The Meg in 3D: Blender edition

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Introduction

- Combining exceptionally preserved fossils with computational modelling has allowed palaeontologists to reconstruct entire bodies of extinct animals, most notably dinosaurs from full skeletons [1,2].
- Extinct sharks, however, have particularly poor preservation due to their cartilaginous skeletons – with only hard teeth and occasional vertebrae preserved.
- In the case of the extinct giant shark, *Otodus megalodon* (Miocene-Pliocene), the Great White Shark (GWS) (*Carcharodon carcharias*) is considered the best available ecological analogue [3-5].
- Moreover, jaws have been reconstructed and a vertebral column (IRSNB 3121/P. 9893) of ~150 vertebrae was discovered in Belgium in 1926 [3].
- Here, we use CT scans of this exceptional vertebral column, and of the GWS, to create the first ever 3D computational model of *O. megalodon*, the largest macropredatory shark that ever lived.

Materials and methods

- *O. megalodon* teeth and vertebrae were measured directly at the Royal Belgian Institution of Natural Sciences.
- Crown height (CH) of A2 teeth were used to calculate possible TL of our model based on previously published equations [6].
- Jaw reconstruction & vertebral column were CT scanned, imported into Blender [7], and scaled to real size based on measurements of the vertebral column (~155 mm diameter for largest centrum).
- A CT scanned GWS skull from a previous study [8] was added to the column, and the flesh was recreated with an octagonal hooping method previously used in dinosaur reconstructions [1,2].
- This hooping method was repeated around the body and individual fins of a full body scan of a GWS (3-3.5 m TL) scaled up to fit the spinal column from head to fork.

Results

- When scaled to real size, the vertebral column is revealed to be ~11.1 m long, significantly longer than a previously calculated TL for the shark this column came from [3].
- CH-TL calculations suggest a shark of ~13.87 m TL (Table 1), but the completed model measures as ~15.93 m TL, a size deemed to be exceptionally large for *O. megalodon* [6].
- Computing geometric measures in Meshlab [9] reveals a shark that weighed ~51.96 metric tons/ 51,959.26 kg.
- 16 2D measurements previously estimated for an *O. megalodon* of this size were measured in Blender [7], with all falling within the predicted mean ± standard deviation ranges of that study [5].

Table 1. Possible model TL calculated from A2 tooth, based on previously published findings that these are the best teeth for calculating TL [6].

Label	3121. 2.1.S.D
Tooth position	2nd right in 1st row; upper jaw
Tooth type	A2
CH (mm)	114.45
Equation [6]	12.103 (CH) + 2.160
TL (cm)	1387.35

Discussion

- The completed model being larger than the CH-TL calculation is due to the teeth not being associated with the vertebral column [3].
- The body is rather thin (close to minimum predicted values of dorsal-abdomen measurements from the 2D study); however this is likely because only a single GWS of ~3 m TL was used to reconstruct the body. The previous 2D study found that using multiple ecological & physiological analogues as a model to recreate *O. megalodon* produced a stockier reconstruction than using only the GWS [5].
- Body mass of ~52 metric tons is consistent with previous suggestions for a shark of this size [3].
- This study marks the first ever 3D computational model of an extinct giant shark; which can now be used to calculate a variety of inertial properties.

Figure 1: The completed model of *O. megalodon* (~15.93 m TL), with the GWS skull and the first section of the vertebral column (IRSNB 3121) used to create the model included. The shark is scaled against a 1.8 m diver.

