Open Wide! : A Morphometric Analysis of Ornithischian Teeth

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Introduction

- As teeth are harder than bone, it preserves at a much higher rate. Palaeontologists often find isolated teeth and without a method of identification, they cannot provide us with much information. (Hudgins et al. 2021)
- There are subtle differences between the teeth of varying species of ceratopsians and members of the ornithischian clade.
- This study will allow future palaeontologists to identify isolated teeth by taking simple measurements and comparing the data to the measurements in this study.

Fig 1: image taken by Connor Duffy of an isolated tooth from the dinosaur family of ceratopsidae. UALVP 57960 from the University of Alberta collections.

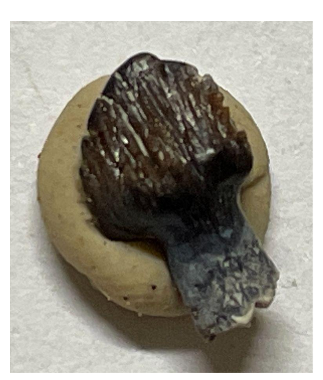

Fig 2: image taken by Connor Duffy of an isolated tooth from the dinosaur genus of stegoceras. UALVP 53 from the University of Alberta collections.

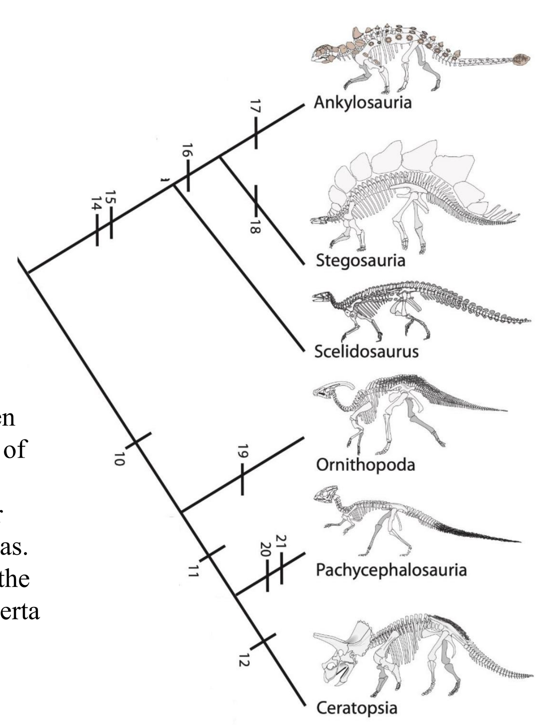

Fig. 3: Proposed cladogram for Genasauria (modified) http://www.geo.utexas.edu/courses/302d/Fall_2010/Ornithischia%20Cladogram.pdf

Methodology

- Close-up pictures were taken of various ceratopsian, pachycephalosaurian, and ankylosaurian tooth specimens. which were then uploaded to a program called ImageJ ™.

