

ESTIMATION OF MASTICATORY FORCES USING PATIENT-SPECIFIC MODELS OF HUMAN MANDIBLES

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Introduction

This study focuses on the biomechanical characteristics of the craniofacial structure, such as a relationship between three dimensional structure of the mandibular bone and mechanical conditions under mastication. It is an essential problem to estimate proper masticatory muscular forces for the research. This paper applies our estimation method of the masticatory forces to two typical mandibles and validates the method.

Materials and Methods

We have proposed an estimation method of the muscular forces using an objective function [1]. The objective function is composed of the following three kinds of criteria considering the shape and function of the human mandible.

- Summation of square of muscular forces.
- Moment around saggital axis (y -axis.)
- Summation of square of reaction forces at condyles.

In consideration of the three criteria, our objective function is described as

$$I = \sum_{i=1}^m (\alpha f_i^M)^2 + k_1 \left| \sum_{i=1}^b (\mathbf{r}_{y_i}^B \times \mathbf{F}_i^B) + \sum_{i=1}^m (\mathbf{r}_{y_i}^M \times \alpha f_i^M \mathbf{e}_i^M) \right| + k_2 (|\mathbf{F}_1^R|^2 + |\mathbf{F}_2^R|^2),$$

where k_1 and k_2 are weighting coefficient combining the three criteria. k_1 is the coefficient of the moment around y -axis that coincides with the center of gravity of the biting forces. k_2 is the coefficient of the summation of square of reaction forces at condyles. The minimization is solved by the steepest descent method under the condition that all muscular forces are positive and the masseter produces the maximum force.

In order to validate the estimation method, we applied the method to two typical mandibles as shown in Fig. 1. Analyses were performed under following conditions.

- Patient-specific models of two subjects are constructed based on the X-ray CT images [2].
- Biting forces at the teeth are measured by pressure sheets.
- Initial values of muscular activities are assumed according to the electromyograms (EMG) of each muscle.
- Directions of the muscular and biting forces are configured based on the anatomical structures of upper and lower jaw bones.

Results and Discussion

Figure 2 shows the estimated forces using the proposed method (dark bars) and assumptions by a medical doctor (bright bars) of the two subjects. The assumptions based on EMG imply asymmetrical forces in spite of symmetrical mandibular shapes of the subjects. It seems that there are some noises in EMG data. On the other hand, the estimated forces show almost symmetrical forces. Furthermore, the estimated forces indicate some differences between two subjects and the differences are consistent to the anatomical knowledge of a medical doctor. This means that our method has a potential to represent biomechanical characteristics in masticatory systems.

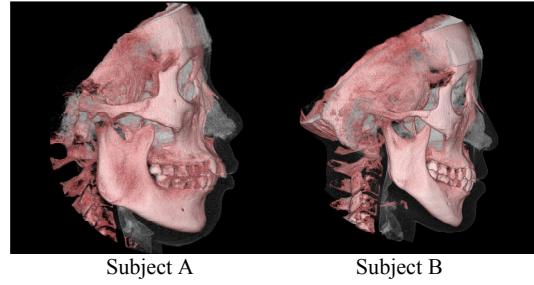


Figure 1 3D reconstructed images of two subjects.

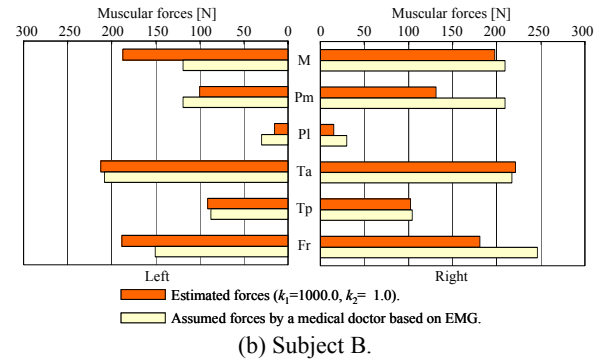
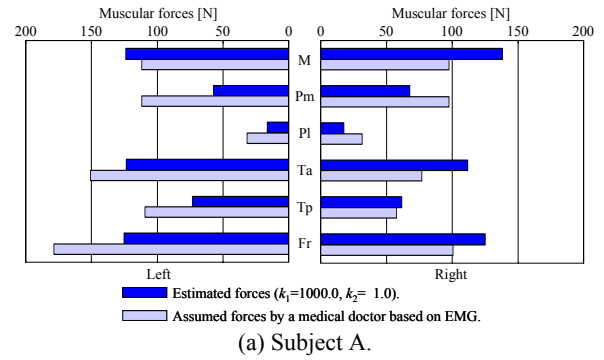


Figure 2 Estimated muscular forces and calculated reaction forces at condyles (Fr.)

Conclusion

We examined the estimation method of muscular forces on the viewpoint of shape and function of masticatory system. Our further study investigates stress states of jaw bones according to the estimated muscular forces.

References

- [1] Koseki, M, Inou, N, Maki K: Estimation of Masticatory Forces for Patient-Specific Analysis of the Human Mandible, *Modelling in Medicine and Biology*, **6**, 491-500, 2005.
- [2] Inou, N, Koseki, M, Maki, K: Patient Specific Finite Element Modeling of a Human Skull; *Advances in Science and Technology*, **49**, 227-234, 2006.