A three-dimensional finite element muscle model of velopharyngeal closure

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Velopharyngeal closure is closure of airway by the elevation of the soft palate and the movement of the pharyngeal wall during physiologic functions such as speech and swallowing. It is a complicated process involving the participation of several muscles. Normal velopharyngeal closure for speech was reported to be classified into four different patterns including coronal, circular, circular closure with the Passavant ridge, and sagittal closure. Although it appears that the patterns were determined by the actions of the muscles, it is not clear whether patterns can be changed or not. The analysis of the possibility of changing patterns of the velopharyngeal closure is important for the palatal insufficiency patients, because the change of the velopharyngeal closure patterns can be beneficial for the patient who underwent soft palate resection surgery due to soft palate cancer.

Most of methods of evaluating velopharyngeal closure are based on two-dimensional analysis. By using three-dimensional computer simulation the whole mechanism can be observed without difficulty and it is possible to investigate muscle coordination of the velopharyngeal closure. In addition the change of muscle activation for the optimal velopharyngeal closure with defective anatomical structures and the influence of difference level of muscle activations in the normal anatomic structures, and the possibilities of changing muscle patterns can be analyzed.

The object of the study was to construct a three-dimensional computer model for the analysis of normal velopharyngeal closure and to evaluate factors related to the changing pattern of velopharyngeal closure. In this study a three-dimensional computational model was developed to simulate a human velopharyngeal closure from a healthy subject’s CT data and sectioned images of a donated cadaver. The sectioned images from one of the dataset of Visible Korean Human Project were used. This study is approved by the Institutional Review Board of Seoul National University Dental Hospital. The sectioned images as tag image file format were processed using segmentation software. Segmented data included cranium, mandible, masticatory muscles, hyoid bone, soft palate and pharynx. Segmented data were converted into geometry files and they were imported into ArtiSynth (The University of British Columbia, Vancouver, Canada), a three-dimensional biomechanical modeling platform. Finally in Artisynth the models of cranium, mandible, hyoid bone, tongue, soft palate, and pharynx were built. Bones were regarded as rigid bodies and soft tissues were made of finite element materials. The directions of muscles were defined using segmentation software and transferred to Artisynth. Previously reported data on muscle activations and material properties of the structures were used. After normal velopharyngeal closure was performed by muscle activations, changing velopharyngeal pattern was tried by
changing activation level of muscles. The cross-sectional areas of the pharynx during velopharyngeal closure were analyzed.