8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

SIMPLIFIED CONTACT ANALYSIS OF TEMPOROMANDIBULAR JOINT BY USING RBSM

***Norio Takeuchi[1], Koichiro Ueki[2] and Kiyomasa Nakagawa[2]**

[1] Hosei University
Kajinocho, Koganei, Tokyo, 184-8584, Japan
takeuchi@hosei.ac.jp

[2] Kanazawa University
Takaramachi, Kanazawa, 920-8941, Japan
kueki@me.kanazawa-u.ac.jp

Key Words: *RBSM, Condyle Surface, Temporomandibular Joint, Contact Pressure.*

ABSTRACT

Temporomandibuar joint morphology is assumed to associated with skeletal morphology and occlusion. Biomechanical factor is very important, but it is difficult to assess the stress distribution of condyle rapidly and explain to the individual patients visually at the clinic. This paper presents new approach for analyzing the contact problem on the temporomandibular joint by using 2-dimensional Rigid Bodies-Spring Model [1]-[3].

On defining the numerical model, the geometry of the model is based on a front cephalogram of each subject. The entire mandible can be considered as a single rigid element. The rigid displacement field is assumed in mandible in terms of the displacement $\boldsymbol{u}^t = \{u, v, \theta\}$ of the point (x_G, y_G) as shown in Fig.1. Then the displacement u_P at the point $P(x,y)$ on the condylar surface with normal direction $\boldsymbol{n}(l,m)$ is as follows:

$$u_P = \boldsymbol{B} \cdot \boldsymbol{u} \quad \text{where} \quad \boldsymbol{B} = \left\{ \begin{array}{ccc} l & m & -l(y-y_G) + m(x-x_G) \end{array} \right\}$$

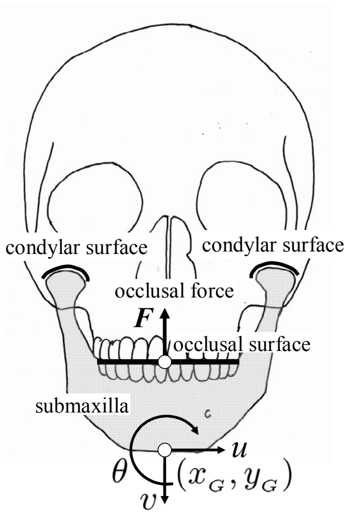


Fig.1 numerical model

In case of the numerical model for the temporomandibular joint, the integral points for calculating the contact stress are defined along the contours of the uppermost face of the condyle as Fig.2. As this portion has relatively smooth surface, a vertical spring k_n only is fitted on each integral point, assuming that the surface bears the vertical surface force (or in other words, contact pressure σ_n) only, and does not bear the shearing force. Fig. 3 show the assumed spring along the contours of the uppermost face of condyle. The glenoid fossa is assumed to be rigid element, and the displacement of this rigid element is set to 0 so it may be treated as a supported element. So the relation of the contact pressure on the condylar surface and the displacement u_P is assumed by the following :

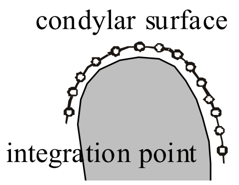


Fig.2 integral point

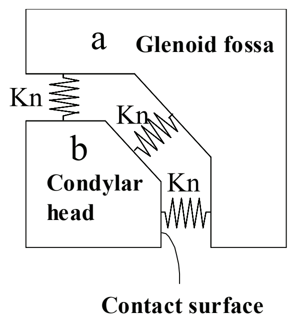


Fig.3 condylar surface

$$\sigma_n = k_n \cdot u_P$$

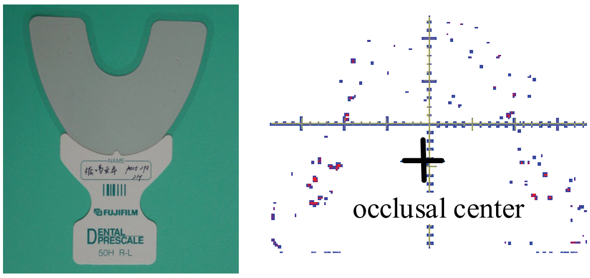
The strain energy expression of the condylar surface can be obtained as the following equation :

$$V = \frac{1}{2}\boldsymbol{u}^t \int (\boldsymbol{B}^t \cdot \boldsymbol{k_n} \cdot \boldsymbol{B}) ds \boldsymbol{u}$$

Applying Castigliano's theorem the following stiffness equation can be derived derived:

$$\frac{\partial V}{\partial \boldsymbol{u}} = \boldsymbol{K} \cdot \boldsymbol{u} = \boldsymbol{F}$$

where $\boldsymbol{F}$ is the normal force at the occlusal center on the occlusal surface. The occlusal force and its action position are determined using the pressure-sensitive system of Fig. 4.



(a) pressure-sensitive sheet (b) result of pressure distribution

Fig.4 pressure-sensitive system

Only compressive force is transmitted in a contact surface. Redistribution of negative contact pressure is calculated, according to the following procedures:

(The first step)

The contact pressure generated on integration points relative to initially given muscular force is obtained.

(The second step)

If negative contact pressure is found on some integral points, it is temporarily removed and a constraint force is added to keep the balance.

(The third step)

As this constraint force does not actually exist, a force equal to this force is added in reverse direction.

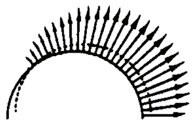


Fig.5 contact pressure distribution

The second and third steps are repeated until the negative contact pressure reduces to negligible value. Then, the contact pressure distribution without negative contact force can be obtain as Fig.5.

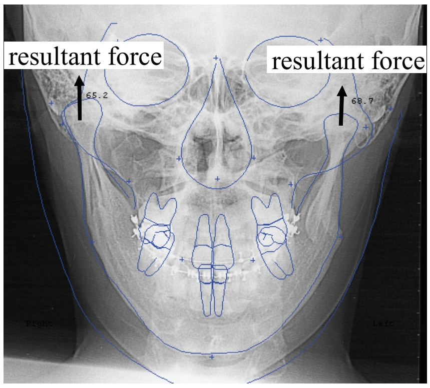


Fig.6 resultant forces

Fig. 6 shows the resultant force on the condylar surface of after an operation. The share rates of the right and left joint were 53% and 47%.

We think that these result provid diagnosis of a doctor with useful information.

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