Application of Dentition and Facial Morphology Integration System for Occlusal Correction

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A system to provide quantitative information on the angle between dentition and face was developed using a three-dimensional (3D) integrated configuration measured by a non-contact 3D digitizer. The integrated configuration angles between the Camper’s plane and occlusal plane on the sagittal and the horizontal projected planes were obtained. Clinical application for a patient to improve the tegmenta of the anterior tooth by setting a temporary bridge on her lower dentition was attempted. Her dentition and face were measured on her first visit and after treatment, and 3D data of them were integrated. The quantitative change of the angle between the Camper’s plane and lower occlusal plane were successfully analyzed by the present system, and after treatment, rotation of the lower occlusal plane for 1° in a clockwise direction on the sagittal plane projection, and that for 1° in a counterclockwise direction on the horizontal plane projection relative to the Camper’s plane were detected.

Key words: 3D measurement, occlusion, computer

INTRODUCTION

In the dental treatment to recover the functional occlusion and esthetic condition of a patient, it is important to comprehend the 3D relation between the dentition and face exactly\(^1\text{–}^3\). Recent technology of computed tomography (CT) and magnetic resonance imaging (MRI) have become available for recording the 3D relation between the dentition and face, but the radiation exposure of patients and the artifacts caused by intraoral metal prostheses obstruct their validity\(^4\text{–}^8\).

In a previous study, we proposed a novel method of measuring the 3D-shape of the dentition and face with a non-contact 3D digitizer, and developed a method of integrating them by devising a common interface\(^9\). In constructed computer graphics of integrated configurations, the relation between the dentition and face could be represented clearly from any angle by drawing the face translucently without artifact. Conducting this procedure pre- and post-operation or treatment enables easy determination of the qualitative change of the relation between the dentition and face.

The present configuration is composed of digital data, and it is possible to extract information such as distance, area and angle between the characteristic locations of the dentition and face. The distance between characteristic points in integrated configurations was acquired using 3D-data processing software\(^9\), but the method to determine the angle between characteristic planes was complicated and undeveloped.

In this study, accordingly, we aimed to develop a method of determining the virtual occlusal plane such as the Frankfurter plane or Camper’s plane, and find the 3D angle relative to the occlusal plane.

Additionally, as an application for clinical dentistry, we applied the present integrated configuration in the occlusal correction of a patient who wished to improve the tegmenta of her anterior tooth. She was treated to set a temporary bridge on her lower dentition, and her dentition and face in pre- and post- treatment were measured and integrated. The relative morphological changes of the dentition and face were analyzed quantitatively using the proposed technique.

MATERIALS AND METHODS

Integrated configuration of the dentition and face used to develop analyzing methods

The computer graphics of integrated configuration of the dentition and face of a 26-years-old male subject used for developing the proposed analyzing methods are shown in Fig. 1\(^9\). Before the experiment we fully explained to the subject about the present method, the application of the interface mentioned later in the mouth while measuring, and to use the images in our study, and he consented to participate and cooperate.

The dentition and face of the subject were measured by a high-speed laser scanner (VIVID 700, KONICA MINOLTA SENSING, INC, Sakai, Japan),
and the data were integrated using an interface with an extraoral marker plate attached to the occlusal record plate as shown in Fig. 1 c). The interface was applied between upper and lower stone models or by the subject directly, and measured including the stone model or face. Integration was done which coincided the shape data of the marker plate in the interface measured between upper and lower stone models and applied by the subject. The method and accuracy of integration were presented in our previous paper.

In the integrated CG from the frontal view in Fig. 1 a), the face is drawn half-transparently so that the dentition within the facial data could be observed. In the sagittal view in Fig. 1 b), the relation between the right hand side of the face and the lingual side of the right half of the dentition can be observed. CG imaging in the arbitral angle and cross section is also possible.

Method to determine the spatial relation between the Camper's plane and occlusal plane

In the appropriated occlusal treatment and postoperative estimation, determination of the basic plane is significant. The present study used Camper's plane III, which is determined by 3 points, a midpoint of the nosewing and the anterior inferior points of the bilateral tragus. Using 3D data processing software (3D-Rugle, Medic Engineering, Kyoto, Japan), these 3 points were indicated by the mouse, and a triangular plane was established in computer graphics. In addition, the occlusal plane was also set up by indicating 3 points, the mid point of the bilateral central incisors and the mesial buccal cusps of the first molar. In the present clinical application, the lower occlusal plane was determined also.

