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A detailed biomechanical finite element tongue model

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For research on surgical modifications of the tongue, e.g., implants for treatment of sleep apnea, we built a detailed finite element model of the human tongue, to experimentally estimate and investigate muscle activations corresponding to observed movement data, and to study possible effects of tissue modifications. Most of the extrinsic and all intrinsic muscles of the tongue are represented as parameterized volumes within the tongue, and muscle fiber directions are specified by a tangent in curvilinear coordinate systems of parametric solids that overlay each muscle region. Fiber regions of different muscles may overlap, for example, for the transverse and vertical intrinsic muscles. Mixed Ogden type hyper-elastic models of strain energy density are used to represent passive tissue properties, and active contraction in muscle fibers is emulated by changing externally specified activation parameters in an anisotropic component of the strain energy density. The activation can vary over time and in its spatial distribution over a muscle, which is accomplished by specifying center point and spread of a Gaussian distribution in the muscle region. The tongue model is realized as a finite element implementation with large displacement/large strain calculations using incompressible 8-node elements in a commercial FE code (Marc by MSC-Software).