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Abstract

In 2001, an *Allosaurus* skull (CMP 279) was discovered in the Skull Creek Basin in Moffat County, Colorado. The skull is one of the most complete for the species and even contains the hyoid bones, which are usually not present. The skull is now permanently mounted, for display purposes, thus making the study of the individual bones difficult for producing a paleo-anatomical description. Computed Tomography (CT) scans of CMP 279 were created in 2017 and then made available for this study in 2019. CT scans are being used to investigate internal anatomy of skulls such as the endocranial cavity, sinuses, or foramina for nerve endings. This approach to using CT scans for skull analyses is becoming popular and, when combined with observations from the actual specimen, a comprehensive description can be derived. The program used for this study was myVGL Viewer. The program allows scans to be viewed in the frontal (anterior-posterior), median (medial-lateral) and transverse (dorsal-ventral) planes at the same time, and a 3-D rendering of the skull. The scans indicate exact known placement of sutures. For example, the mandibular sutures can be difficult to determine by physical examination of the specimen, but through the use of the scans they can be clearly identified. The scans also give access to bones that are unreachable because of the display-mounting of the actual skull, an example being the palatine complex. Additionally, internal anatomy like the endocranial cavity from the scans reveal the lobes and cranial nerves within the brain. CT scans have provided a high-tech approach to doing detailed analysis of CMP 279 which, in turn, will facilitate a detailed description that is important in understanding the anatomy and diversity of the *Allosaurus* genera.

Material and Methods

CT scans were utilized in the software program myVGL Viewer. This software takes the individual slices (scans) and connects them together to form 2D stacked images in one of the 3 planes: transverse, median, frontal (Figure 8). The software also renders a 3D model for manipulation and location of an individual slice (Figure 9). At first, the location of sutures was hard to determine from the stress fractures and other large fractures. This was especially difficult for sutures in the mandibles. Madsen's 1976 *Allosaurus fragilis* monograph, as well as a comparison with Eddy and Clark's 2011 *Acrocanthosaurus atokensis* description, was extensively used to approximate the location of sutures. Stress fractures appear to be smaller and concentrated closer to the surface of the bone, running only a small distance in the bone (Figure 10). Larger fractures appear to be vertical and tend to offset bone (Figure 11). Sutures appear as dark contacts between bones and taper off at longer distances than fractures (Figure 10).

For this study, slices were observed in all of the respective plains to determine the exact placement of bones. Once the exact location of bones were known, bones were then measured in centimeters, using either the polyline or caliper tool in the software. Then a description was written up for each individual bone in the skull. The process is outlined in Figures 13-16 with the final descriptions.

Conclusion

Though personal observations of the actual skull of CMP 279 would be preferable, CT scans act as a substitute due to the permanent installation of the skull. The skull has also undergone hours of excellent preparation, which have sought to repair damage done during the taphonomic and depositional processes. The use of glue to repair broken bones and plaster/resin used to reconstruct missing/broken bones makes the skull look pristine. As a result, the scans have also allowed the study of the skull without damage to those repairs. CT scans along with observations of the actual specimen would yield more detailed descriptions but because of these factors CT scans alone for CMP 279 are a great alternative.

Acknowledgements

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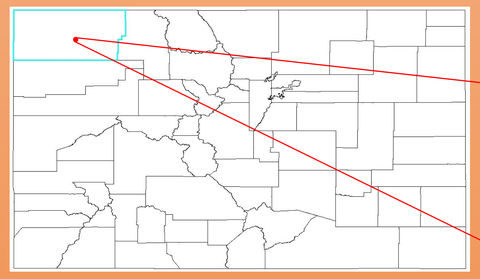

Figure 1: Colorado County Map, Moffat County highlighted in blue and the red dot approximate CMP 279 site location.

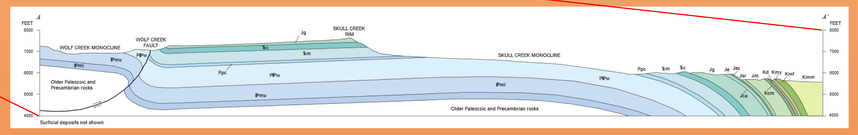

Figure 2: Geologic Cross-Section of the Skull Creek Basin from Geologic Map of the Skull Creek Basin Quadrangle by Van Loenen, Bryant 1999

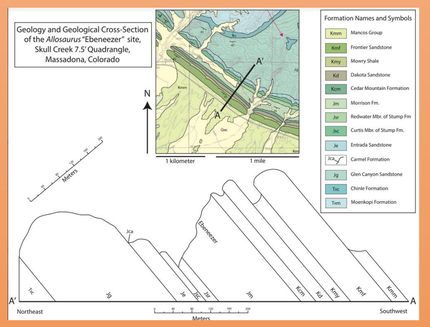

Figure 3: Layers outcropping around the CMP 279 site. The skull was found in the Brushy Basin Member of the Morrison Formation (Jm) about 2/3 up the exposed section. Figure from Snelling and Whitmore 2014.

Figure 4: CMP 279 site with the quarry circled in red. Photo Credit- John Whitmore

Figure 5: Right lateral view of the mounted skull. Photo Credit- Michael Sprague

Figure 6: Frontal view of the mounted skull showing the slight right offset. Photo Credit- Michael Sprague

Figure 7: Left lateral view of the mounted skull. Photo Credit- Michael Sprague

Figure 8: Picture of the 4 panes in myVGL Viewer software.

