Cretaceous Theropod Teeth from Western North America

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Introduction

Theropod dinosaur teeth are common in Mesozoic fossil deposits, but are typically found isolated from skeletal remains. Although these teeth have many distinctive morphological features, few are unique to individual species. As a result, it is difficult to assign theropod teeth to species, and to track diversity through time and space, despite the density of this fossil record.

We developed a morphological database of theropod dinosaur teeth from Cretaceous (145 to 66 mya) deposits in western North America. Its purpose was to investigate whether different combinations of features allowed us to identify and classify individual specimens, and at what taxonomic level. By combining our result with previously published efforts, we assess the reliability of our observations.

Materials and Methods

We studied 50 theropod tooth specimens and made qualitative taxonomic identifications based on gross morphology. Next we identified 8 continuous measurements (Fig. 1) to document linear aspects of size (height, basal width and length, curvatures) and denticle density, and calculated 4 proportional indices. These measurements were taken with calipers and measuring tape. We added 27 characters, coded as discrete states, to capture information about features such as interdenticular sulci, enamel wrinkling, and denticle density variations (Fig. 2). Observations were aided by use of a Zeiss Stemi microscope and a Hitachi ESEM. We also developed a reference dataset of published continuous data that included additional identified specimens.

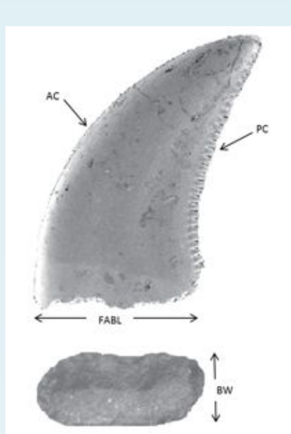


Figure 1. Theropod tooth showing the anterior carina (AC), posterior carina (PC), basal length (FABL) and basal width (BW). Taken from refrence 2.

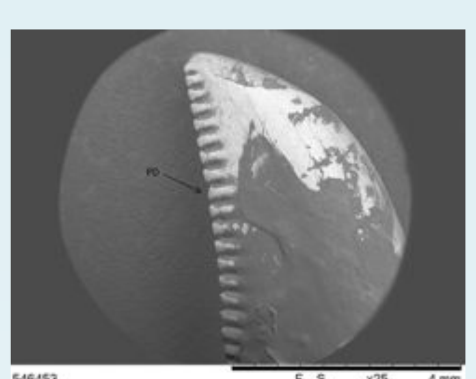


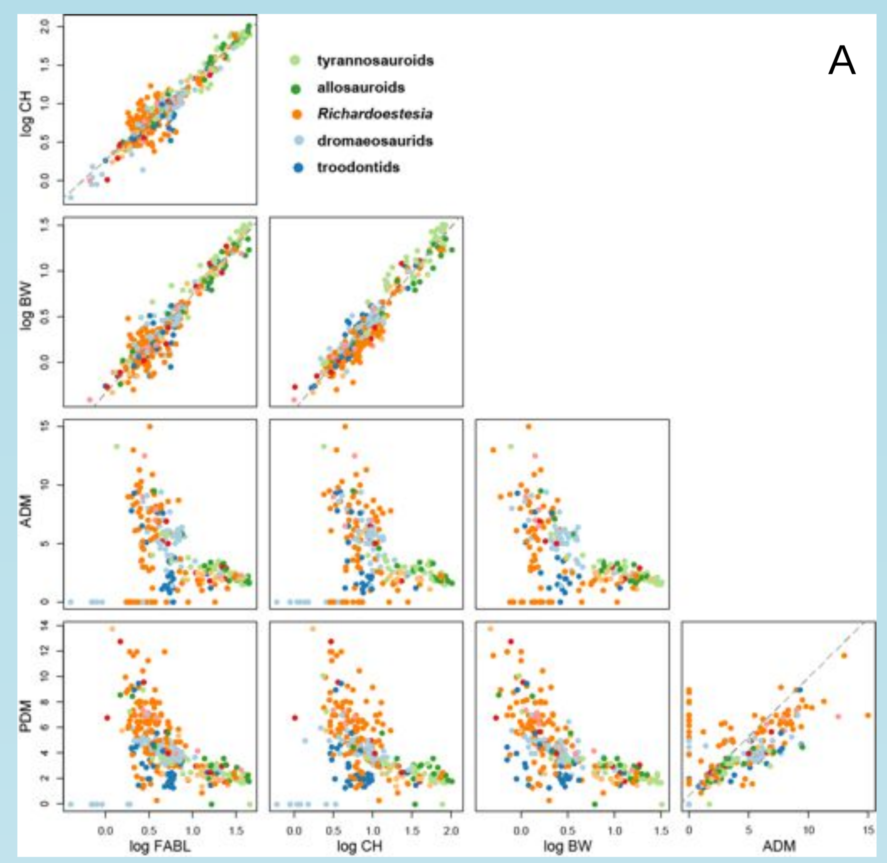
Figure 2. SEM photograpgh of a theropod tooth showing the posterior denticles (PD).

