During the evolutionary transition from land to sea, pinnipeds (seals and relatives) underwent a dramatic shift in their craniometric anatomy. Evolving from ancestors with functionally differentiated tooth shapes (heterodonty) to simple and undifferentiated teeth (homodonty), pinnipeds adopted snapping bites and ceased mastication. Here, we use CT-based 3D models and engineering simulations of masticatory behaviors of five pinniped species to analyze the relationship between cranial biomechanics and tooth morphology.

We hypothesize that there would be a smaller difference in cranial efficiency and stiffness between bite positions in pinnipeds compared to terrestrial carnivores due to undifferentiated tooth functions in the former group.

Result (Continued)

Mechanical efficiency (ME) versus adjusted strain energy (SE) profiles of a small group of pinnipeds obtained via finite element analysis (FEA) showed an overall range of 0.13 – 0.21 for the maximum difference in ME and 0.06 – 0.35 Joules for the maximum difference in SE (Fig 2).

Pinnipeds and terrestrial carnivores (Fig. 3A) have similar median ME (0.16 – 0.19, respectively); however, median SE is significantly greater in pinnipeds (0.12 J) than in terrestrial species (0.01 J).

For unilateral bites, at analogous tooth positions (carnassial tooth equivalent, at the anterior orbital boarder), pinnipeds (Fig. 4B-F) exhibited visibly higher stress at the bite position and the fronto-parietal region compared to Canis lupus (Fig. 4A).

Discussion: FEA shows that the MEs of the select pinnipeds fall into the terrestrial carnivoran range obtained from a separate portion of this project, while the SEs sit higher than, if not above, the norm. The visibly higher SE reveals that pinnipeds have weaker, less stiff skulls than the terrestrial carnivores. Therefore, the results reject the hypothesis that pinnipeds have a smaller difference in cranial efficiency and stiffness compared to terrestrial carnivores. These findings may be a result of retention of ancestral traits and non-feeding demands (e.g., hydrodynamics).

Conclusions: Using FEA on five extant pinniped species (seals and relatives), we compared pinnipeds, carnivores that have snapping bites and display homodonty, to terrestrial carnivores that masticate and display heterodonty. The results showed that pinnipeds have relatively similar ME in comparison to the terrestrial group, but have far higher SE (lower skull stiffness). Future studies with behavioral and hydrodynamic analyses could allow us to link pinniped biomechanics to specific feeding strategies. Knowledge of feeding mechanisms and biomechanics of extant species could help us infer the feeding mechanisms of extinct species throughout the fossil record.

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