Development of Patient-specific Display System of the Human Mandibular Movements

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Abstract: This paper deals with an intelligible diagnostic system of temporomandibular disorders for both medical doctors and patients. We propose a display system that visualizes motion of the human mandible. The proposed system provides not only three-dimensional visual information of mandibular movements as animations but also quantitative information of time series of position, velocity and acceleration. This paper reports a newly designed facebow that enables patients with various types of alignment of teeth to apply the system.

Introduction

Temporomandibular disorders (TMD) are conditions with pain affecting the jaw joint and the masticatory muscles. It is important to know exact mandibular movements for the proper diagnosis. Although there are several reports on the measurement system of mandibular movements, almost of them cannot provide a geometrical relationship between the mandibular movements and the jawbone [1,2]. We have developed the three-dimensional display system that individually visualizes mandibular movements using the patient-specific model [3,4,5]. This paper addresses a measurement method of mandibular movements to improve usability of the system.

Methods

The visualization of mandibular movements is realized by the several processes as shown in Fig.1. Motion capture of the human mandible is performed using two facebows attached to upper and lower teeth of a patient. The each facebow has three optical markers for capturing mandibular movements. Motions of the optical markers are measured by two CCD cameras. The patient with the facebows is also CT scanned for patient-specific modeling. The similar display system has recently been reported by other research group[6].

In view of clinical applications, we propose a new design of facebows as shown in Fig. 2. The new facebow is composed of two parts; an arch with the optical markers and a brace for connection to the surface of the teeth. The arch part has also spherical indicators in addition to the optical markers. The indicators are utilized to extrapolate positions of the optical markers even if the markers are out of the CT scan area. Scanning data of a dental cast (plaster model) of the patient is obtained by a digitizer, then the patient-specific brace is fabricated using a rapid prototyping as shown in Fig. 3. The total facebow weighs only 15 gram so that the patient performs mastication with no burden.

The modeling process of the facebow reduces not only cost but also workload of a medical doctor to attach the facebows to the patient. Moreover, the brace is applicable to not only a person with a normal bite, but also one with a overbite that the upper row of teeth lies abnormally forward of the lower row of teeth. The brace for the person with a overbite was designed to be attached to the surface of premolars.

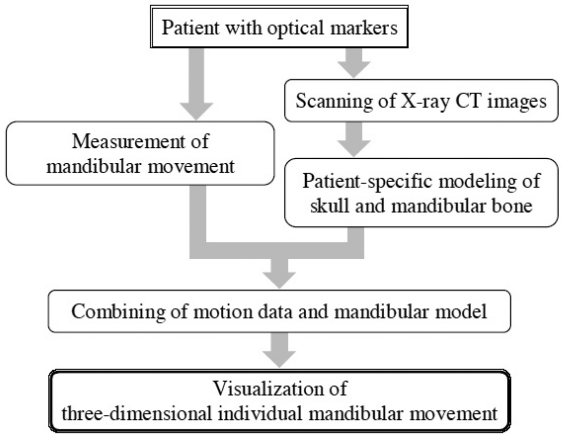

Fig. 1 Diagram of the three-dimensional display system.

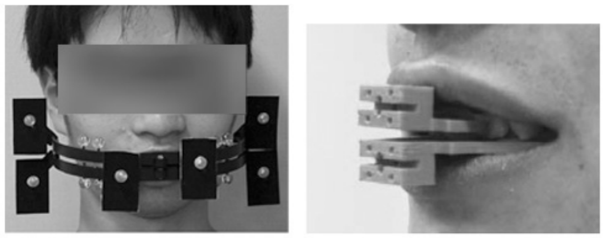

Fig. 2 The new facebow attached to a patient.

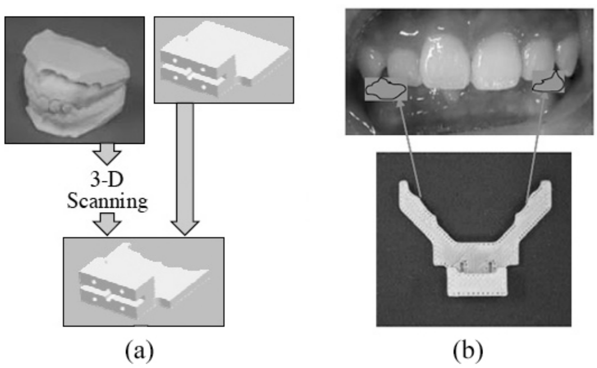

Fig. 3 Fabrication of the patient-specific brace.
(a) Modeling process of the brace,
(b) The brace designed for an overbite person.

The new design of facebows was applied to two subjects. One of them has TMD, the other one has no TMD, but an overbite. The patient-specific models of the subjects were generated by our modeling method [7] based on the multi-sliced CT data. The geometrical relationship between the mandible and maxillary part of bone were computed by the extrapolated positions of the optical markers.

Results

The attachment of the facebows for the two subjects was easily performed. The braces were exactly fitted to the teeth of the each subject. The display system successfully demonstrated the three-dimensional mandibular movements for the both subjects. We can observe the mandibular motion of the each subject from an arbitrary direction while interactively scaling the image size of the model with a mouse operation as shown in Fig. 4. We clearly recognized discontinuous motions caused by TMD from the visual information of the mandibular movements.

