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Dimensional Accuracy of Optical Bite Registration in Single and Multiple Unit Restorations

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Clinical Relevance

Based on the dimensional accuracy measured *in vitro,* the optical bite registration was shown to be more effective in single posterior restorations in comparison with the conventional physical method using silicone material.

SUMMARY

The dimensional accuracy of optical bite registration in the CEREC system was compared to that of the conventional physical method *in vitro* using a bite registration material. Maxillary and mandibular full-arch dentate epoxy models mounted on an articulator were used to measure the interarch distance and the angles created by the occlusal planes. The preparations for a single restoration on the maxillary first molar or for multiple restorations on the maxillary posterior quadrant were made on the model. Optical impression and bite registration data were collected to construct virtual models using computer-aided design software. A silicone material was used for the physical method, and the dimensional accuracy was measured by means of the coordinate measuring machine. The discrepancy relative to the baseline before preparation was analyzed in each registration record. For the single restoration, the optical method created a mean discrepancy of 243.2 μm relative to baseline at the prepared tooth, which was insignificantly but slightly lower than the mean discrepancy of 311.1 μm obtained with the physical method. The mean rotational deviation in the horizontal plane was significantly lower for the optical method. For the multiple preparations, the optical method showed significantly larger discrepancy on the right molar and on the left premolar and molar sites. In the frontal view, the optical method created significantly larger rotational deviation than the physical method. The result indicates that the optical bite registration was effective in terms of dimensional accuracy for single posterior restorations.

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INTRODUCTION

Computer-aided design/computer-aided manufacturing (CAD/CAM)–generated restorations have gained popularity as the technique has evolved and improved over time. Long-term prospective studies[1,2] on CAD/CAM ceramic restorations reported survival probabilities of over 85% at 10+ years. More recently, advanced CAD/CAM systems have been introduced with an optical bite registration method in which the occlusal relationship between the prepared tooth and its antagonist is determined by the CAD software. The data are used to fabricate a restoration at chairside and to place the completed restoration on the same day.[3] The system employs intraoral cameras for optical impression and subsequent bite registration, and the occlusal relationship is digitally determined without the use of a bite registration material.[4] Conventional bite registration materials, such as wax and silicones, expand or shrink[5-9] more or less under varying temperature and moisture conditions after hardening[10] and gradually deform over time during storage.[9,11-13] Since recent clinical case series[4,14] indicated that the optical bite registration method was fairly predictable, the system looks promising and may be potentially effective for extended restorative and prosthodontic reconstruction. However, the accuracy of the optical method has not been compared with that achieved by the conventional physical bite registration. Furthermore, only limited information is available regarding the accuracy of the system when it is applied to multiple restorative units.

The objective of this study was to assess the three-dimensional accuracy of the optical system in comparison with that shown by the conventional bite registration method. The accuracy was evaluated *in vitro* using maxillary and mandibular casts with preparation for single or multiple restorative units. We hypothesized that the optical method increases accuracy of the reproducibility of the interarch relation in comparison with the conventional method using silicone material and that the accuracy of the optical system is not affected by extension of the restorative units.

MATERIALS AND METHODS

Maxillary and mandibular dentate models (D18FE-500A-QF, Nissin, Tokyo, Japan) were duplicated to create epoxy resin casts for the simulation of a patient (Diemet-e, Erkodent, Pfalzgrafenweiler, Germany). The casts were mounted on a semiadjustable articulator (Denar Mark II, Whip Mix Corp, Louisville, KY, USA), with the maximum intercuspal position determined manually by the examiner. The maxillary cast was mounted using a split-cast technique. The occlusal contacts were marked with articulating paper and adjusted in the conventional manner using diamond burs until the baseline occlusal relationship was established. As a result, all teeth had equal contacts with their antagonists, and the molars and premolars had at least two contacting points. To mark the reference points (RPs) for measurement, stainless-steel pins were fixed with light-curing composite material (Premise, Kerr, CA, USA) to the center of the buccal maximum convexity of teeth 14, 24, 34, 44 (premolar RPs), 17, 27, 37, and 47 (molar RPs) and at proximal contact points between teeth 11 and 21 and between teeth 31 and 41 (anterior RPs) (Figure 1a,b).