The angles between Camper's plane and the occlusal plane were determined by 3D-Rugle as follows. Initially, a line between the anterior inferior points of the bilateral tragus was drawn on the Camper's plane, and a perpendicular line was drawn down from the mid point of the nosewing. On the occlusal plane, a perpendicular line was drawn down from the mid point of the bilateral central incisors on the intersection between the mesial buccal cusps of the lower bilateral first molar. These 2 perpendicular lines were projected on the sagittal and the horizontal planes, and the angles between them were measured. The changes of the angles at pre- and post-treatment are discussed.

Clinical application to a patient to improve the tegmenta of her anterior tooth

As an application of the proposed integrated configuration for dental clinics, we applied the present technique in a case of occlusal correction of a 66-year-old female patient who wished to improve the tegmenta of her anterior tooth. Before the treatment we fully explained about the present method, the application of the interface mentioned later in the mouth while measuring, and to use their clinical images in our study, and the patient consented to participate and cooperate.

Photographs of the patient's face, anterior teeth and lower stone models at pre- treatment was shown in Fig. 2 a), b) and c), respectively. A small occlusal vertical dimension was observed as shown in Fig. 2 b). The stone model was colored gray to measure precisely. The interface to integrate the 3D shape of the dentition and face shown in Fig. 2 d) was applied between upper and lower stone models or by the patient directly, and measured by VIVID 700 including the stone model or face and the stone models. 3D data of her dentition were integrated to her face using software (Polygon Editing Tool, KONICA MINOLTA SENSING, INC, Sakai, Japan).

The patient was treated to elevate the lower occlusion by 6.5 mm at the incisor by setting a temporary bridge on her lower dentition. An oral photograph of her anterior teeth and lower stone model after treatment were shown in Fig. 3 a) and b). Her face and stone models were measured with the interface again, and the stone models and her face were integrated.

The relative changes of the angle between the Camper's plane and the lower occlusal plane pre- and post- treatment were analyzed quantitatively according to the proposed method. The measurement of the angle was carried out for ten times and averaged.

RESULTS

Determination of the spatial relation between the Camper's plane and occlusal plane

The Camper's plane of the subject was determined initially, and represented half transparently in green as shown in Fig. 4. In this triangular plane a red perpendicular line was drawn down from the mid point of the nosewing to the line between the anterior inferior points of the bilateral tragus.

The lower occlusal plane was set up and represented half transparently in light red, and a blue perpendicular line was drawn down from the mid point of the bilateral central incisors. This 3D configuration was projected onto the sagittal and horizontal plane as shown in Fig. 5. In each projection, two configurations with dentition and without dentition were presented so that the complex relations between analyzed planes could be explained comprehensively. The bold red line in the configuration without dentition is the perpendicular line of the Camper's plane, and the bold blue line is the perpendicular line of the lower occlusal plane.

The planer angle between the perpendicular lines was measured using 3D-Rugle, and the its sign was determined positively when the perpendicular line of
Table 1  Summarized angle between the Camper’s plane and lower occlusal plane (analyzed for 10 times measurement)

<table>
<thead>
<tr>
<th></th>
<th>First visit</th>
<th>After elevation of occlusion</th>
</tr>
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<tbody>
<tr>
<td>Sagittal plane</td>
<td>Average 0.5° (0.2°)</td>
<td>1.5° (0.2°)</td>
</tr>
<tr>
<td></td>
<td>Average 2.1° (0.2°)</td>
<td>1.1° (0.2°)</td>
</tr>
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</table>

(n=10)

the occlusal plane was located in the clockwise direction against that of the Camper’s plane.

Clinical application to a patient to improve the tegmenta of anterior tooth

The frontal views and sagittal views of the integrated configuration of the patient on her first visit are shown in Figs. 6a) and Fig. 7a), and those made after treatment are shown in Figs. 6b) and 7b). By comparing these figures, qualitative changes of lower dentition and facial morphology such as the movement of the lower dentition toward the anteroinferior direction, elevation of the occlusion, decrease in the flap of the skin around the mentum and distinctness of the inferior border of lower jaw were observed.

Quantitative changes of the angle between the Camper’s plane and the lower occlusal plane were analyzed in the configuration projected on the sagittal and horizontal plane as shown in Fig. 8, and the quantitative results were summarized in Table 1.

