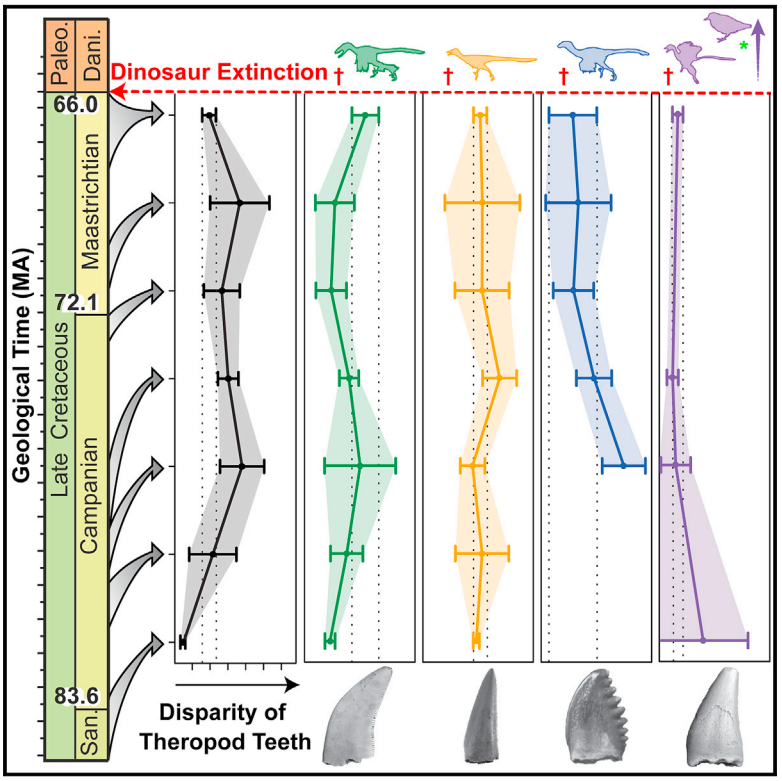
Report

Current Biology

Dental Disparity and Ecological Stability in Bird-like Dinosaurs prior to the End-Cretaceous Mass Extinction

Graphical Abstract



Highlights

- Tooth shape disparity in small maniraptoran dinosaurs is examined in the Cretaceous
- Results show stability and sudden extinction in this guild at the end of the Cretaceous
- Groups are mostly static in shape space except for larger size in the early Maastrichtian
- Evolution of an edentulous beak and granivory may have been key to the survival of birds

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In Brief

Larson et al. determine that tooth shape disparity, a proxy for ecological stability, in small maniraptoran dinosaurs shows that this clade was stable prior to the end-Cretaceous mass extinction. This indicates a sudden extinction for most members of the group but suggests that diet may have played a role in the survival of crown group birds.

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Dental Disparity and Ecological Stability in Bird-like Dinosaurs prior to the End-Cretaceous Mass Extinction

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SUMMARY

The causes, rate, and selectivity of the end-Cretaceous mass extinction continue to be highly debated [1–5]. Extinction patterns in small, feathered maniraptoran dinosaurs (including birds) are important for understanding extant biodiversity and present an enigma considering the survival of crown group birds (Neornithes) and the extinction of their close kin across the end-Cretaceous boundary [6]. Because of the patchy Cretaceous fossil record of small maniraptorans [7–12], this important transition has not been closely examined in this group. Here, we test the hypothesis that morphological disparity in bird-like dinosaurs was decreasing leading up to the end-Cretaceous mass extinction, as has been hypothesized in some dinosaurs [13, 14]. To test this, we examined tooth morphology, an ecological indicator in fossil reptiles [15–19], from over 3,100 maniraptoran teeth from four groups (Troodontidae, Dromaeosauridae, *Richardoestesia*, and cf. Aves) across the last 18 million years of the Cretaceous. We demonstrate that tooth disparity, a proxy for variation in feeding ecology, shows no significant decline leading up to the extinction event within any of the groups. Tooth morphospace occupation also remains static over this time interval except for increased size during the early Maastrichtian. Our data provide strong support that extinction within this group occurred suddenly after a prolonged period of ecological stability. To explain this sudden extinction of toothed maniraptorans and the survival of Neornithes, we propose that diet may have been an extinction filter and suggest that granivory associated with an edentulous beak was a key ecological trait in the survival of some lineages.

RESULTS

Analysis of 3,104 maniraptoran teeth from 18 lithostratigraphic units in western North America showed that morphological disparity of tooth shape (as calculated from linear measurements; see the Supplemental Experimental Procedures; Tables S1 and S2) remained remarkably stable over the last 18 million years of the Cretaceous and was not decreasing before the end-Cretaceous boundary. Examination of the total dataset at both lithostratigraphic-unit-level and North American Land Mammal Age (NALMA)-level time binning respectively shows both significant (Figure 1A) and non-significant (Figure 1G) decreases in disparity in the latest Cretaceous Lancian (68–66 Ma) units leading up to the end-Cretaceous extinction. However, this decrease is driven by size changes in troodontids (Figures 2 and 3) and is not present when this clade is excluded from this dataset (Figures 1B and 1H). Both analyses show that the lowest levels of disparity in toothed maniraptorans occur in the Late Santonian Aquilan (84–83 Ma) Milk River Formation, approximately 18 million years before the end of the Cretaceous, followed by a consistent, significantly higher disparity in all later units leading up to the end-Cretaceous extinction.

With respect to individual clades, no significant decline in disparity is seen between the penultimate and ultimate time bins (Figures 1C–1F and 1I–1L). An increase in disparity between the Aquilan and Judithian (80–73 Ma) NALMAs is significant for both dromaeosaurids and *Richardoestesia* (troodontids are not present in the Aquilan sample; Figures 1C–1E). Such an increase is also reflected in the lithostratigraphic-unit-level dataset between the Milk River and Dinosaur Park formations (Figures 1I and 1K). Also, although no significant shifts occur in the lithostratigraphic unit dataset, there is a trend of decreasing disparity in troodontids through time (Figure 1J) but no decline immediately preceding the latest Cretaceous time bin, and it is this notable trend that is similarly observed in the NALMA data (Figure 1D). The cf. Aves group shows a significant decrease in disparity between the Aquilan and Judithian NALMAs (Figure 1F), but no such significant shifts are seen in the lithostratigraphic-unit-level data, possibly due to the low sample of cf. Aves teeth in the Milk River Formation (Figure 1L). The pattern of morphological disparity is also broadly similar between different lithostratigraphic units along the Western Interior Basin of approximately the same age (Figure S1), indicating that the patterns of disparity seen in the lithostratigraphic-unit-level bins is broadly comparable to the whole record in western North America.

Tooth shape patterns show a similar pattern of stability. Occupation of tooth shape morphospace was visualized on principal components 1 and 2 (PC1 and PC2; Figures 2 and 3), as most (91.9%) of the variation in the principal component analysis