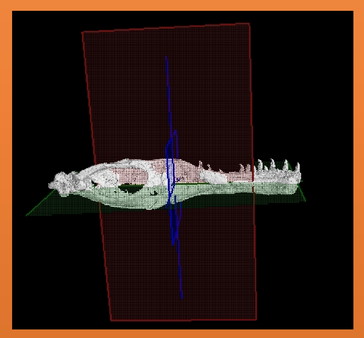

Figure 9: 3D rendering of the left mandible with the planes used to view individual slices. Frontal Plane (Anterior-Posterior)- Blue, Transverse Plane (Dorsal-Ventral)- Green, Median Plane (Lateral-Medial)- Red

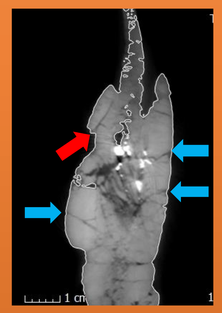

Figure 10: A single slice of the left dentary shows the stress fractures along the edge of the bone and the suture between the supradentary (intercoronoid) and dentary. Stress fractures indicated by blue arrows and suture indicated by a red arrow.

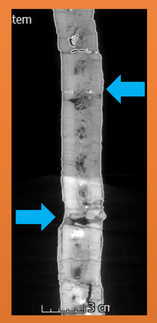

Figure 11: Large vertical fractures running through the left dentary indicated by the arrows.

Figure 12: Resin or plaster was used in the preparation of the skull and appears as large grey areas, usually filling in large fractures. Resin/plaster indicated by arrows.

The Description Process

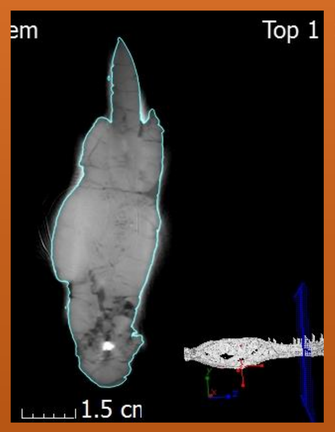

Figure 13: Single slice of the left dentary with indications of location of slice in 3D rendering. Slices in this plane were observed anterior to posterior.

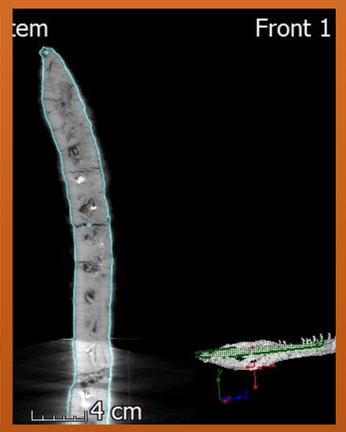

Figure 14: Single slice of the left dentary with indication of the location of slice in 3D rendering. Slices in this plane were observed dorsal to ventral.

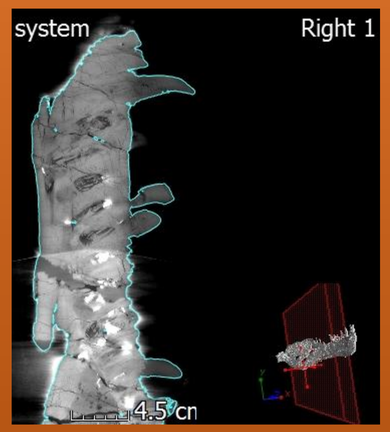

Figure 15: Single slice of the left dentary with indication of location of slice in 3D rendering. Slices in this plane were observed lateral to medial.

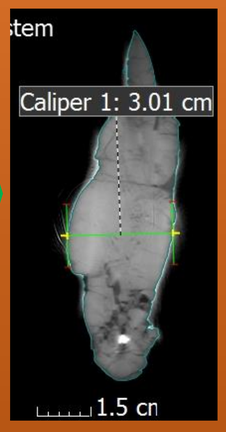

Figure 16: Single slice showing the use of the caliper tool in myVGL Viewer software.

Final Description of the Left Dentary

The longest of the mandibular bones holding 12 exposed teeth in various states of eruption. Most of the teeth are fully erupted. 3 of the teeth are not fully erupted with only the tips of the teeth visible. The rest of the teeth were either shed by the animal in life or shed during the taphonomic and/or depositional processes. With the use of the CT scans germ teeth can be seen in various positions of replacement. Most of the germ teeth are crushed and several teeth only have 1 complete germ tooth. 16 dental alveoli were observed. The dentary slightly curves inward medially to meet the right dentary. The symphysis occurs at the most anterior portion of the dentary. The surface of the symphysis is flattened, which according to Madsen would be a site of attachment for a ligament. This would allow for kinetic movement between the two mandibles (Madsen 29). The dentary is thickest at the center, which bulges out medially. The dentary tapers dorsally towards the dental alveolus and ventrally from the center. Medially underneath the central bulge the Meckelian groove is well developed on the dentary's anterior portion. The Meckelian groove starts at the symphysis and continues anteroposteriorly until the anterior end of the splenial covers the groove. On the dorsolateral surface of the dentary a row of foramina runs parallel with the tooth row. A few foramina run dorsoventrally, running parallel to the flattened surface of the symphysis. A smaller row of foramina runs parallel to the ventral surface of the dentary. Because of the fractured nature of the internal bone it is hard to determine the origin of those foramina. The dentary articulates with the supradentary dorsomedially and the splenial dorso and ventromedially, in which both bones rest upon the dentary. The anterior end of the coronoid also articulate with dentary dorsomedially on its posterior margin. The anterior edge of the surangular articulates with the posterior edge of the dentary dorsolaterally to ventrolaterlly, this articulation ends at the dorsal edge of the external mandibular foramen. The dentary thinly covers the lateral edge of the articular until it tapers near the articular's ventral surface.