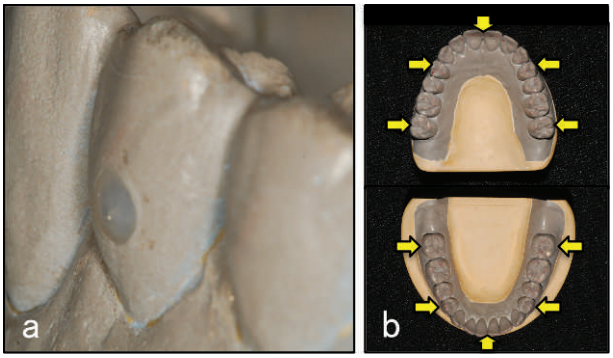

Figure 1. *The RPs for the measurements. Stainless-steel pins (black arrow) were fixed with light-curing composite on the center of the buccal surface (a) of teeth 14, 24, 34, 44 (premolar RPs), 17, 27, 37, and 47 (molar RPs) and at proximal contact points between teeth 11 and 21 and between teeth 31 and 41 (anterior RPs) (b).*

The calibration of the measurement was conducted using a flat plastic plate, whereby five RPs were linearly placed at 3-mm intervals. The distances between the RP on one edge and the others were measured by the coordinate measuring machine (QM–Measure 353, Mitutoyo, Kawasaki, Japan). After this process was completed, each plate was sprayed with titanium oxide powder (CEREC Optispray, Sirona, Bensheim, Germany). The optical impression was taken for each distance using an intraoral camera (CEREC Blue-CAM, Sirona) and recorded on the CAD software. Linear regression analysis indicated that the measured and the optically recorded distances correlated well (r^2=0.9996).

The location of each RP on the articulated casts was recorded by means of the coordinate measuring machine. The measurements were repeated five times by a single examiner (Y.I.), and the mean distances between the RPs on the upper and lower

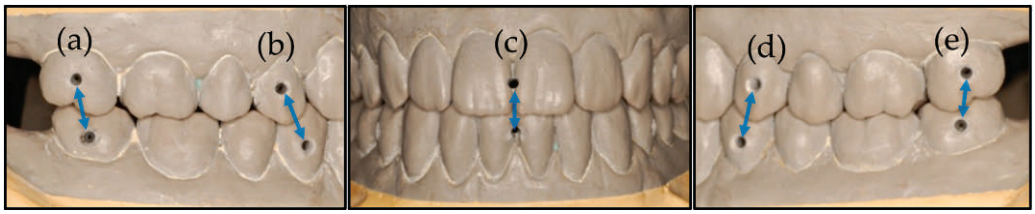

Figure 2. *The measurement sites for the interarch distance. The distances between the reference points of the upper and lower corresponding teeth (arrows) were measured at the right molar (a), premolar (b), anterior (c), left premolar (d), and molar sites (e).*

corresponding teeth (Figure 2) were calculated. The maxillary and mandibular planes were defined so that the right and left molar RPs and the anterior RP were included on each plane (Figure 3). The angle created by the maxillary plane relative to the mandibular plane was calculated on the horizontal and frontal planes for baseline records. A positive angle was recorded when the maxillary plane was deviated to a counterclockwise direction in the horizontal plane when viewed from above (Figure 3a) and when the maxillary plane on the left side was upright in the frontal plane when viewed from the front (Figure 3b).

For the first experiment, the maxillary right first molar in the cast was prepared for an all-ceramic, full-coverage restoration, with tooth reduction of 2.0-mm thickness on the buccal and lingual cusps, 1.5-mm thickness on the occlusal surface, and 1.0-mm thickness on the axial surfaces (Figure 4a). The upper and lower models were sprayed as indicated earlier, and a full-arch optical impression and scanning from the buccal side for the optical bite registration were carried out. Using the CAD software, distances between the maxillary and mandibular RPs of corresponding teeth (Figure 2) were measured 10 times. The mean horizontal and frontal angles of the maxillary plane relative to the mandibular plane were calculated based on the recorded distances between the RPs. The discrepancies of the mean distances and plane angles with the baseline records before preparation were then computed to determine the accuracy of the method.

For physical bite registration, a silicone bite registration material (Blu-Mousse Super-Fast, Parkell, Edgewood, NY, USA) was mixed and placed on the entire lower arch of the casts in the baseline interarch relation, and the casts were kept in occlusion until the material had hardened completely. This process was repeated to create five occlusal registration records. The materials were thereafter stored dry at room temperature for 24 hours before testing and trimmed with a sharp scalpel to eliminate excess material extending into undercuts. The upper split-cast was detached from the articulator. Each record was placed back on the lower model, and the upper model was returned on the top of the lower cast. After ensuring that the models fit together accurately, the relative positions were marked with line patterns on the cast surface using pencil, and the material was removed. The upper model was remounted on the articulator with mounting stone (Elite Arch, Zhermack, Polesine, Italy). The coordinates of the RPs were measured using the coordinate measuring machine. All of the above procedures were repeated for each registration. The discrepancies between the mean distances and the plane angles in comparison with the baseline before preparation were then computed.

