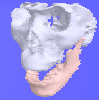


DEVELOPMENT OF THE SUPPORT SYSTEM FOR INDIVIDUAL STRESS ANALYSIS OF A BONE

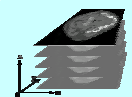


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1. Introduction

Individual modeling is a significant technique for examination of biomechanical characteristics of living bodies. Although the modeling methods are a powerful tool, there are still two problems to be solved for speedy individual simulations. One is setup of boundary conditions of the finite element model. The other one is estimation of muscular forces in the musculoskeletal system. This paper discusses these subjects from viewpoints of individual simulations.

2. Setup of Boundary Conditions

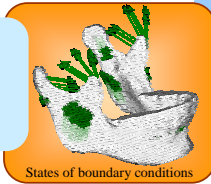


Multi-sliced images

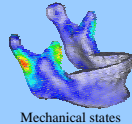
Implementation of the stress analyses requires a lot of time because of difficulty in setting the boundary conditions !!



Individual FE model



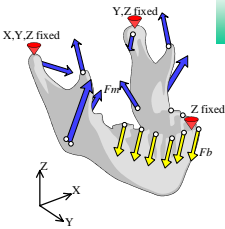
States of boundary conditions



Mechanical states

Required functions to set up the boundary conditions for individual simulations

- ✓ Selection of nodal points on muscular attachment sites
- ✓ Dispersion of the muscular forces
- ✓ Setting the direction of the muscular forces
- ✓ Calculation of the reaction forces around a joint portion



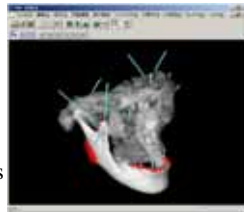
3. Setting Support System for BC data

Procedure to set up of boundary conditions for stress analysis of a bone

1. Specify displacement constraints
2. Specify directions of muscular forces and reaction forces at the teeth
3. Adjust the moment balance at the condyles
4. Calculate the reaction forces at the condyles

$$(C_b \times F_b) + \alpha (C_m \times f_m) = 0$$

$$F_{r1} + F_{r2} + F_b + \alpha f_m = 0$$



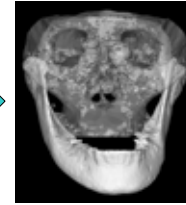
FEATURES of the DEVELOPED SYSTEM

- ✧ Full GUI operation !
- ✧ Display the individual model from any points of view !
- ✧ Automatic balance calculation !

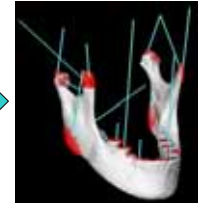
4. Estimation of Muscular Forces & Stress Analyses



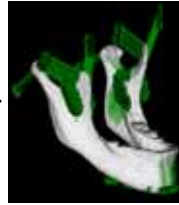
3D reconstructed image
(Male, 18years old)



FE model of the mandible
Node: 108, 572
Element: 71, 267



BC setting
using the system



Boundary condition
in bilateral biting

Estimate activities of muscles using an optimization method

Objective functions to minimize the values:

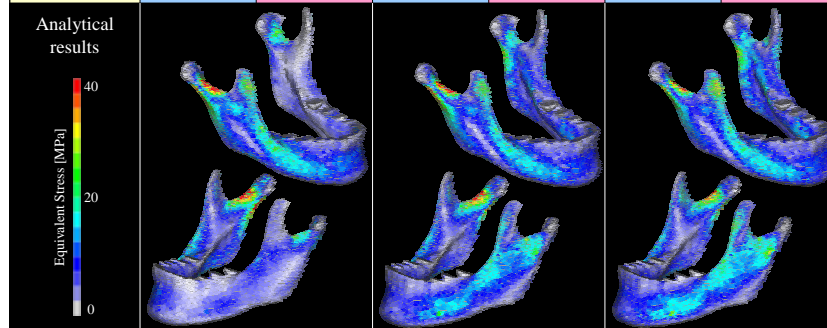
a. Summation of muscular forces ($n=1$)

b. Summation of square of muscular forces ($n=2$)

c. Summation of third power of muscular forces ($n=3$)

$$I = \sum (\alpha f_m)^n = \sum \left(\frac{\sum (C_b \times F_b)}{\sum (C_m \times f_m)} f_m \right)^n$$

Objective func.	Muscular forces [N]					
	$\sum (\alpha f_m)$		$\sum (\alpha f_m)^2$		$\sum (\alpha f_m)^3$	
side	L	R	L	R	L	R
Masseter	116.1	188.3	144.9	164.1	146.6	155.9
Medial Pterygoid	162.8	62.4	157.3	130.6	152.7	139.2
Lateral Pterygoid	0.9	1.0	23.1	12.7	58.7	43.6
Anterior Temporalis	119.0	275.0	145.7	187.2	147.0	166.8
Posterior Temporalis	0.8	0.8	46.9	38.6	83.5	75.7
$\sum (\alpha f_m)$	399.6	527.5	517.9	533.2	588.5	581.2
Reaction forces	159.1	295.1	165.8	237.0	160.8	213.2



5. Conclusion

The above mentioned support system was applied to a human mandible for stress analyses under several masticatory conditions. Detailed mechanical states were presented by the computations.