We used two primary methods for data exploration. First, each continuous measurement or index was plotted against another, using a least-squares regression line for reference. We then identified whether any taxonomic groups could be distinguished. Second, we performed principal coordinates analysis (PCO) and non-metric multidimensional scaling (NMDS) on the entire dataset, using continuous + discrete data as well as continuous data only. We again determined whether any taxonomic groups could be distinguished on each axis. Both sets of results were compared.

Using the reference dataset, we compared our results with those obtained for previously identified specimens. We also examined whether time and geological formation could be discriminated based on the constituent specimen morphologies.

Results

Bivariate plots were useful for distinguishing some larger taxonomic groups using certain character combinations (Table 1; Fig. 3), but we were not able to recognize individual species. Time and geological formation were only distinct when they were represented primarily by particular taxonomic groups.



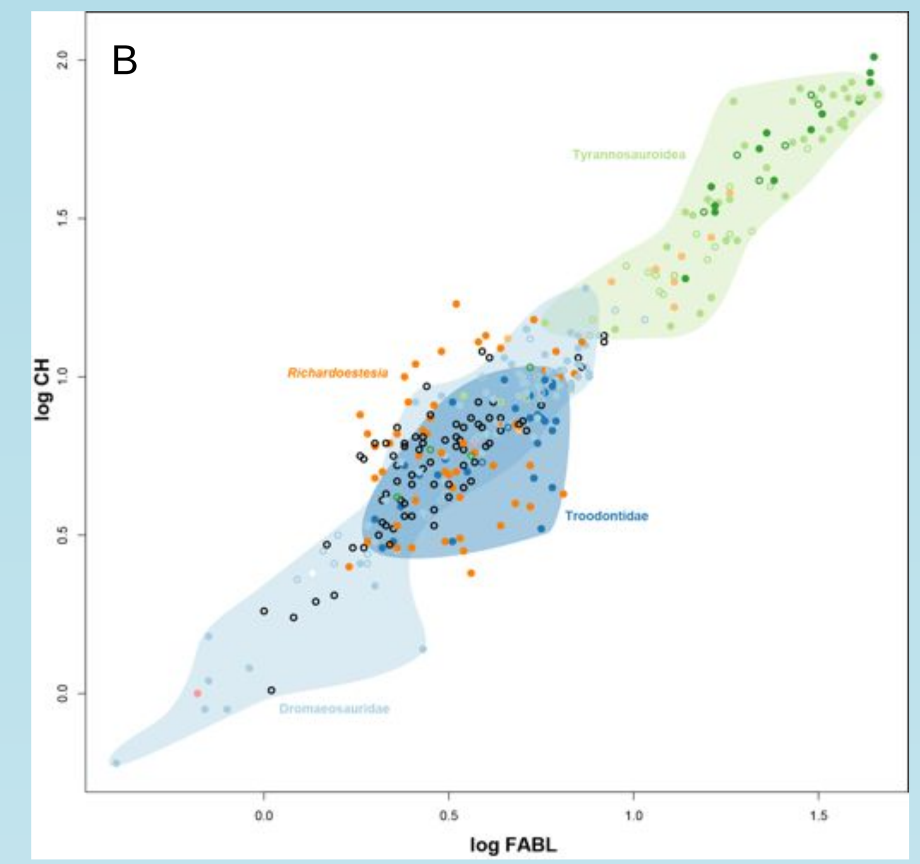


Figure 3.

