Evaluation of occlusal relationship reproducibility with CAD/CAM techniques

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Purpose: The objective of this study was to evaluate the reproducibility of determining the area of the occlusal contact regions by CAD software.
Materials and Methods: Nine subjects were recruited. The maxillary right first molars were the subject teeth. Optical impressions were taken six times. An optical impression of each antagonist was taken once. For optical bite registration, optical impressions from the buccal side during clenching were taken six times. The occlusal contact regions obtained by optical impressions and optical bite registration were represented using CAD software. The variabilities derived from changes in optical impressions were compared with those derived from changes in optical bite registration.
Results: The variability of the area of the clearance region depending on changes in optical bite registration was significantly higher than that depending on changes in optical impressions.
Conclusion: It was demonstrated that changes in optical bite registration affected the reproducibility of the area of the clearance region.
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Key Words: CAD/CAM, occlusal contact, optical impression, reproducibility

Introduction

The technique of computer-aided design/computer-aided manufacturing (CAD/CAM) has evolved by way of improvements in the measuring system, processing technique, and software. Long-term prospective studies of CAD/CAM ceramic restorations have reported survival rates of over 85% after 10 years.[1,2] More recently, CAD/CAM systems have been introduced that incorporate a new optical bite registration method to determine the occlusal relationship between the abutment tooth and its antagonist using CAD software. With these systems, an intraoral camera can be utilized for optical bite registration as well as optical impressions of the dentition. Optical bite registration is based on optical impressions of the buccal surface of the dentition from the buccal side during clenching at the intercuspal position, without any bite registration materials.[3,4] These optical impression data are used to fabricate restorations at the chair-side, and it is possible to replace the restorations on the same day.[5]

In prosthodontic treatment, the shape and function of the prosthesis must be harmonized with the stomatognathic system to maintain good functional condition for a long time after the treatment.[6] Many studies have reported that teeth were moved in function, that is, the amount and direction of tooth displacement and the occlusal relationship between the maxillary and mandibular dentition were changed, depending on the biting force.[6-11] The occlusal relationship between the abutment tooth and its antagonist during clenching at the intercuspal position in vivo differed from the occlusal relationship calculated by CAD software. Moreover, optical powder must be applied to the occlusal surfaces to make the dentition visible to the intraoral camera.[12] Therefore, data from optical impressions cannot duplicate the actual dentition precisely, because of the thickness of the optical powder covering the occlusal surfaces. Although previous studies[13] have evaluated the accuracy of optical bite registration in the context of resin models, few have evaluated it in the context of actual dentition in vivo. Additionally, it has been reported that the occlusal surface is closely related to masticatory efficiency, the main occluding area, and tooth displacement in function.[7,14-18] Therefore, to fabricate prostheses with functional occlusal surfaces using CAD/CAM systems, it is important that CAD software duplicate the occlusal relationship between the maxillary and mandibular dentition in vivo with high precision.

The objective of this study was to evaluate the reproducibility of determining the area of the occlusal contact regions of the maxillary and mandibular dentition by CAD software.

Materials and Methods

The surfaces of the subject tooth and adjacent teeth were air-dried, then sprayed with titanium oxide powder (Cerec Optispray, Sirona, Bensheim, Germany) uniformly. Optical impressions were taken using an intraoral camera (Cerec Blue-CAM, Sirona) and recorded via CAD software (Cerec AC, Sirona). These procedures were performed six times (P1-P6). An optical impression of each antagonist was taken and recorded only once (Q). For optical bite registration, optical impressions from the buccal side during clenching with moderate biting force at the intercuspal position were taken using the intraoral camera and recorded via CAD software. These procedures were performed six times (BS1-BS6). The occlusal contact regions obtained by optical impressions and optical bite registration were represented using CAD software. The occlusal contact regions were divided into several groups based on the distance between the maxillary and mandibular occlusal surface; specifically, light-blue-colored regions (within 100 µm of the close contact, A), green-colored regions (0-50 µm of the penetrated contact, B), yellow-colored regions (50-100 µm of the penetrated contact, C), and red-colored regions (over 100 µm of the penetrated contact, D) (Fig. 1).

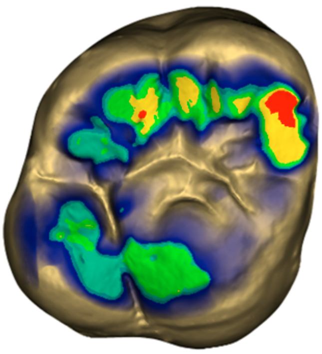

Fig. 1
The occlusal contact regions were divided into several groups based on the distance between the maxillary and mandibular occlusal surfaces.

dark-blue-colored regions	(100-1000 µm of the close contact) not evaluated in this study
light-blue-colored regions	(within 100 µm of the close contact, A)
green-colored regions	(0-50 µm of the penetrated contact, B)
yellow-colored regions	(50-100 µm of the penetrated contact, C)
red-colored regions	(over 100 µm of the penetrated contact, D).