The second experiment was conducted using the same cast. The maxillary right first premolar and

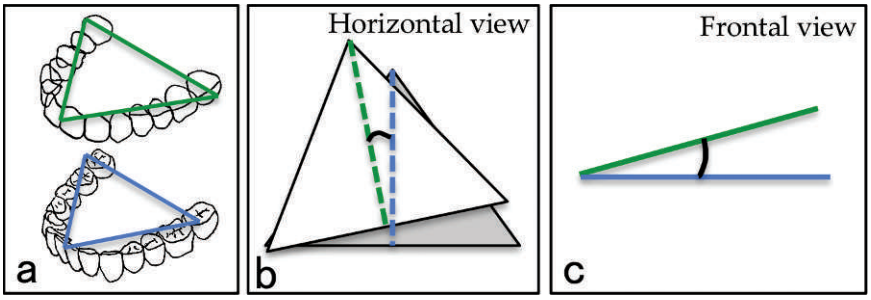

Figure 3. *Occlusal planes and the angles. (a) The maxillary and mandibular planes were created by inclusion of the right and left molar RPs and the anterior RP on each plane. The angle of the maxillary plane relative to the mandibular plane was calculated in the horizontal (b) and frontal (c) views. The discrepancy between the angle of the baseline record and the angle after bite registration was calculated for the physical and the optical methods.*

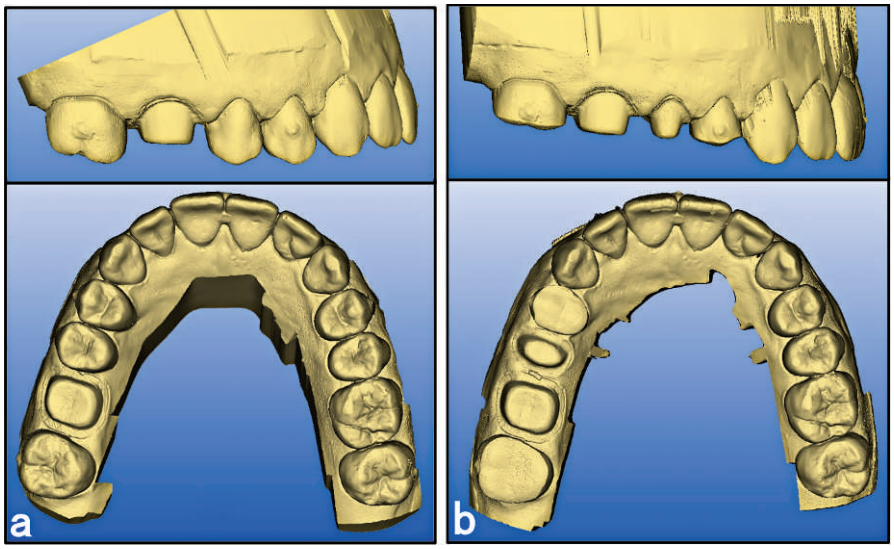

Figure 4. *CAD models. Preparation was made for the single restoration on the maxillary right molar tooth (a) and for the multiple restorations on the premolars and molars in the maxillary right quadrant of the master cast (b).*

second molar were prepared for occlusal onlays without damaging the RPs (Figure 4b). The second premolar was prepared for an all-ceramic restoration with the same regimen as used for the first molar. For the onlay preparation, a tooth reduction of 2.0-mm thickness on the buccal and lingual cusps and of 1.5-mm thickness on the occlusal surface was prescribed. The optical and physical bite registrations were performed with the same procedure as used in the first experiment.

The difference in the discrepancy between the two bite registration methods was statistically analyzed using the Student *t*-test (SPSS 11.5, SPSS Inc, Chicago, IL, USA). The significance level was set at 5%.

