Biomechanical tongue model prediction of fossil hominins: evaluation and uncertainties propagation

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ABSTRACT

The phylogenetic emergence of speech is a debated issue in human evolution studies. It was claimed for a long time that speech could emerge once the descent of the larynx occurred [1]. Two recent papers discarded this hypothesis showing that monkeys, considered to represent an early stage of human evolution, have “speech ready” vocal tracts [2] and produce distinctive vowel-like sounds [3]. Our long-term project consists of assessing the capacity of fossil hominins to articulate speech sounds, by building a Finite Element model of their vocal tract. Since the tongue and its surrounding soft tissues do not fossilize, our approach relies on transforming an existing model [4], which represents a modern *Homo sapiens* reference subject, to estimate the tongue morphology of a fossil hominin. Based on medical images of a fossil skull and the reference subject, a 3D displacement field is computed with an image registration process [5]. Then, the displacement field is applied to the reference model to shape it into a fossil tongue model. Our ultimate goal is to activate muscles in the fossil model and to assess the range of possible vocal tract shapes.

In this specific study, we assessed the reliability of the methodology by testing it on anatomical data from living monkeys, with known ranges of vocal tract articulations and vocalization repertoires. First, registration accuracy was evaluated with multiple metrics, including the Dice similarity coefficient and Hausdorff distance. Then, the plausibility of the resulting transformations was assessed using the spatial Jacobian and deformation vector field images. Finally, the uncertainty resulting from the registration process was quantified using a non-intrusive adaptive stochastic collocation approach based on simplex elements [6].

As a next step, we wish to analyze the validity of the predictions of lingual mobility by propagating and quantifying the parametric uncertainties in the biomechanical simulations.

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