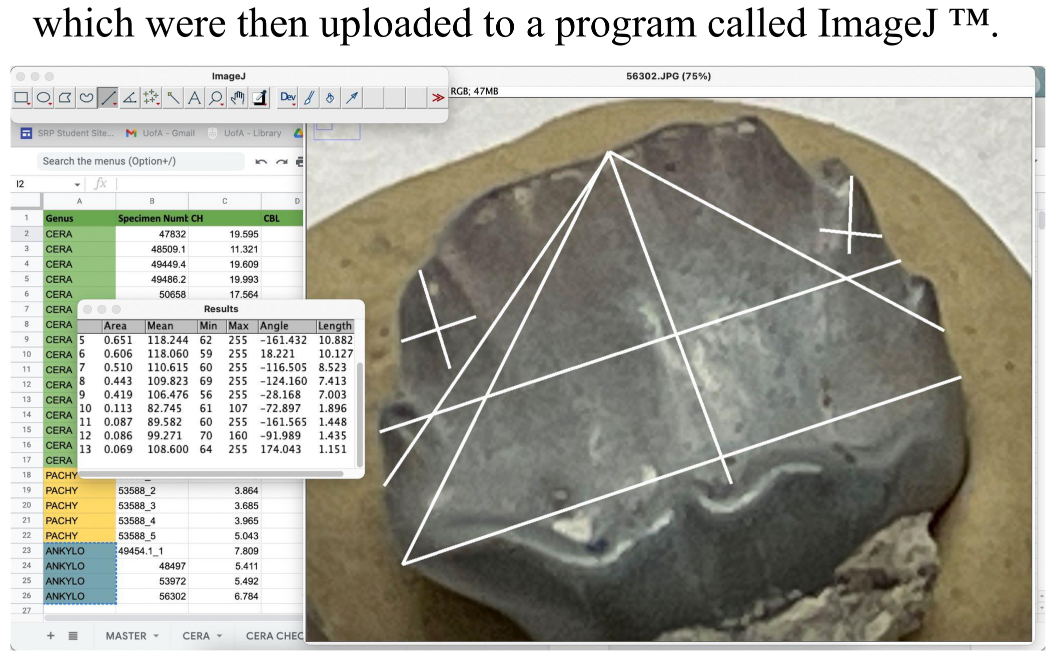

Fig 4: image of my desktop during the process of measuring UALVP 36302 using the program ImageJ

- A scale bar must be included in each image so the measurements are as accurate as possible.
- After each measurement was taken, the data was organized into a spreadsheet for later analysis.

Methodology

- Using the proposed terminology of theropod teeth by Hendrickx et al. (2015) we took 7-11 different measurements of each tooth.
- We measured 16 ceratopsian teeth, 5 pachycephalosaurian teeth, and 4 ankylosaurian teeth.

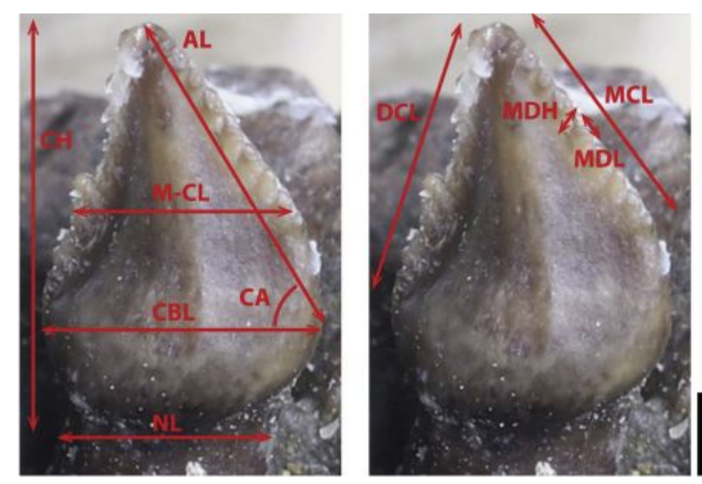

Fig 5: Hudgins et al. (2022) - Dental assessment of *Stegoceras validum* and *Thescelosaurus neglectus*. Morphometric terminology used in this study. **AL**: apical length. **CA**: crown angle. **CBL**: crown base length. **CH**: crown height. **DCL**: distal carina length. **DDH**: distal denticle height. **DDL**: distal denticle length. **M-CL**: mid-crown length. **MCL**: mesial carina length. **MDH**: mesial denticle height. **MDL**: mesial denticle length.

- If parts of the tooth were obscured, then the measurement was simply left blank.
- The entire dataset was analyzed in PAST ™ using principal components analysis (PCA), linear discriminant analysis (LDA), and PERMANOVA. Hammer and Harper (2005)