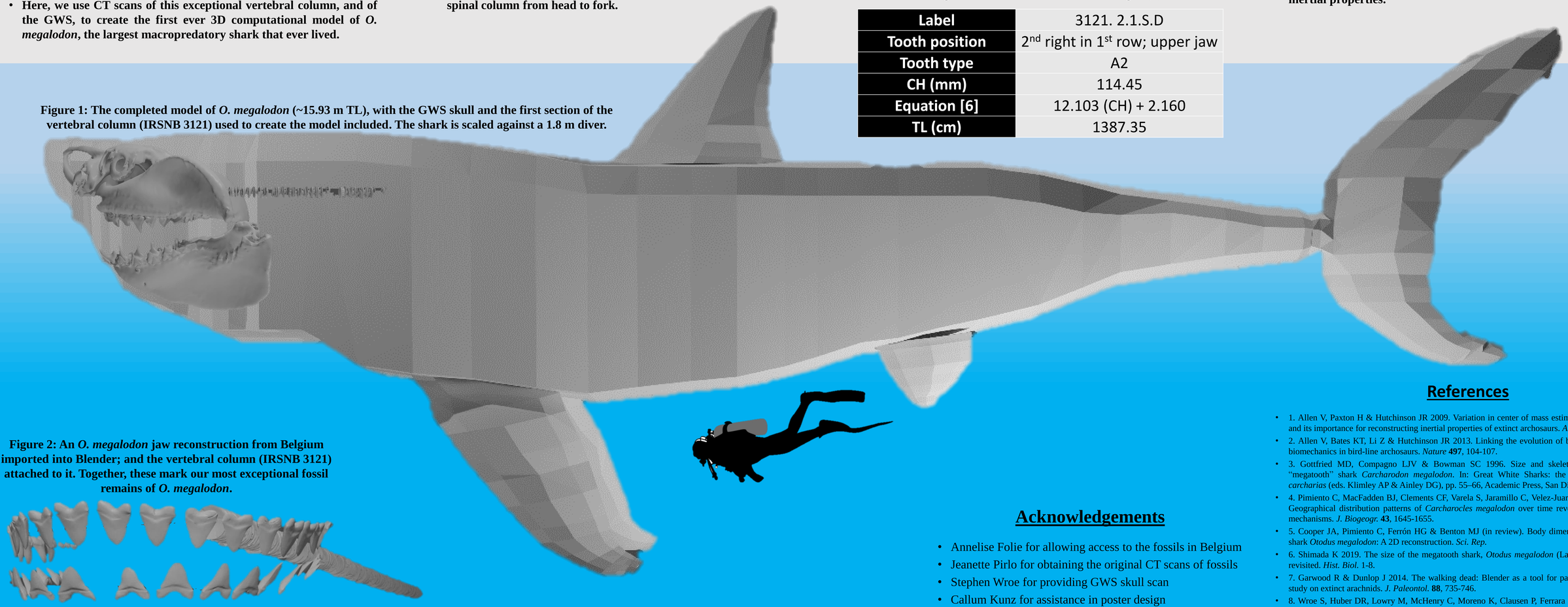

Figure 2: An *O. megalodon* jaw reconstruction from Belgium imported into Blender; and the vertebral column (IRSNB 3121) attached to it. Together, these mark our most exceptional fossil remains of *O. megalodon*.

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References

- 1. Allen V, Paxton H & Hutchinson JR 2009. Variation in center of mass estimates for extant sauropsids and its importance for reconstructing inertial properties of extinct archosaurs. *Anat. Rec.* **292**, 1442-1461.
- 2. Allen V, Bates KT, Li Z & Hutchinson JR 2013. Linking the evolution of body shape and locomotor biomechanics in bird-line archosaurs. *Nature* **497**, 104-107.
- 3. Gottfried MD, Compagno LJV & Bowman SC 1996. Size and skeletal anatomy of the giant "megatooth" shark *Carcharodon megalodon*. In: Great White Sharks: the biology of *Carcharodon carcharias* (eds. Klimley AP & Ainley DG), pp. 55–66, Academic Press, San Diego.
- 4. Pimiento C, MacFadden BJ, Clements CF, Varela S, Jaramillo C, Velez-Juarbe J & Silliman BR 2016. Geographical distribution patterns of *Carcharocles megalodon* over time reveal clues about extinction mechanisms. *J. Biogeogr.* **43**, 1645-1655.
- 5. Cooper JA, Pimiento C, Ferrón HG & Benton MJ (in review). Body dimensions of the extinct giant shark *Otodus megalodon*: A 2D reconstruction. *Sci. Rep.*
- 6. Shimada K 2019. The size of the megatooth shark, *Otodus megalodon* (Lamniformes: Otodontidae), revisited. *Hist. Biol.* 1-8.
- 7. Garwood R & Dunlop J 2014. The walking dead: Blender as a tool for palaeontologists with a case study on extinct arachnids. *J. Paleontol.* **88**, 735-746.
- 8. Wroe S, Huber DR, Lowry M, McHenry C, Moreno K, Clausen P, Ferrara TL, Cunningham E, Dean MN & Summers AP 2008. Three-dimensional computer analysis of white shark jaw mechanics: how hard can a great white bite?. *J. Zool.* **276**, 336-342.
- 9. Cignoni P, Callieri M, Corsini M, Dellepiane M, Ganovelli F & Ranzuglia G 2008. Meshlab: an open-source mesh processing tool. In Eurographics Italian chapter conference (Vol. 2008, pp. 129-136).