Stress Analysis of a Human Mandible with the Patient-Specific FE Model

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The computational results of individual stress analyses provide useful information for diagnoses and medical treatments of illnesses of musculoskeletal systems. The purpose of this study is to examine biomechanical characteristics of the human mandible using a patient-specific finite element model. The mandibular body has a complicated shape and receives various masticatory forces under biting conditions. In order to execute reliable and rapid analyses, accurate modeling method for the bony shape and setting technique of the boundary conditions are required. This paper discusses these points.

For generating precise model of the bone, we propose a meshing algorithm that adaptively controls element size according to characters of the bony shape. The algorithm consists of the following four processes;
Step 1: a voxel space of a bone is provided from the CT images.
Step 2: nodal points are distributed in the space.
Step 3: tetrahedral elements are generated by use of Delaunay triangulation.
Step 4: the model is finished by removing excessive elements.
It is desirable to use small size of elements to express regions with small radius of curvature or small thickness. To control the size of element according to bony shape, we introduce a “form factor” that indicates high value at the portion with small curvature or small thickness. The form factor is directly calculated by a local arithmetic computation in the voxel space of the CT data. Nodal points are distributed according to the form factor in Step 2. That is, nodal points are densely arranged at the portion where the form factor is large. The proposed method automatically controls size of finite element according to shape of the object.

For stress analysis of a human mandible in the biting condition, we have to consider four kinds of masticatory muscles as boundary conditions. General purposed software tools called pre-post processors have a function of setting boundary conditions. However, these ready-made tools are not suited for analyses of bones and it usually takes a lot of time to set up the conditions. To solve the problem, we develop a new system that easily set up boundary conditions for biomechanical analyses. The realized functions are as follows; a visual interface for easy operation, selection of nodal points on muscular attachment sites, dispersion of the muscular forces, setting of the direction of the muscular forces and calculation of the reaction forces around a joint portion.

The proposed individual modeling method is applied to a human mandible. Boundary conditions of the mandible during bilateral biting are set up with the developed system. The computational results of the patient-specific model provide useful biomechanical information.