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PROJECT TITLE:
Identifying Jurassic Theropod Genera Using GIS Maps of Tooth Serrations

Identifying Jurassic Theropod Genera Using GIS Maps of Tooth Serrations

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Abstract

Theropods are carnivorous dinosaurs that have serrations on their teeth, like serrations on a steak knife. A serration is a row of sharp tooth-like projections found on the edges of theropod dinosaur teeth. There are two main theories surrounding the origin and purpose of serrations on theropod teeth. In the first theory, serrations are thought to help maintain the strength and integrity of the tooth along the curve of the tooth. The second, and more widely accepted theory, is that serrations evolved to aid in the killing of prey, which helped theropods become the apex predators of their time. Many attempts have been made to morphometrically analyze theropod teeth as an aid in their identification, including measurements of serration density and the microanatomy of the denticles. However, none of these techniques have been able to successfully identify theropod genera from isolated teeth and teeth fragments. The purpose of this study was to use GIS mapping of tooth serrations of previously identified theropod teeth acquired from museum collections, to establish criteria for identifying theropod genera based on tooth serration geometries.

This study used photographs of 92 theropod teeth and ARCmap GIS software to characterize the geometry of serrations on Ceratosaurus, Marshosaurus, and Allosaurus teeth. By using the software to digitize the serration outline on 73 teeth, this study was able to identify patterns in among each individual genus using qualitative observations. Ceratosaurus denticles typically have mushroom- and tapered-shaped denticles with relatively little space between individual denticles and a deep interdenticular dentition. Allosaurus serration display a blocky shape, and there is a relatively large space in between individual denticles and a relatively shallow interdenticular dentition. Marshosaurus serrations show jagged puzzle-like shaped denticles with a moderate amount of space between individual denticles and a deep interdenticular dentition. Using these specific denticle patterns, unidentified theropod teeth were successfully classified as either Allosaur or Ceratosaur genera using qualitative observations that led to defining characteristics of the serrations of each genus. This study shows justification for future efforts to identify theropod genera from a detailed study of individual tooth fragments

Figure 1: Theropod tooth showing serrations with scale in lower left corner.

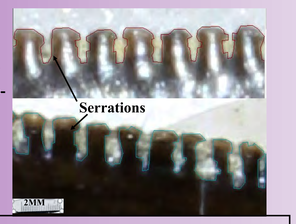

Figure 2: Photos of serrations with serration outline.

Objective

- Digitize a diverse set of theropod teeth in order to outline the serrations on their tooth
- Find unique patterns in the serration outlines among the different genera
- Use those patterns to discover the genera of unidentified theropod teeth and tooth fragments

Introduction

Theropods are a group of saurischian dinosaurs that are ancestrally carnivorous but later evolved to include herbivores. All carnivorous theropods have serrations (denticles) on their teeth like steak knives (Figure 1 and 2). A serration is a row of sharp or tooth like projections, that are present on the edge of the tooth. Dinosaur teeth tend to be unique at the genus level, so perhaps the shape and pattern of denticles on the edges of their teeth can be used to identify genera as well. In order to differentiate between theropod genera using only their teeth, Jurassic theropod tooth serrations was mapped, contrasted, described, and characterized using GIS.

Study Area

Due to the uniqueness of this project there is not just one study area. All of the data was collected from museum collections found at The Museums of Western Colorado: Dinosaur Journey, and The Denver Museum of Nature and Science. Despite this, all of the teeth are Jurassic in age from the Morrison Formation. While the teeth from the Denver museum come from many different quarries, the teeth from Dinosaur Journey were found at the Mygatt Moore Quarry in the Brushy Basin Member of the Morrison Formation (see figure 3 and 4).

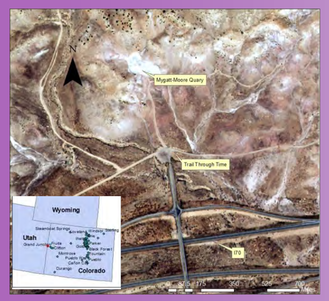

Figure 3: The location of the Mygatt Moore Quarry in Rabbit Valley with an inset map showing the position in relation to the surrounding states

Figure 4: Brushy Basin Member of the Morrison Formation outcrop.

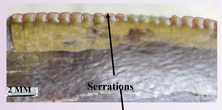

Figure 5: Well preserved serrations that were easily digited and used to create a pattern.

