# Patterns and Constraints in Carnivoran and Rodent Dental Complexity and Tooth Size


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## Summary

- Tooth row complexity is correlated with diet, and so can be used to predict diet in extinct species.
- Here, we investigate whether isolated teeth can be used to reconstruct diet.
- Isolated lower teeth were reasonable in predicting diet whether tooth position is known or not.
- Dental complexity is correlated with the inhibitory cascade rule of relative tooth sizes, and it is likely that inhibition controls both features.


## Introduction

It has been known for centuries that **general tooth shape correlates with diet** in mammals. Our previous work showed that the 3D complexity of cheek tooth rows is a robust measure of broad diet in carnivorans and rodents. This used a measure of tooth complexity termed Orientation Patch Count (OPC).

Here, we introduce a modification of the method to make the result less sensitive to tooth orientation, termed Orientation Patch Count Rotated (**OPCR**).

As most fossil remains do not include full cheek tooth rows, it is important to know whether the method is capable of **reconstructing diet from isolated teeth**. Therefore, we also extend this to investigate patterns of dental complexity of individual teeth along a row. In addition, the position of the tooth (e.g. 4th premolar, 2nd molar) may not be able to be identified. Therefore, we examine the efficacy of the method in the cases of **known and unknown tooth position**.

Finally, we examine the relationship between OPC and the **inhibitory cascade** (IC), first identified by Kavanagh *et al.* (2007). In murines, the relative sizes of the molars follow a predictable relationship of m3/m1 = 2(m2/m1) - 1. Inhibition between teeth appears to be the primary driver of this pattern. We investigate whether this pattern holds for carnivorans, and whether there is any relationship between relative tooth sizes and dental complexity.

## Materials and Methods

- Specimens, teeth and diet categorisation all follow Evans *et al.* (2007). Species were placed into five diet categories (hypercarnivore, carnivore, animal-dominated (A-D) omnivore, plant-dominated (P-D) omnivore and herbivore).
- Complete upper and lower molar tooth rows (and up4 in carnivorans) were surface laser scanned. l/u refers to lower/upper, p/m to premolar/molar.
- OPC was calculated according to Evans *et al.* (2007) using 8 orientations and a minimum patch size of 3.
- OPCR was the mean of eight OPC calculations, each time rotating the orientation boundaries by 5.625º.
- Two types of resampling were carried out:
  1. for the Row150 sample, the tooth row was resampled at exactly 150 data rows in the anterior-posterior direction. The single teeth were then isolated from the tooth row sample at the same relative resolution as in the tooth row sample; e.g. 80, 50 and 20 rows long.
  2. the Tooth50 sample started with the full resolution grid, and the teeth were isolated and then resampled so that each tooth was exactly 50 rows in the anterior-posterior direction.

## Results

- OPCR was found to be very highly correlated with OPC measurements (adjusted $R^2 > 0.98$ for both upper and lower).
- For carnivorans (Fig. 1), hypercarnivores have no clear trend of OPCR along the row, carnivores and A-D omnivores peak at m1, and P-D omnivores and herbivores peak at m2 or m3.
- Rodents show a simpler pattern: there is a consistent decrease in OPCR from anterior to posterior, with herbivorous species having higher OPCR than the omnivores and carnivores.
- For the Tooth50 sample, the patterns of individual tooth OPCR is quite similar to the Row150 sample, with the exception of a relatively lower OPCR value for the P-D omnivores at lm1 and um2, and a very high value (>150 patches) for the lm3 of the herbivorous giant panda.
- When all teeth in a row are pooled, the distinction between diets is clear in the lower row for the carnivorans, but not as clear for the upper carnivoran and both rodent rows (Fig. 2).

