Press Release from *Nature*

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A simple rule that can explain the evolution of tooth size in hominins is reported online in *Nature* this week. The study enables the prediction of the expected sizes of a row of teeth using a single isolated tooth.

Hominin tooth size has decreased throughout evolution. Although this phenomenon has been attributed to changes in diet or the advent of cooking, the mechanism underlying variation in tooth size has not been well understood.

Alistair Evans and colleagues analysed tooth size in modern humans and fossilized hominins to determine whether a developmental mechanism (the inhibitory cascade model) that controls relative molar size in mice could be applied to hominins and great apes. They find a strong relationship between the absolute and relative sizes of the primary postcanine teeth, which include the 'baby' premolars and permanent molars. This pattern of tooth size is constant with absolute tooth size in the australopiths, but the scaling relationship differs in species of *Homo* on the basis of the size of the first molar. These findings could help to resolve a number of controversies in human evolution.

FAQ

Why are teeth important in the study of human evolution?

A: First, they are what we find most often when we look for the bones of our ancestors because they are the hardest tissues in our body. Second, teeth are central to how a fossil ancestor lived and can tell us about which species they belonged to, how they are related to other species, what they ate, and how quickly or slowly they developed during childhood. Third, unlike the bones of the skeleton, teeth do not remodel their tissues (enamel and dentine) during life and thus their shape is closely tied to the genetic framework that was responsible for their development. Finally, and at the heart of this paper, we have greatly increased our understanding of this genetic framework and this is revealing new insights about human fossils, some of which were discovered over 80 years ago.

How does this study change our understanding of human evolution?

A: This study has revealed two important insights about human evolution. When we examine the human fossil record we see a number of different patterns of tooth size in our ancestors. Some have their largest teeth at the back of their mouth and some in the middle of their jaw. This type of variation is likely related to their diet and reflects the selective pressures that acted on different ancestral species over the last 7 million years. Our study has demonstrated that changes in patterns of tooth size can be occur quite easily with small alterations to the genetic instructions underlying tooth development, but also that there are a limited number of patterns that can be achieved. Secondly, our study has identified that human ancestors that lived before 2.5 million years ago tended to follow one pattern, while members of our own group, *Homo*, tended to follow another pattern. This suggests that the selective pressures that led to this shift in pattern was a key adaptation in the lineage that eventually led to modern humans.

What controversies the rule/method can resolve?

A: One controversy has been the origins of our own genus *Homo*, and what fossils are the first members of our genus. *Homo habilis* 'handy man' is generally considered to be the earliest member of *Homo*, but there has been continuing debate about whether *Homo habilis* is an *Australopithecus* or *Homo*. Our analyses suggest that the dentition fits better with the *Australopithecus* rule.

What new does the method provide?
A: When studying bones and teeth, palaeontologists try to compare large numbers of fossils. As an analogy, rather than seeing just one, first looking at many cars/apples/etc. makes it easier to predict what a typical car/apple/etc. looks like. Our study provides a mechanistic basis and a development-based rule to predict what dentitions of hominins can be expected to look like, even without first having to measure many fossils. Just from a single tooth one can predict the sizes of the other teeth, a potentially helpful discovery when studying fossils because they do not commonly have all the teeth preserved.

What is the inhibitory cascade mechanism?
A: We have earlier showed using experiments that tooth size in the mouse is determined by combination of factors inhibiting and activating tooth development. A mathematical extension of the inhibitory cascade provides a developmental baseline or rule that predicts how tooth size and proportions should evolve.

What is the hobbit?
A: The teeth of *Homo floresiensis*, the 'hobbit', seem to be distinct from the other hominins, fitting with the conclusions from an increasing number of studies. The tooth proportions are quite comparable to *Home erectus*, for example, but the teeth are 40 percent smaller. The results do not mean that the hobbit is modern *Homo* with a disease, however.

Can one detect a hybrid between species?
A: There are an increasing number of studies suggesting hybridization between *Homo sapiens* and Neanderthals *Homo neanderthalensis*. We have not addressed hybridization but this would be somethings that could be examined. Early sapiens and Neanderthal teeth are relatively similar in size and proportions, however.

What does it mean when a fossil does not fit the rule?
A: Developmentally/mechanistically it means that some other factors are at play in determining tooth size. This means exceptions are interesting cases as they could implicate factors such as environmental stress influencing development. Also, some fossils are composite reconstructions of individual teeth, and there may be simple errors in determining which teeth belong together.

Can the rule explain why wisdom teeth are lost?
A: It appears that the seed for the loss of the wisdom teeth was laid down at the onset of *Homo*, when tooth size and proportions got mechanistically coupled based on our analyses. We, modern humans, have finally reach the point where the tooth reduction has reached a point where wisdom teeth are increasingly failing to develop.

Did you study/What is *Homo naledi*?
A: The Rising Star Cave fossils from South Africa were not included in our study and they will be very interesting to investigate using our method. The combination of *Australopithecus* and *Homo*-like features reported to be present in *Homo naledi* makes these fossils especially interesting because we found a distinct rules to apply to *Australopithecus* and *Homo*.

What makes *Homo* different from *Australopithecus*?
A: In *Homo* the change in tooth proportions and absolute size seem to be coupled. Mechanistically this means that a single factor could have been responsible for the reduction of the dentition in our own genus. It may have facilitated rapid evolutionary change in the dentition. In *Australopithecus* absolute size and proportions are not coupled.

What caused the change (link between size and proportion) in *Homo*?
A: Changes in diet linked to tool use and cooking may have caused relaxed selection to grow large jaws, which in turn caused a strong selective pressure to make one's teeth smaller. Our analyses suggest that a decrease in activation of tooth development could be driving the changes (in size and proportion) in *Homo*.

Can the rule/method be used in medicine?
A: Not directly. However, the rule may be useful in finding direct genetic links to tooth size because our study suggests that a few genes may be responsible for the regulation of tooth proportions in humans.