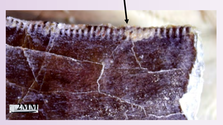

Figure 6: Degraded serrations, NOT DIGITIZED

Specimen Break Down

	Dinosur Journey	Denver Museum	Total Specimens	Minimum Number of idividuals	NUMBER OF DEGRADED TEETH	NUMBER OF TEETH DIGITIZED
Ceratosaur	17	0	17	17	2	15
Allosaur	7	20	27	20	7	20
Marshosaur	0	8	8	1	0	8
Torvosaur	1	1	2	2	N/A	0
Theropoda	16	22	38	28	8	30
Total	41	51	92	68	17	73

Table 1: The specimen breakdown of the data set. There were 17 Ceratosaur specimens, 27 Allosaur specimens, 8 Marshosaur specimens, and 38 Theropod specimens that were used in this study.

Methods

In order to obtain the data needed for this study, 2 different museums were visited. At these museums, photographs were taken of 92 specimens (see break down in table 1). The photographs consisted of, if possible, zoomed in views of the serrations on every side of the tooth. Many of the specimens that were looked at could not be used due to degradation. Degraded serrations are incomplete, broken off, or covered up serrations that change the pattern and the outline of the serrations. Despite the pursuit of accurateness some of the serrations that were digitized showed signs of degradation that explain some inconsistencies in the patterns. Figure 5 is an example of well preserved serrations with some degraded serrations separating two sections. Figure 6 shows degraded serrations that would be impossible to use for this study due to the level of degradation of the serrations. Out of the 92 specimens that were included in this study, only 73 were digitized, while 17 teeth were too degraded to be useful, and 2 (the Torvosaur teeth) were not digitized due to the lack of specimens. Of those 73 digitized teeth, there were a minimum of 68 individuals. The difference between number of teeth and individuals is due to the fact that some teeth were in fragments or multiple teeth were placed under the same id number. When this happens, one must assume that all of the teeth with same specimen ID number came from the same individual. Once the data was gathered all of the serrations were digitized using ARCmap a GIS software.

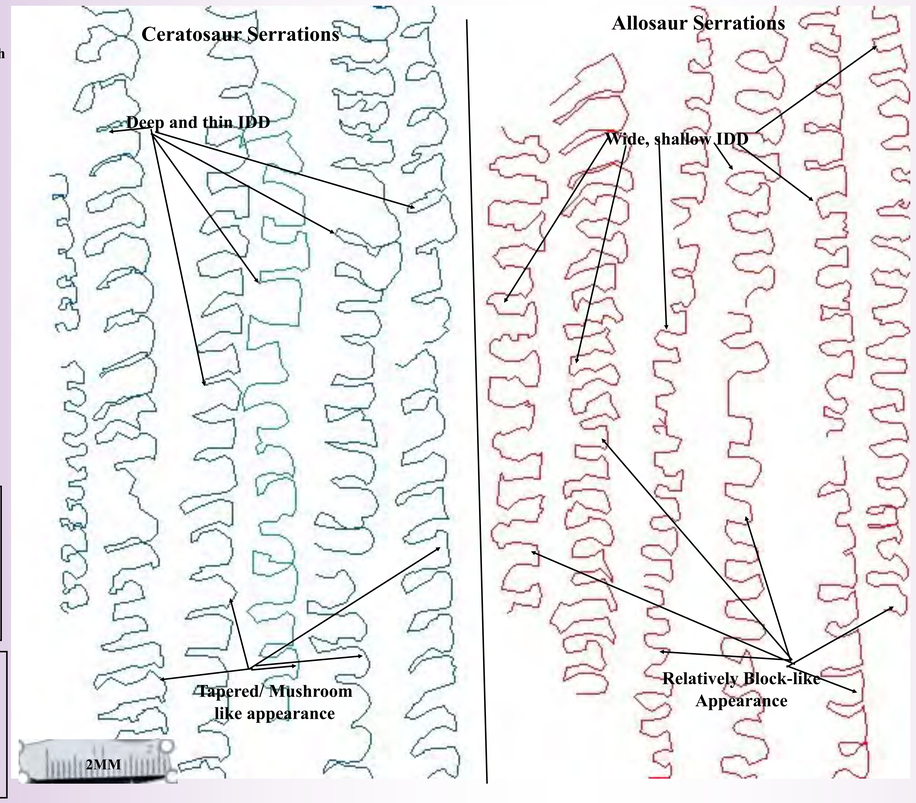

Figure 7: The above figure shows the base serration pattern of ceratosaur (left: blue) and allosaur (right: red). Ceratosaur denticles typically have mushroom- and tapered-shaped denticles with relatively little space between individual denticles and a deep interdenticular dentition (idd) (see arrows). Allosaur serration display a blocky shape, and there is a relatively large space in between individual denticles and a relatively shallow interdenticular dentition (idd) (see arrows). These patterns are both unique and consistent enough to be used as guidelines for the identification of the unidentified theropod teeth.