Results

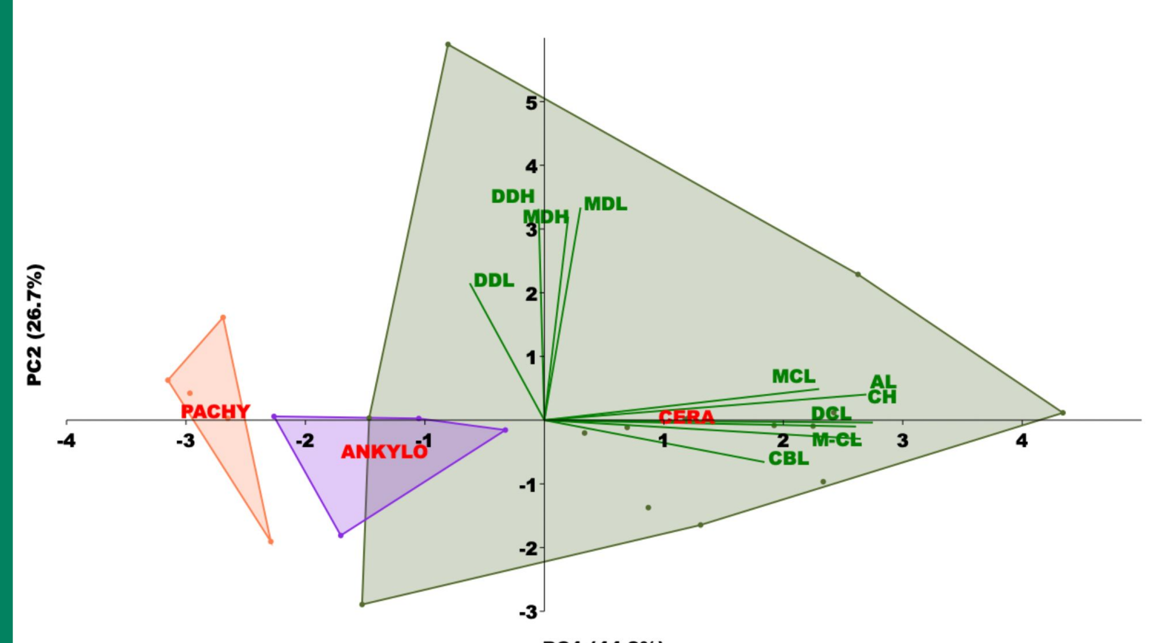

Fig 6: results on the PCA of ceratopsian, pachycephalosaurian, and ankylosaurian teeth series. The eigenvectors (green lines) on the biplot represent the impact each measurement had on PC1 and PC2.

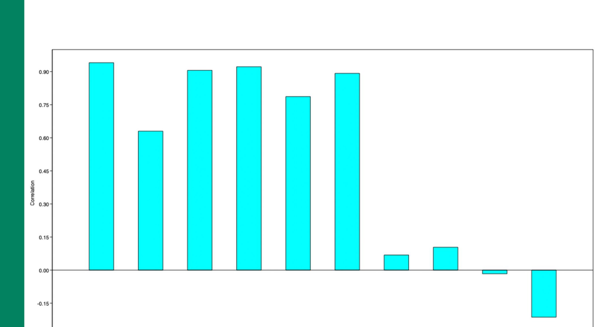

Fig 7: loadings plot of the principal component analysis of PC1. The measurements of the crown of the tooth (CH, CBL, M-CL, AL, MCL, and DCL) have the greatest impact on PC1.

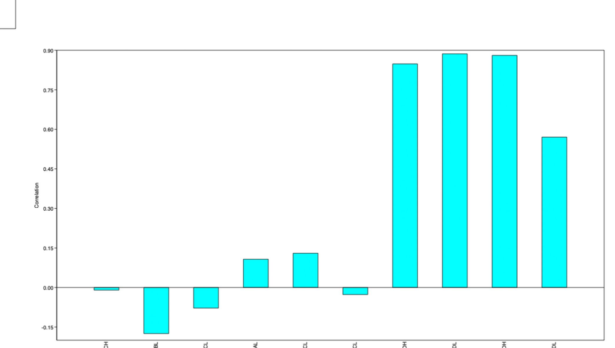

Fig 8: loadings plot of the principal component analysis of PC2. The measurements of the denticles of the tooth (MDH, MDL, DDH, and DDL) have the greatest impact on PC2.

