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Technical procedure

Application of photogrammetry for analysis of occlusal contacts

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Abstract

Introduction: The conventional 2D-analysis methods for occlusal contacts provided limited information on tooth morphology. This present study aims to detect 3D positional information of occlusal contacts from 2D-photos via photogrammetry. We propose an image processing solution for analysis of occlusal contacts and facets via the black silicone method and a photogrammetric technique.
Materials and methods: The occlusal facets were reconstructed from a 2D-photograph data-set of inter-occlusal records into a 3D image via photogrammetry. The configuration of the occlusal surface was reproduced with polygons. In addition, the textures of the occlusal contacts were mapped to each polygon.
Difference from conventional methods: Constructing occlusal facets with 3D polygons from 2D-photos with photogrammetry was a defining characteristic of this image processing technique. It allowed us to better observe findings of the black silicone method. Compared with conventional 3D analysis using a 3D scanner, our 3D models did not reproduce the detail of the anatomical configuration. However, by merging the findings of the inter-occlusal record, the deformation of mandible and the displacement of periodontal ligaments under occlusal force were reflected in our model.
Effect or performance: Through the use of polygons in the conversion of 2D images to 3D images, we were able to define the relation between the location and direction of the occlusal contacts and facets, which was difficult to detect via conventional methods.
Conclusion: Through our method of making a 3D polygon model, the findings of inter-occlusal records which reflected the jaw/teeth behavior under occlusal force could be observed 3-dimensionally.

Keywords: Occlusal contact; Interocclusal record; Triangular surveying technique

1. Introduction

In daily dental practice, occlusal contacts are examined via occlusal registration paper and a bite impression material. From biting down on the occlusal registration paper, a bright residue is left on the teeth. From this resultant residue, we can identify and examine the occlusal contact. A second approach involves examining occlusal contacts from the perforated state of the bite impression material. Nevertheless, it remains difficult to evaluate quantitatively from the macroscopic findings via these methods. Furthermore, these findings are difficult to save and compare through observation. Thus, there is a need in the field for a more thorough means to evaluate the occlusal contacts. In relation to the occlusal contacts, doing so would allow us to more accurately diagnose anomaly of occlusal contacts and to evaluate the occlusal stabilization both quantitatively and visually.

While the 2-dimensional photo [1] and digital scanning system [2] has been proved to be useful for analyzing occlusal contacts, they have not always been effective in analyzing the precise location and direction of occlusal contacts on the occlusal surface; nor has it provided further analysis of occlusal facets. By developing a 3D profilometric system to analyze the occlusal contacts, McDowell et al. [3] attempted to address this issue in 1988. However it was too complicated to use in practice and had issues with handling finer details. Since 1990, various systems [4–6] have appeared on the market for 3D analysis of occlusal contacts. However, they required expensive equipment, specific materials, and a sometimes lengthy analysis

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Table 1
Previous studies for analyzing the occlusal contacts (○: detectable item).

	Device	Analysis dimension	Number of points	Occlusal force	Area	Inclination of facets
Nakao (1970)	2D profile projector	2D	○	–	–	–
Tosa et al. (1987)	CCD	2D	○	–	○	–
Shiono et al. (1995)	Prescale	2D	–	○	○	–
Sato (2000)	Optical 3D scanner	3D	○	–	○	○
Gurdsapsri et al. (2000)	CCD	2D	○	–	–	–
DeLong et al. (2002)	2D scanner	2D	○	–	○	–
Owens et al. (2002)	2D scanner	2D	○	–	○	–
Matsui et al. (2004)	AnaBiter	2D	○	–	○	–
Furuki et al. (2007)	Prescale	3D	○	○	○	○
Kamegawa et al. (2008)	Micro CT	3D	○	–	–	–
Ando et al. (2009)	Prescale + occluser	2D	○	○	○	–

time. Furthermore, there have been incompatibility issues with 2D data. While Table 1 shows several systems used in previous studies [6–16], data on 2D photos is limited. In other words, in the conventional 2D analysis methods, other than the number and area of occlusal contacts, it was difficult to detect detailed occlusal contact conditions.

As a solution, we considered detecting 3D positional information from 2D photos via photogrammetry. Photogrammetric techniques with triangulation are used in various fields such as civil engineering, architecture and astronomy [17,18]. Special software is required for the digital photogrammetry. However, there are several operable 3D photogrammetric programs (freeware/shareware) available on the web for triangulation and 3D-reconstruction.

This present study aims to detect 3D positional information of occlusal contacts from 2D-photos via a photogrammetric technique. In this present report, we provide an image processing solution via the black silicone method [7] and a photogrammetric technique for analysis of occlusal contacts and facets.

2. Materials and methods

2.1. Taking inter-occlusal record

The inter-occlusal record was taken with a silicone bite impression material. The mandibular position was not limited to the intercuspal position. The inter-occlusal record was also taken at the terminal point of habitual closing movement and/or an eccentric position.

There are not any limitations for the impression material used. While any suitable impression materials will suffice for a record, we had to grasp the relation between the intensity of transmitted light and the material thickness in each material. In this present study, CorrectPlus (PENTRON, CT, USA) was used for the inter-occlusal record. This was selected as it is widely used throughout our clinic.

2.2. Taking photos of the occlusal record and image processing

The bite impression material was put on a film viewer or in the natural light, and photos were taken with a digital camera.

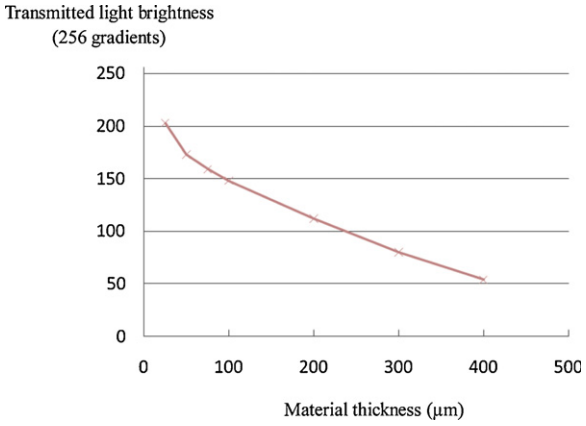

Fig. 1. Calibration curve.

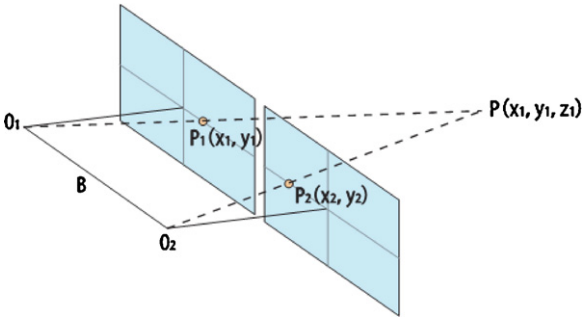

Fig. 2. Foundation of triangulation in photogrammetry (P_1, P_2: reference points, O_1, O_2: camera position, P: calculated 3-dimensional coordinate value).

Over three photos were taken from different directions in each condition to reconstruct a 3D model via the photogrammetric technique.

The camera setting and parameters were arbitrary. However, to calibrate the relation between the intensity and thickness in each setting, we had to prepare for the calibration sample or the calculated curve. In this present study, we calculated and used the calibration curve in the following condition (Fig. 1).

To create samples for a calibration curve, CorrectPlus was selected. Creating the calibration curve was carried out through the following method. The contact relation between a metal plate and 10 mm steel sphere (JIS 28 grade, Daio Steel Ball