Pattern Identification

In order to identify the genera of unidentified theropod teeth qualitatively, there must first be a pattern to compare the theropod serrations to. After all of the teeth were digitized the front (if specified) inside curve of each tooth for each genera was lined up side by side in order to discern a pattern. Due to Marshosaurs being Megalosaurids their pattern was easily identifiable and easily distinguished. It is not included above because it is a relatively rare dinosaur that is only found by the Denver museum. Allosaurs and Ceratosaurs however, are common throughout Colorado despite this, Ceratosaurs are less common than Allosaurs which is suggested in the sample dataset. Ceratosaurs and Allosaurs are similar dinosaurs that have teeth that are difficult to discern when the entire tooth is not available, even then genera identification can be difficult. However, by using the methodology described above and qualitatively observing the serration outlines one can discern a clear pattern in each genera. Ceratosaur denticles typically have mushroom- and tapered-shaped denticles with relatively little space between individual denticles and a deep interdenticular dentition (idd) (figure 7). Interdenticular dentition is the space in between serrations, as long as the serrations are well preserved, the idd can be an identifying characteristic as well as the shape of the denticle. Allosaur serrations display a blocky shape, and there is a relatively large space in between individual denticles and a relatively shallow interdenticular dentition. Marshosaurs, though not shown above have a unique pattern of their own centered around these identifying characteristics. Marshosaur serrations show jagged puzzle-like shaped denticles with a moderate amount of space between individual denticles and a deep interdenticular dentition. Due to the consistency of these identifying characteristics, they can be used to discover the genera of unknown theropod teeth and tooth fragments.

Genera Identification

Genera identification begins with picking the best and most accurate serration outlines. Once this has been done, in order to observe easily all of the serration outlines are lined up side by side (figures 8 and 9) with the (red) allosaurs on the left and the (blue) ceratosaurs on the right. A space is left in the middle to place the unidentified theropod serration outline , then qualitative observations are made. Using the guidelines that were created during pattern identification, one simply goes down the list seeing which characteristics the outline has the most of. For example: figure 8 shows a specimen from The Denver Museum of Nature and Science with the specimen ID of EPV21968. The specimens outline is the greenish one in the middle while the Allosaurs are on the left in red and the Ceratosaurs are on the right in blue. This serration outline clearly shows a wide relatively shallow idd, the serrations themselves, despite having the look of being tapered, are extremely block like. Therefor EPV21968 must be an Allosaur tooth. These particular serrations are mostly well preserved but there were frequent areas where the serrations were covered up by surrounding rock. Due to the fact that serrations are so small, fossil preparators do not make an effort to get rock off of the serrations which would be the cause of the tapered look of some of the serrations. In this case the idd is so obviously allosaur the shape of the block can be slightly overlooked. Figure 9 shows the serration outline of a specimen from The Museums of Western Colorado: Dinosaur journey with the specimen ID of MWC9504. This is the same set up as before with the specimen under question in purple in the middle. This serration outline is so well preserved that the practice eye need only to glance in order to see that this specimen is a Ceratosaur. It has a deep and thin idd with mushroom shaped serrations. Despite the fact that not all identifications are this easy, the identifying characteristics can clearly be used to identify the genera of unidentified theropod teeth and tooth fragments.

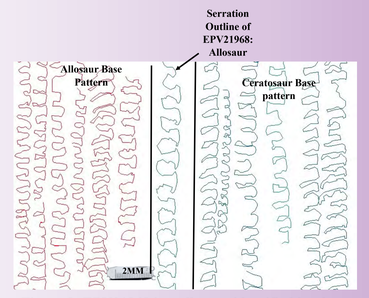

Figure 8: EPV21968 is a allosaur identified by the

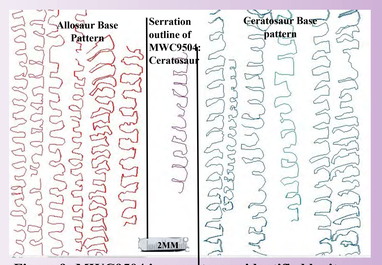

Figure 9: MWC9504 is a ceratosaur identified by its unique serration pattern.

Conclusions

- All objectives met.
- Successfully digitized 73 teeth.
- Successfully identified 24 Unidentified theropod teeth and 22 unidentified theropod individuals with 10 allosaurs identified and 12 ceratosaurs identified.
- Justified identification process by confirming all teeth that have the same ID number also have the same genera identification.
- Mitigated error as much as possible by maintaining the same scale on all photographs and by having all serrations at the same scale.
- Successfully created a method of identifying the genera of theropod teeth and tooth fragments proving the necessity for future studies.

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