Results

The results derived from each subject are shown (Table 1). The variability of the area of the clearance region depending on changes in optical bite registration was significantly higher than that depending on changes in the optical impressions ($p<0.05$) (Fig. 2). Conversely, the variability of the area of the penetration region depending on changes in optical bite registration did not differ significantly from the variability of the area of the penetration region depending on changes in the optical impressions.

As shown in a representative example of the results, the location of the occlusal contact regions among the sequence of the results in the same subjects was almost the same, when optical impressions or optical bite registration were changed (Fig. 3). However, there were some differences in the areas of each occlusal contact region.

Table 1. The variability of the area of the clearance and penetration regions depending on changes in optical impression and optical bite registration (mm²)

Subject		A	B	C	D	E	F	G	H	I	Mean	SD
Clearance	Optical impression	1.17	0.37	0.79	0.46	0.38	1.4	0.04	0.33	0.81	0.64	0.44
	Optical bite registration	2.18	0.27	0.39	0.74	0.35	2.88	0.05	0.17	1.77	0.98	1.03
Penetration	Optical impression	1.01	0.56	0.32	1.43	0.65	0.36	0.99	0.06	0.28	0.63	0.44
	Optical bite registration	1.1	1.32	0.27	1.6	0.49	0.58	1.51	0.13	0.49	0.83	0.56

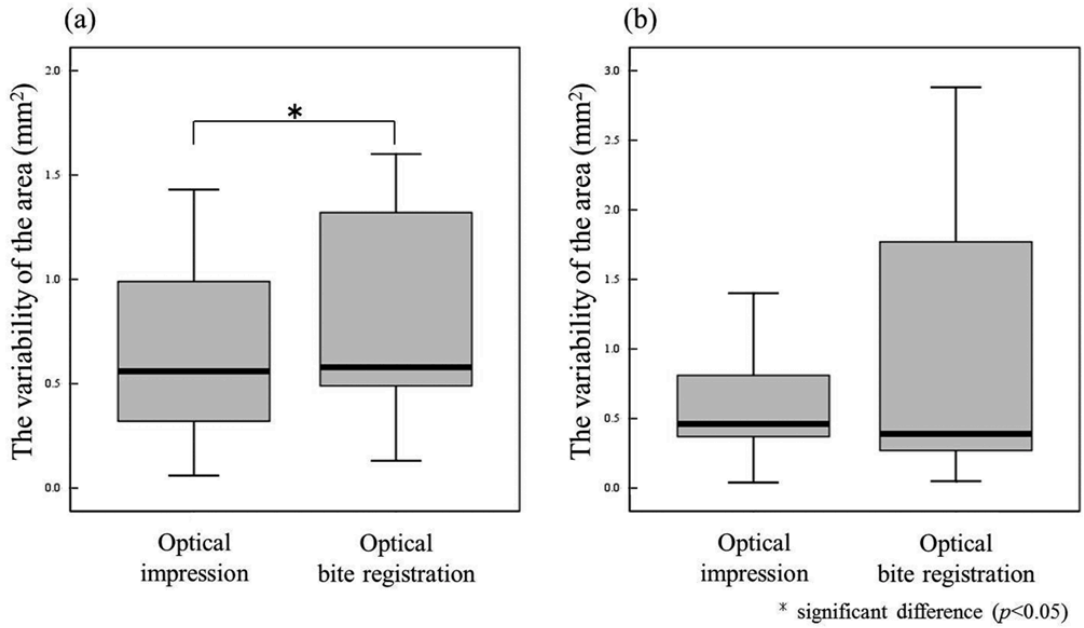

Fig. 2 The variability of the area of the clearance (a) and penetration (b) regions depending on changes in optical impression and optical bite registration

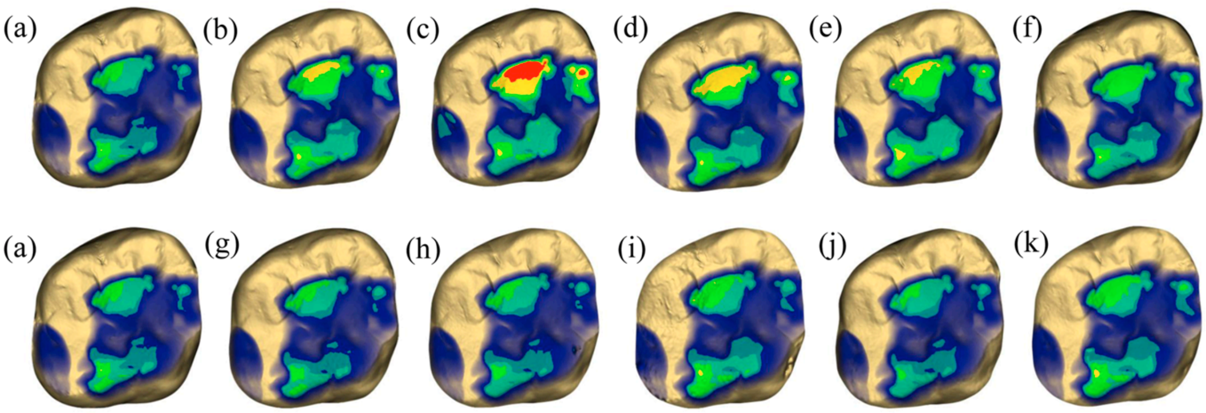

Fig. 3 A representative example of the results in the same subject
P1, Q with BS1 (a), P1, Q with BS2 (b), P1, Q with BS3 (c), P1, Q with BS4 (d), P1, Q with BS5 (e), P1, Q with BS6 (f), P2, Q with BS1 (g), P3, Q with BS1 (h), P4, Q with BS1 (i), P5, Q with BS1 (j), P6, Q with BS1 (k)