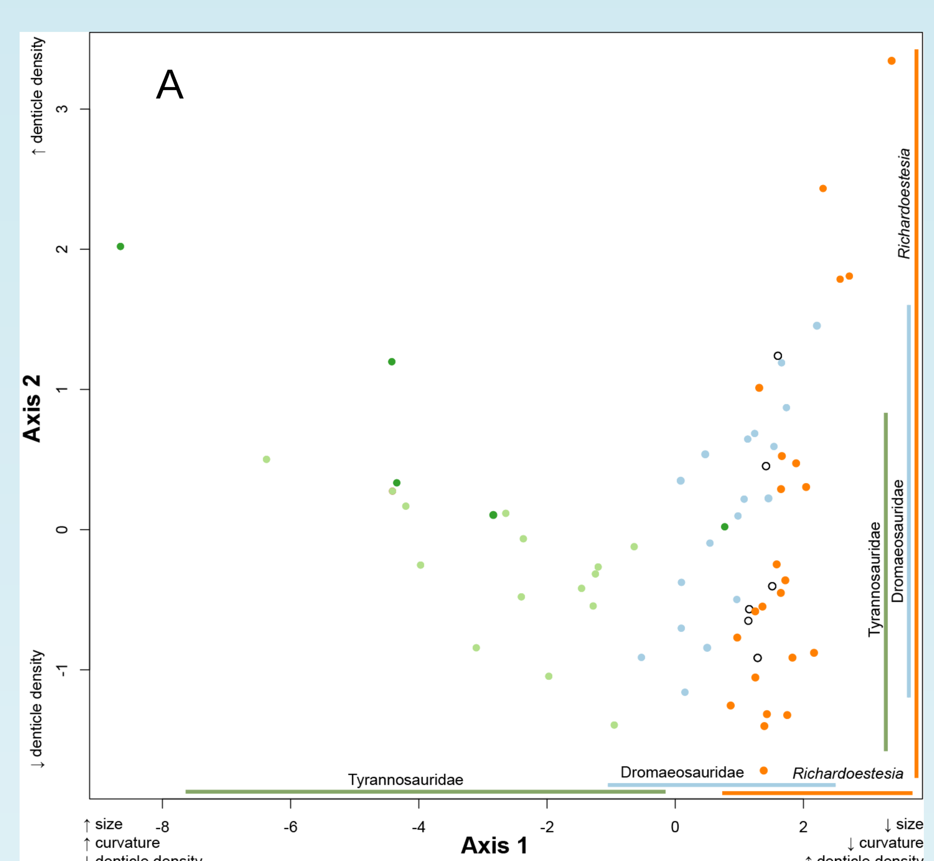
A: Set of scatterplots comparing several continuous variables. Dashed lines show least-square regression lines.

B: Sample bivariate log-log scatterplot (CH versus FABL), highlighting major taxonomic groups. Abbreviations: ADM = denticles per millimeter, anterior carina; BW = basal width; CH = crown height; FABL = fore-aft basal length; PDM = denticles per millimeter, posterior carina.

Features	Taxon				
	Tyrannosauroids	Allosauroids	Dromaeosaurids	*Richardoestesia*	Troodontids
Crown Height	Tall	Tall	Short	Short	Short
Basal Width	Wide	Wide	Narrow	Narrow	Narrow
Basal Length	Long	Long	Short	Short	Short
Denticle Density	Low	Low	High	High	Low

Table. Representative taxonomic groups and continuous characters used in this analysis. General trends for each group are shown.

PCO and NMDS showed very similar results (Fig. 4), distinguishing between larger taxonomic groups but not between individual species. One exception was the problematic genus *Richardoestesia*, which has a distinct morphology but may represent early ontogenetic stages of another form. A second was *Tyrannosaurus*, which has a uniquely robust dentition among theropods. The contributions of different variables to each axis were consistent with the patterns observed for the same variables in the bivariate plots.