The angles between the Camper’s plane and the occlusal plane projected on the sagittal plane were 0.5° at first visit and 1.5° after the elevation of the occlusion, and the lower dentition was accordingly rotated 1.0° clockwise. On the horizontal plane projection, they were 2.1° at first visit and 1.1° after the elevation of the occlusion, and the lower dentition was accordingly rotated 1.0° counterclockwise.

DISCUSSION

The cephalogram is generally used for maxillofacial position analyses of the head and face. This is an excellent method for judging the angular relation between the osseous tissue of the dentition and head, and is useful for judging the growth stage. However, it has some disadvantages such as an inhomogeneous magnification rate, indistinctive image in the soft tissue and limitation of obtaining the specific distance and angle due to 2 dimensional analyses.

As a method of analyzing the 3D change of the dentition and face quantitatively, CT and MRI have been used, however, they are often disadvantageous because of artifacts by metal prostheses, and that X-ray exposure caused by CT makes its use unattractive except in cases where it is essential.

In the proposed method, by using 3D integrated configurations of the dentition and face measured by laser scanner, quantitative analyses of relative angles between the virtual occlusal plane and occlusal plane between pre- and post- occlusal treatments were accomplished. Quantitative analyses were carried out on the distance between the dentition and face as mentioned in our previous paper in the accuracy of integration, so they are not presented in the results of the present patient.

Using the proposed analyzing method, the quantitative 3D relations between the virtual occlusal plane such as the Camper’s plane and the occlusal plane were obtained. This valuable information will be useful for doctors and patients to compare and estimate quantitative changes pre- and post- intraoral operation. In addition, this noninvasive method is also applicable to cases of occlusal reconstruction, jaw deformity and designing denture treatment. Moreover, it may simulate changes in facial morphology with different occlusal conditions. These applications will be presented in forthcoming articles.

The time required for measurement and analyses was about 2 hours, and then it is possible to apply the findings clinically. One problem was that the resolution of VIVID 700 was insufficient to reproduce pits and fissures of dentition. However, VIVID 900 with higher resolution has recently been developed. The interval of measurement is 0.2 mm in the X and Y direction, and the resolution is 3 times as good as VIVID 700. We have already acquired the equipment, and are switching over the integration system using the new machine.

The portability of the VIVID is another striking advantage. In our work cooperating with the oral surgery group, we brought VIVID to a developing country and measured cleft palate patients. Their facial morphology and stone models were measured and integrated using interface and the method developed. The portability of VIVID enables such outdoor measurements. In our following paper, we will report on these applications under progress.

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REFERENCES
Fig. 1 Integrated configurations of the dentition and face of the subject. 
   a) Frontal view, b) Left hand side view, c) Interface for 3D data integration

Fig. 2 Patient and stone models at first visit. 
   a) Photograph of the patient, b) Oral photograph of anterior teeth, c) Lower stone model, d) Interface for 3D data integration

Fig. 3 After occlusal elevation. 
   a) Oral photograph of anterior teeth, b) Lower stone model

Fig. 4 Analyses of the Camper’s plane and occlusal plane. Red and blue bold lines are perpendicular lines of the Camper’s plane and lower occlusal plane, respectively.
Fig. 5 Analyzing items.

a) A: anterior inferior points of bilateral tragus, B: midpoint of nosewing, C: mesial buccal cusps of the first molar, D: midpoint of bilateral central incisors

b) A1: anterior inferior points of left tragus, A2: anterior inferior points of right tragus, C1: mesial buccal cusps of the left first molar, C2: mesial buccal cusps of the right first molar. Red and blue bold lines are perpendicular lines of the Camper's plane and lower occlusal plane, respectively.

Fig. 6 Integrated configuration of dentition and face in frontal view.

a) First visit, b) After occlusal elevation
Fig. 7  Integrated configuration of dentition and face in sagittal view.  
a) First visit, b) After occlusal elevation

Fig. 8  Change of the angle between the Camper's plane and lower occlusal plane.  
Sagittal plane a) First visit, b) After elevation of occlusion  
Lower occlusal plane rotated clockwise 1 degree after elevation.  
Horizontal plane c) First visit, d) After elevation of occlusion  
Lower occlusal plane rotated counter-clockwise 1 degree after elevation.