Results

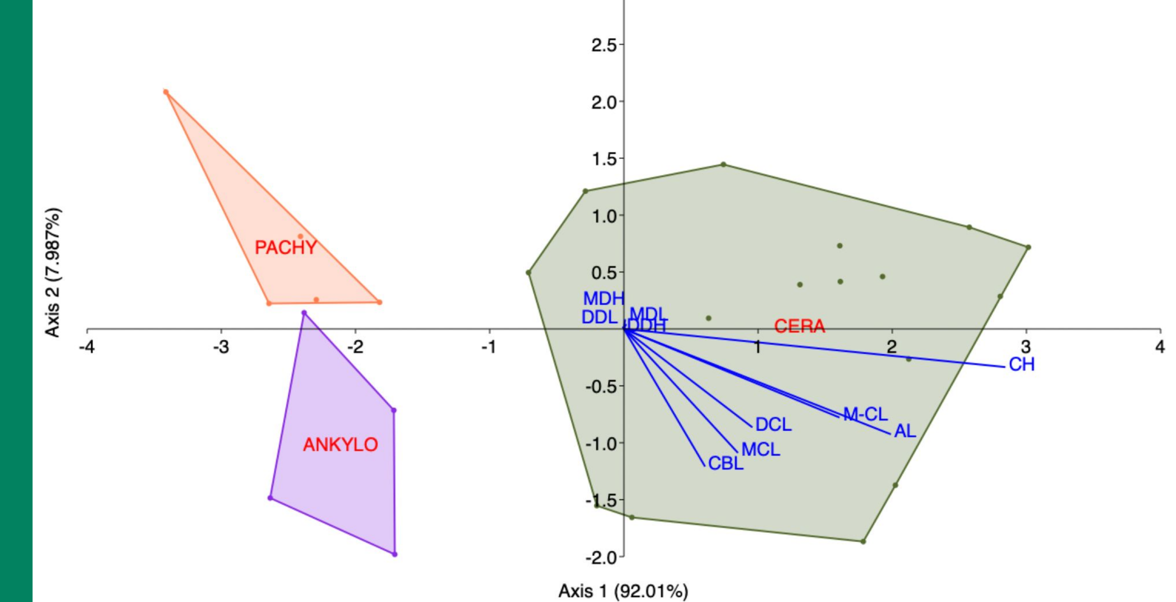

Fig 9: results on the LDA of ceratopsid, pachycephalosaurid, and ankylosaurid teeth series. The eigenvectors (blue lines) on the biplot represent the impact each measurement had on Axis 1 and Axis 2.

	CERA	PACHY	ANKYLO	Total
CERA	14	1	1	16
PACHY	0	5	0	5
ANKYLO	0	1	3	4
Total	14	7	4	25

Fig 10: a confusion matrix was performed on the LDA. In total, 88% of the time, the program was able to correctly identify the teeth by the measurements taken in this study. 100% of the time it correctly identified ceratopsian teeth. 71% of the time for pachycephalosaurids and 75% of the time for ankylosaurids.

PERMANOVA	
Permutation *N*:	9999
Total sum of squares:	4144
Within-group sum of squares:	1646
F:	16.7
p (same):	0.0001

Fig 11: results of the Permutational multivariate analysis of variance (PERMANOVA) revealed statistically significant separation in groups when considering taxonomy. F = 16.7 and p(same) = 0.0001.

- The principal components analysis found that PC1 explains 44.3 percent of the variation and PC2 explains 26.7 percent. (Fig 6).
- The crown measurements have the greatest impact on PC1 and the denticle measurements have the greatest impact on PC2 (Fig 7-8).
- In the linear discriminant analysis, Axis 1 and 2 explain 92.01% and 7.987% of the variation respectively. (Fig 9)
- In both the PCA and the LDA, the ceratopsian cluster shows much variation within the group whereas pachycephalosaurs and ankylosaurs occupy a much smaller morphspace.

Conclusion

- In both the PCA and the LDA, ceratopsians occupy a large morphospace indicating there was a sizable variation in tooth morphology within this suborder. This finding may provide insight as to why so many ceratopsian species were able to coexist in the same environment. (Black et al., 2022)
- There is excellent separation among groups in the LDA, meaning these three suborders underwent enough change during evolution that their teeth may be identified using morphometric analysis. This is further supported by the PERMANOVA test in which the p-value was <0.05.
- These conclusions strongly suggest that this method of microsite identification has implications for the future of palaeontology.
- As demonstrated in Fig 9, much of the variation between pachycephalosauria and ankylosauria is found on the second axis. This indicates that most of the difference between these two suborders is related to their denticles. Future research into these differences may reveal further insight into the niche partitioning of ornithischian dinosaurs.

Acknowledgements and References

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References:

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