine worms to giant vertebrate carcasses. Since hagfish do not have moveable jaws, their “bite” is created through a rasping motion of a tongue-like structure containing teeth called a dental plate. Hagfish protract and retract the dental plate using cartilages, muscles, and connective tissues elaborately arranged into what is known as the feeding apparatus. The rigid components of the feeding apparatus can be visualized using microCT scans, however, the soft tissues are more difficult to describe. In this study, we characterized the soft tissues that join and actuate the rigid components of the feeding apparatus through traditional histological techniques. We used serial sections from multiple body planes to create a three-dimensional interpretation of morphology. This analysis indicated that the plates of the feeding apparatus are joined by connective tissue hinges. The musculature of the feeding apparatus is complex and variously organized into antagonistic groups, allowing the protraction and retraction of the dental plate.

Introduction

The hagfish feeding apparatus is composed of two parts, an anterior and posterior. The anterior portion containing rigid cranial cartilages and seven cartilaginous components referred to as plates (Clubb et al. 2019). Five of these plates are together known as the basal plates, but individually they are referred to as the two anterior, the single middle, and the two posterior basal plates. Teeth anchored to the dental plate rest in a V shaped groove formed by the lateral bars of the anterior basal plate and the posterior basal plates. The second part of the feeding apparatus is the soft posterior component, referred to as the retractor complex. The retractor complex is thought to power the forceful movement of protraction/retraction of the dental plate in and out of the mouth cavity. While the force production of the retractor complex is understood, the functional morphology of the soft tissues of the anterior portion is more obscure. In this study, the morphology of the anterior portion is described using histology guided by CT scans.

Methods

Three species of Atlantic hagfish (*M. glutinosa*) were euthanized using a solution of 400mg MS222 (with $NaCHO_3$ as a buffer) per 1 L of seawater as outlined in authorized VSU protocol AUP-00070-2017 and preserved in 10% buffered formalin. The anterior portion of the feeding apparatus was dissected from each specimen to create parasagittal, frontal, and transverse sections as described in Kier (1992). The sections were stained using Milligan’s Trichrome [Magenta: muscle and nuclei; Blue: collagen; Orange: erythrocytes] and viewed using standard light microscopy. CT scans provided by Bemis (2012) and Clark et al (2020) were used as a guide to understand the 3-dimensionality of the sections.

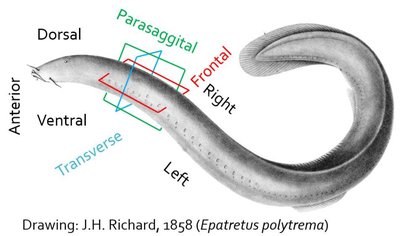

Fig. 1 Illustration of hagfish (*Eptatretus polytrema*) by J.H. Richard (1858) with directional terms and body planes superimposed

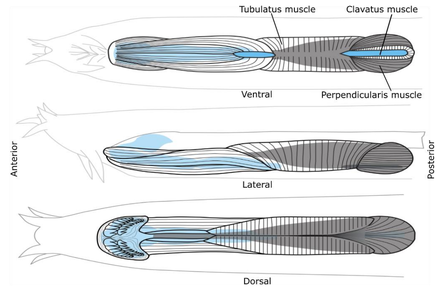

Fig. 2 Anatomy of the hagfish feeding apparatus. Cartilaginous structures are shaded in blue. Soft tissues are shaded in grey and white, except for the clavatus muscle, which is shaded in blue.

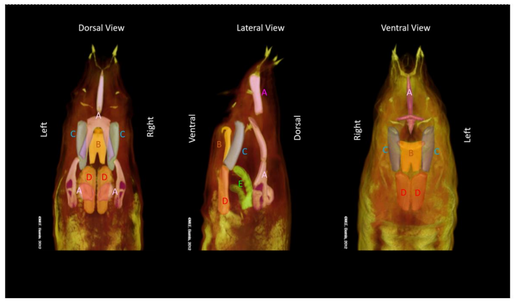

Fig. 3 microCT scans of the anterior portion of the hagfish feeding apparatus (Bemis 2012)

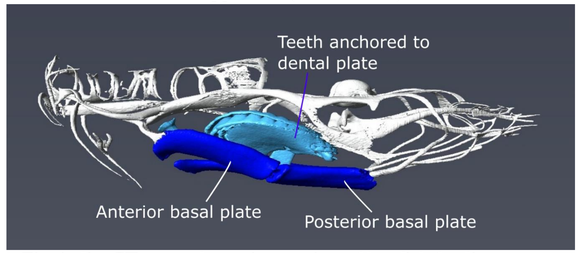

Fig 4. diceCT scan of anterior portion of hagfish feeding apparatus (Clark et al 2020)

Results

The cartilaginous plates of the anterior complex are encompassed by sheaths of connective tissue. It is noted that this connective tissue stains like collagen.

The connective tissue is continuous with a complex organization of muscle fiber orientations. The connective tissue forms flexible joints between the anterior and posterior basal plates.

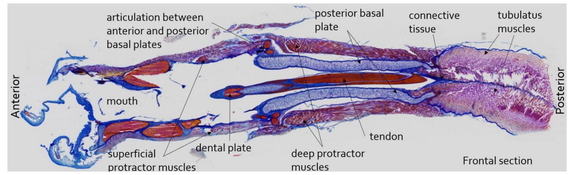

Fig. 5 Frontal section of anterior hagfish feeding apparatus

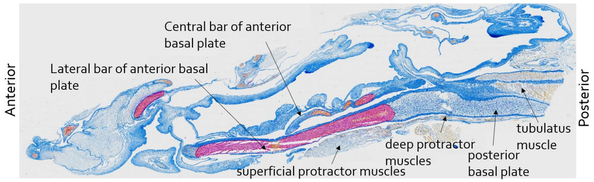

Fig. 6 Parasagittal section of anterior portion of hagfish feeding apparatus

Conclusion

The rigid components of the anterior feeding apparatus are fixed in a complex arrangement of muscle and connective tissue fibers that function to both support and power movements that help orient the dental plate and control the volume of the mouth cavity. We hope this descriptive study of the anterior feeding apparatus anatomy may provide a solid basis for testable hypotheses of feeding apparatus cartilage and dental plate function.

Literature Cited

Bemis, W. 2012. Personal communication.

Clubb, B.L., Clark, A.J., and Uyeno, T.A. 2019. Powering the hagfish “bite”: the functional morphology of the retractor complex of two hagfish feeding apparatuses. J. Morph. 280:827-840.

Kier, W.M. 1992. Hydrostatic skeletons and muscular hydrostats. In Biomechanics (Structures and Systems): A Practical Approach. 205-231.