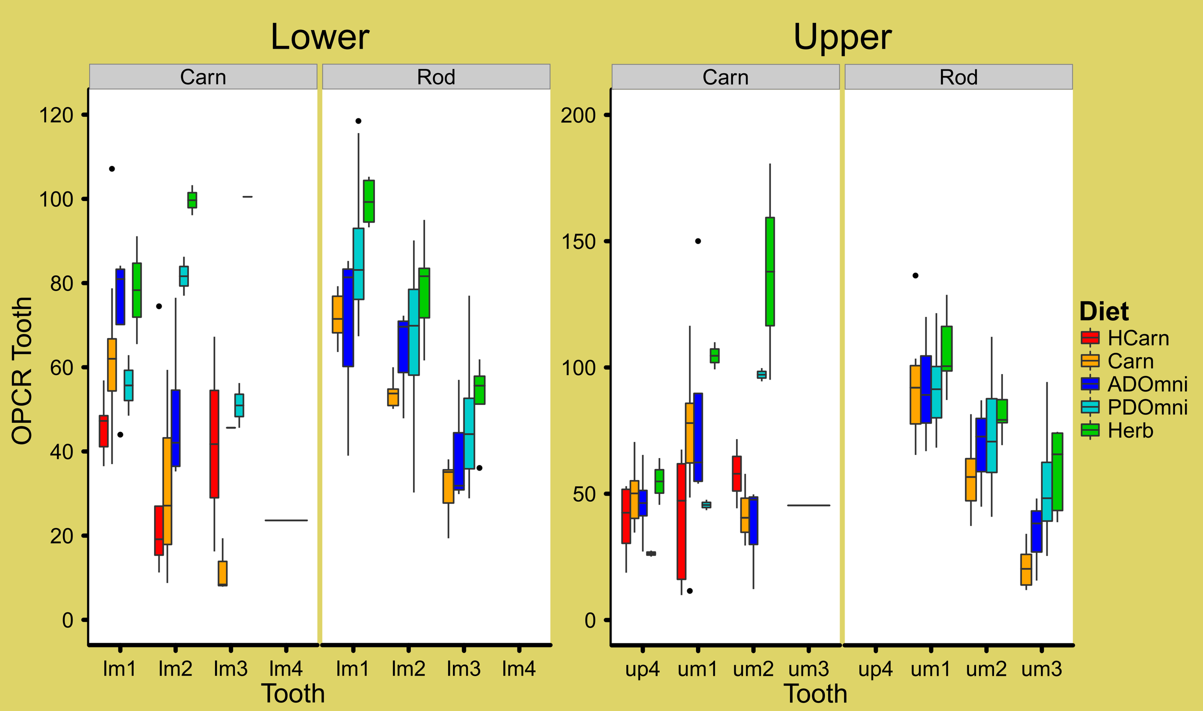


**Fig. 1.** OPCR for individual teeth for lower (left) and upper (right) tooth rows for Row150 sample.

- Rodents largely follow inhibitory cascade rule (Fig. 3a).
- The largest exception are the otomyine rodents (*Otomys* and *Parotomys*).
- Most of the carnivorans do not have third molars, and so plot at zero on the y axis (Fig. 3a).
- Remaining carnivorans do not exactly follow the IC rule; instead, they tend to fall close to a line of lower slope (0.9).
- OPC and IC are highly correlated at low values (Fig. 3b).

## Discussion

- The patterns of dental complexity described in Evans *et al.* (2007) are supported by the addition of OPCR. OPCR should be more robust, and will be used in dental complexity comparisons in preference to simple OPC.
- Unlike previously found for tooth rows, dietary prediction based on isolated teeth does depend on taxonomic Order – the pattern of tooth OPCR varies between carnivorans and rodents.
- There are predictable changes in OPCR with diet and tooth position in rodent lower rows. Rodent upper rows have more overlap between diets. Carnivorans are more variable, but lower m2 gives a good indication of diet.
- If tooth position is unknown, lower tooth rows do distinguish most diets. For upper tooth rows, there is more overlap.
- Rodents appear to be very strongly constrained in variation of dental complexity along the row.
- The carnivorans do not strongly follow the strict inhibitory cascade rule, with most of the species falling some distance from the line. Interestingly, the species that is closest to the line is the only species with four molars, *Otocyon megalotis*.