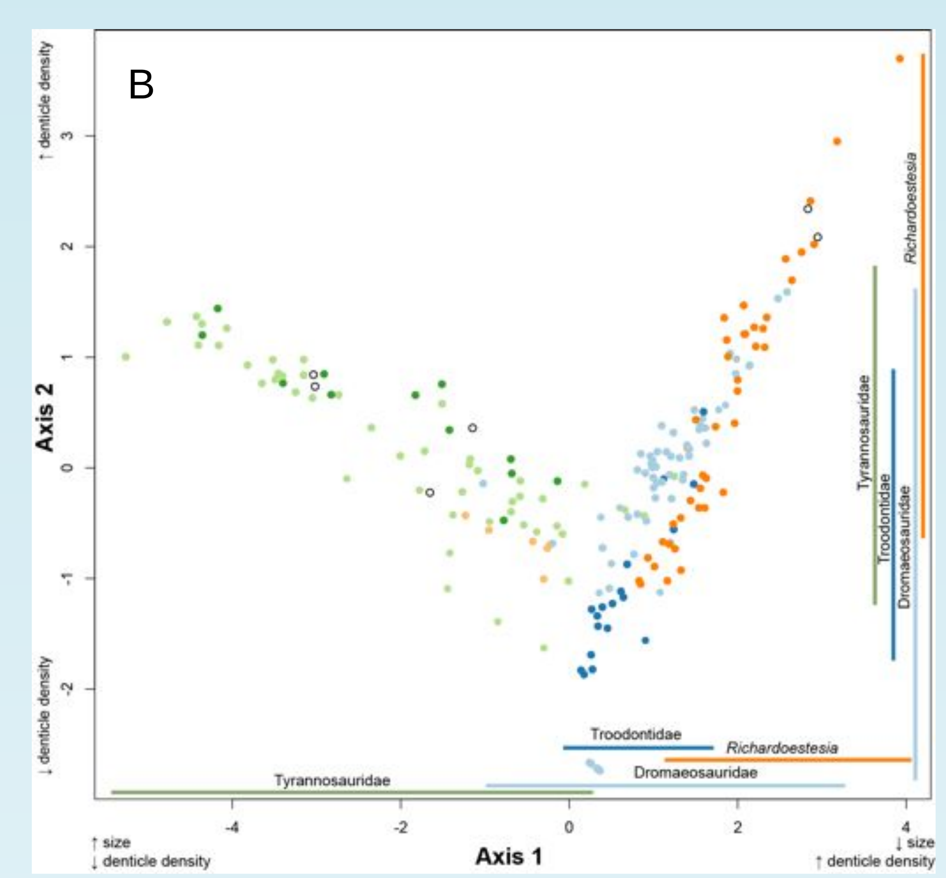


Figure 3. Sample PCO results, showing ranges of taxonomic groups and important variables for each axis.

A: PCO results of original dataset with qualitative identifications.

B: PCO results including reference dataset.

Discussion

Theropod dinosaur teeth preserve taxonomically relevant information in spite of their relatively limited morphological variation (3). Although damaged and incomplete specimens were common in our dataset, these tended to reduce the available sample size rather than the total amount morphological data. These data are best used to make higher-level taxonomic distinctions, rather than species identifications.

These results were consistent across the methods used, and with larger, previously published datasets (2–4). The strongest morphological support distinguishes troodontids + dromaeosaurids from tyrannosaurids + allosauroids based on a combination of size plus serration density. *Richardoestesia* is distinguished primarily by size, and may represent an ontogenetic variant. *Tyrannosaurus* is also distinct. This general consistency suggests that these measures capture relevant morphological data that overlaps with qualitative assessments.

Neither time nor formation showed any consistent patterns beyond those also associated with specific taxonomic groups. However, both could be added to higher-level taxonomic identifications to achieve greater resolution.

Finally, given the apparent limits on the morphological data preserved in theropod teeth, it is likely that only the most unusual species will be identifiable based on teeth alone. Future work will need to address how to combine morphological data with spatial and temporal data to refine taxonomic identifications and maximize the utility of these fossils.

Conclusion

Based on our study of discrete and continuous data, we were able to determine that some larger taxonomic groups can be distinguished based on similarities in size and shape. Groups such tyrannosaurids and dromaeosaurids show substantial differences, but individual species did not. **Theropod tooth morphology seems best suited to higher-level taxon discrimination.**

The patterns observed were consistent using PCO, NMDS and bivariate plots, and when compared with previously published data. This suggests that **our measurements captured relevant data for taxon identification**.

Theropod teeth can be identified based on morphology, but to improve their usefulness these data should be combined with spatial and temporal information.

References

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