Discussion

The variability of the area of the clearance region depending on changes in optical bite registration was significantly higher than that depending on changes in the optical impressions. One of the reasons for this variability was the non-uniform thickness of the optical powder. The scanning area for the optical impressions was larger than that for optical bite registration. In other words, the optical impressions required a larger powdered area than was required for optical bite registration. It has previously been reported[19] that the precision of the intraoral camera of this system was only 19 μm in the context of a stone cast, therefore, the precision of the intraoral camera and the thickness of the optical powder had an insignificant effect on the precision of this system considering the values of the clearance and penetration regions. Moreover, given the acceptable range of the occlusal height of crown restorations, threshold level of the periodontal ligament,[20] and the accuracy of crown restorations fabricated with indirect methods, the precision value of 19 μm was considered acceptable.

Based on an in vitro study, Iwaki et al.[13] reported that with CAD/CAM systems, the optical bite registration method provided better dimensional accuracy in the interarch relationship in comparison with the conventional physical registration. However, in the context of actual dentition the precision of the optical impressions is affected by numerous factors including a lack of space for inserting an intraoral camera, movement of patients during taking the optical impressions, saliva, and humidity.[21] Therefore, it is important to evaluate the precision of optical bite registration in vivo.

In this study, the variability of the area of the clearance region depending on changes in optical bite registration was significantly higher than that depending on changes in the optical impressions. These results may have been caused by the difference in the occlusal relationship between the maxillary and mandibular molars during clenching at the intercuspal position. The difference was caused by a difference in the direction of tooth displacement, rather than the amount of tooth displacement. The stress-strain curve (SSC) represented the relationship between the amount of tooth displacement and the biting force[11]. The SSC of the maxillary molar showed two-phase, with the first phase mainly caused by distortion of the periodontal ligament and the second phase representing distortion of the alveolar bone in addition to the periodontal ligament. In the first phase, the maxillary molar was substantially displaced in the apical direction with a slight biting force, approximately 5 N. Conversely, in the second phase, the molar was displaced only slightly, regardless of the increase in the biting force. In this study, optical bite registration was taken during clenching with moderate biting force at the intercuspal position. Therefore, in the case of each optical bite registration, the differences in the amount of tooth displacement of the molars may have been slight. However, even with moderate biting force, the tooth was not only translated but also rotated in function, and the occlusal relationship between the maxillary and mandibular molars was easily changed because these molars were moved in the lingual direction with rotation. In function, the maxillary first molar is displaced approximately 100 to 150 μm in the palatal apical direction with rotation, while the mandibular first molar is displaced approximately 50 to 100 μm in the lingual direction with rotation.[6-11] Thus, the occlusal relationship between the maxillary and mandibular dentition is easy to change, and in the context of CAD software, the occlusal contact regions were also easy to change depending on slight differences in the biting force. Moreover, the buccal side optical bite registration data were less informative than optical impression data of the occlusal surface because the buccal surface was smoother than the occlusal surface,[22] and so the variability of the area of the clearance region depending on changes in optical bite registration was higher than that depending on changes in the optical impressions.

Given high variability, it may be difficult to duplicate the occlusal surface of the dentition and the occlusal relationship between the maxillary and mandibular dentition with high precision using CAD software. Therefore, it may not be possible to fabricate prostheses with adequate occlusal contact, and there is a possibility that prostheses with excessive high occlusal contact or inadequate occlusal contact may be fabricated. In the case of excessive high occlusal contact of prostheses, occlusal trauma or changes in the sensation threshold of the dental pulp may occur.[20,23-26] In the case of inadequate occlusal contact, disuse atrophy of the periodontal ligament and extrusion of the tooth may occur.

It is very important to fabricate prostheses with adequate close contact (the clearance region defined in this study), as well as adequate actual occlusal contacts on the occlusal surface, to maintain good functional condition for a long time. Recently, it was reported[7,14-18,27,28] that close occlusal contacts had a strong influence on masticatory efficiency, the stability of the main occluding area, and the formation of Squeezing Room at the latest stage of mastication.

It was demonstrated that changes in optical bite registration affected the reproducibility of the area of the clearance region in this study. To fabricate prostheses with functional occlusal surfaces using CAD/CAM systems, it is important that optical bite registration is performed with high precision. Further development of CAD/CAM systems is expected.

The variability depending on changes in optical bite registration was significantly higher than that depending on changes in the optical impressions in the clearance region that was closely related to fabrications of prostheses with functional occlusal surfaces even though there was no significant difference in the penetration region.

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