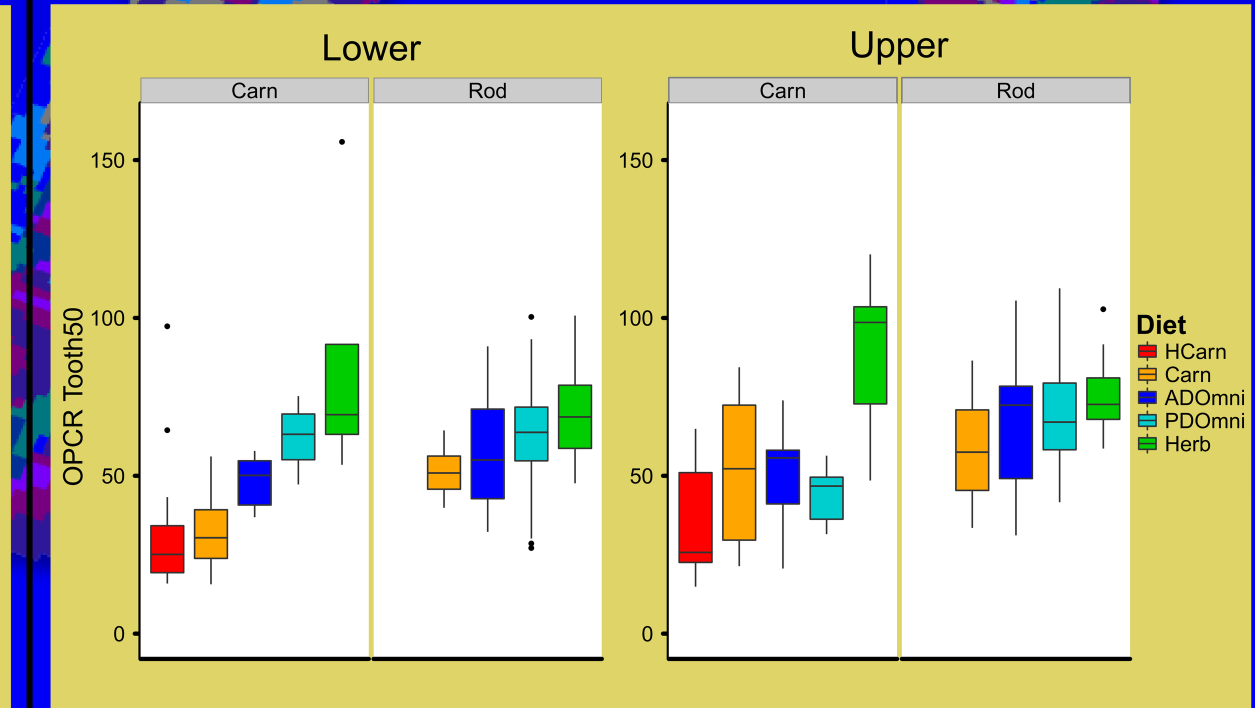


**Fig. 2.** OPCR for all individual teeth resampled at 50 data rows (Tooth50) for lower (left) and upper (right) tooth rows.

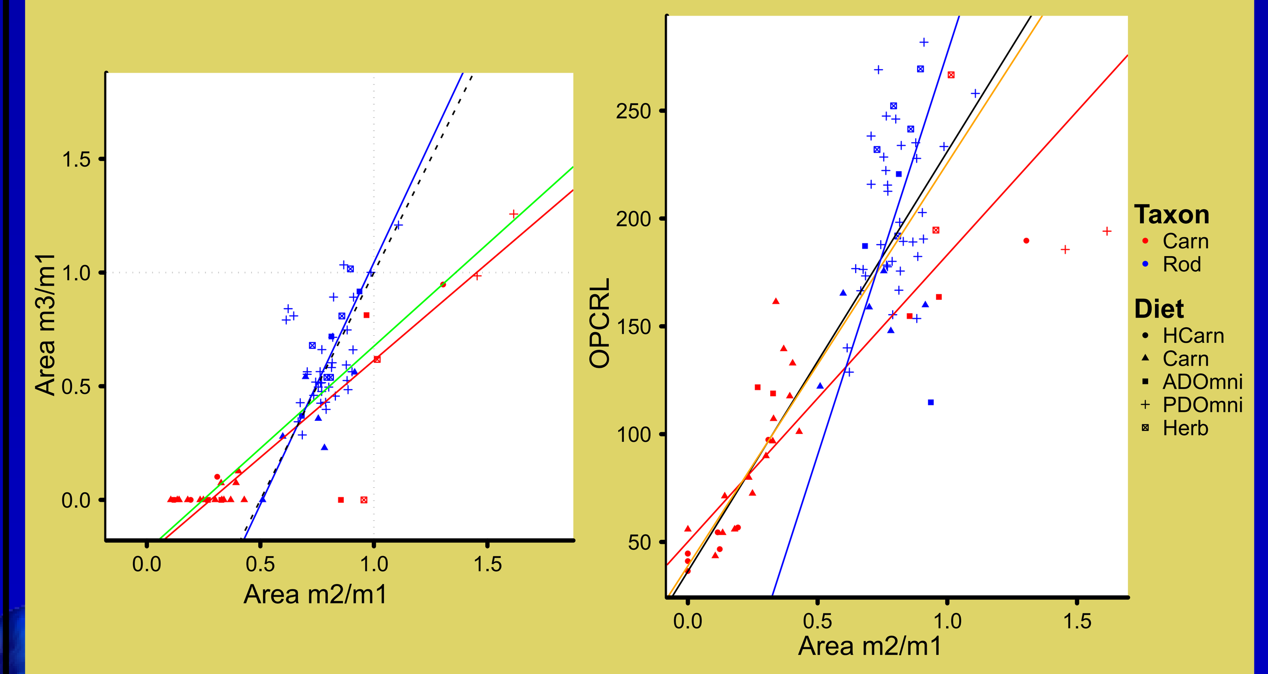


**Fig. 3.** a) Relative sizes of molars in a tooth row for carnivorans and rodents. Dashed line: inhibitory cascade rule. b) Relative inhibition (m2/m1) vs dental complexity. Solid lines are RMA regressions – black: full data set; green: only carnivorans with lm3; orange: carnivorans excluding Ursus species.

- There appears to be a very strong relationship between inhibitory cascade and we hypothesise that the overall level of inhibition highly influences both relative tooth sizes and dental complexity.

## Conclusions

- Dietary reconstruction for identified teeth works reasonably well with lower rodent molars, and less so for upper molars.
- Dietary reconstruction based on isolated teeth of unidentified position is possible within lower teeth; there is less confidence in using upper teeth.
- Carnivorans are more flexible in the number of teeth and the range of complexity along the row compared to rodents, but both still show a strong relationship between OPC and IC.
- Level of inhibition within the developing tooth system appears to control both relative sizes and complexity of tooth surface.


## Acknowledgements

We thank Finnish, Swedish and Berlin Museums of Natural History for specimen loans. Thanks to David Jones and Daniela Winkler for comments on the poster. Funding from Australian Research Council, Monash University and Academy of Finland.


## References


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