The proposed display system provides not only three-dimensional visual information as animations but also quantitative motion data. That is, the system provides time series of position, velocity and acceleration at an arbitrary point of the model. Figure 5 shows time series of velocity at right and left sides of condyles in opening-closing movements for the two subjects. The velocities were calculated as follows. First, a three-dimensional interpolation of the positions of condyles was computed using a cubic spline. Then, the velocity in time-series were calculated.

There is clear difference between the subjects in the graph. The velocity profile of subject A who has no signs of TMD is almost synchronized with right and left sides of condyles and has no large velocity. On the contrary, the velocity profile of subject B has strong peaks in the each cyclic movement. The velocity profile also shows that there exists a clear phase lag between right and left sides in the each closing movement.

The proposed system also enabled to observe mandibular movements in mastication of foods such as peanuts or a chewing gum owing to lightness of the new facebows. We found some characteristics of the velocity profiles in mastication. It is possible to obtain new physiological knowledge about mastication by further analyses of the data.

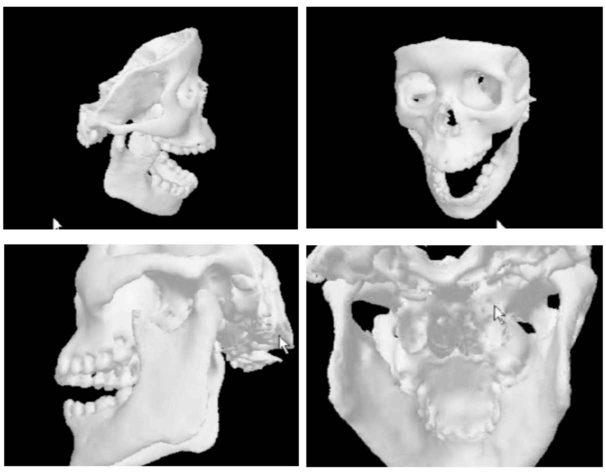

Fig. 4 Snapshots of the display system.
The attitude and scale of the patient-specific model are easily controlled by a mouse operation.

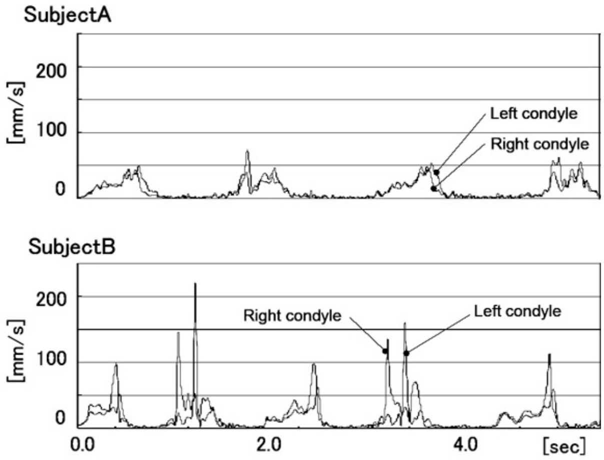

Fig. 5 Time series of mandibular velocities
at both condyes of the two subjects.

Conclusions

This paper described newly designed facebows for improving usability of the patient-specific display system of the human mandible. We applied them to two subjects and confirmed performance of the facebows. The new facebows enabled to observe even mastication of foods. This study also showed that time series of velocities were useful to know detailed characteristics of mandibular movements. The proposed display system will contribute to a proper diagnosis of TMD and also help patients understand their own symptoms.

References

[1] Jankelson,B., Swain,C.W., Crane,P.F. and Radke,J.C.(1975): ‘ Kinesiometric instrumentation: a new technology ’ , Journal of the American Dental Association, Vol.90, No.4, pp.834-840

[2] Tsuruta,J., Mayanagi,A., Miura.H. and Hasegawa,S. (2002):‘An index for analysing the stability of lateral excursions’ , Journal of Oral Rehabilitation, vol.29, pp.274-281

[3] Inou,N., Kurami,T., Maki,K. and Ujihashi,S. (1997): ‘ Three-dimensional display system of mandibular movement using x-ray CT data’, World Congress on Medical Physics and Biomedical Engineering (Nice/ France) , pp.613

[4] Inou,N., Akaana,N., Kurami,T. and Ujihashi,S. (1998): ‘ Three-dimensional display system of individual mandibular movement ’ , Proceedings of the Fifth Japan-USA-Singapore-China Conference on Biomechanics, pp.172-173

[5] Koseki,M., Niitsuma,A., Inou,N. and Maki,K. (2005): ‘ Three-dimensional Display System of Individual Mandibular Movement ’ , Proceedings of The First International Conference on Complex Medical Engineering (CME2005), pp.249-254

[6] Shigeta,Y. et al(2002): ‘ Development of Four-Dimensional Analysis System of Mandibular Movements with Optical Position Measuring and Real-time Imaging ’ , Journal of Japan Society of Computer Aided Surgery, vol.4, no.2, pp.61-66 (In Japanese)

[7] Inou,N. Koseki,M. Jonishi,M. and Maki,K.(2004) : ‘ Automated Individual Modeling Method Based on the Multi-sliced Images ’ , Proceedings of The IASTED International Conference on Biomechanics, pp.142-145