RESULTS

For the single preparation, the discrepancy in the distance was not significantly different between the methods on the right restorative side and the anterior site ($p>0.05$) (Table 1). However, on the left intact dentition, the optical method showed a significantly larger discrepancy than the physical method ($p<0.05$). The largest mean discrepancy of 522.6 μm was indicated at the left molar site with the optical method, whereas the physical method resulted in a discrepancy of 77.5 μm. For multiple preparations, the optical method showed significantly larger discrepancy on the right molar and on the left premolar and molars. The largest mean discrepancy of 833.2 μm was indicated at the left molar site by the optical method. For the physical method, the largest discrepancy of 116.8 μm was recorded at the right molar site.

The discrepancy in the horizontal and frontal plane angles between before and after bite registration is shown in Table 2. For the single preparation, the optical method made the upper plane horizontally deviate by only 2° on average, while the physical method made the upper plane deviate approximately 13°, and the difference in the discrepancy was statistically significant ($p<0.05$). For the multiple preparations, the optical method created significantly larger horizontal deviation than did the physical method, but the mean angles obtained by both methods were no more than 3°. From the frontal view, the occlusal planes revealed a rotational deviation; the left side of the maxillary plane was recorded more upwardly than the right side. The optical method created a significantly larger rotational deviation than the physical method for the single and multiple preparations.

DISCUSSION

As shown by the distances between the maxillary and mandibular RPs of the corresponding teeth, the interarch distance increased as a result of the optical and the physical bite registration methods. At the site of the abutment for the single preparation, the optical method created a mean discrepancy of 243.2 μm relative to the baseline, which was insignificantly but slightly lower than the mean discrepancy of 311.1 μm caused by the conventional physical

Table 1: *Mean Discrepancy in Distance Between the Reference Points (RPs) on the Maxillary and Mandibular Teeth*

Preparation	Bite Registration	Distance Discrepancy Relative to Baseline, μm				
		Right Molar	Right Premolar	Anterior	Left Premolar	Left Molar
Single	Optical					
	Mean	243.2	40.1	132	353.1[a]	522.6[a]
	(SD)	31.2	12.8	17.4	94.8	259.2
	Physical					
	Mean	311.1	42.8	137.4	79.9[a]	77.5[a]
	(SD)	33.2	11.8	23.9	7.6	31.3
Quadrant	Optical					
	Mean	554.0[a]	70.7	74.7	441.5[a]	833.2[a]
	(SD)	39.1	7.6	26.4	22.6	90.9
	Physical					
	Mean	116.8[a]	51.9	85.6	54.4[a]	60.4[a]
	(SD)	62	14.4	19.9	10.2	11.4

Abbreviation: SD, standard deviation.
[a] *Significant difference between optical and physical within the same preparation group ($p<0.05$).*

method ($p>0.05$). The difference was significant when the statistical test was based on the significance level of 0.10.

The discrepancy in the optical method at the nonoperational left molar site was significantly larger than that created by the physical method, which was consistent with the larger deviation of the plane angle of the optical method in the frontal view. However, this discrepancy may not cause a critical error in the completed restoration because it was away from the prepared tooth. In contrast, the mean rotational deviation in the horizontal plane was significantly lower for the optical method. In this context, within the scope of the single posterior restoration, it is suggested that the optical bite registration method provides better dimensional accuracy in the interarch relationship in comparison with the conventional physical method.

The increase in the interarch distance via bite registration was largest at the molar site on the nonoperational left side in both the single and multiple preparations. For optical bite registration, matching of the upper and lower occlusal surfaces was digitally carried out based on the images that were scanned from the buccal side of the right posterior dentition. A previous study[15] indicated that the precision of the intraoral camera of this system was 19 μm and that the optical impressions of the full arch obtained with this system are highly accurate when compared with conventional impressions obtained using silicone. However, when reconstructing the full dentition from the partially segmented morphometry, marginal discrepancy in the interarch reproduction was likely to be induced, even though the previous studies[15,16] concluded that the system was still usable. The findings of the current study indicate that accuracy is compromised when matching of the full arch dentition is

Table 2: *Mean Angle Discrepancy of the Maxillary and Mandibular Occlusal Plane Relation Relative to the Baseline Relation (°)*

Preparation	Bite Registration	Horizontal	Frontal
Single	Optical		
	Mean	−2.05[a]	1.76[a]
	(SD)	0.57	0.002
	Physical		
	Mean	13.19[a]	0.18[a]
	(SD)	2.64	0.12
Quadrant	Optical		
	Mean	−2.95[a]	1.77[a]
	(SD)	0.58	0.02
	Physical		
	Mean	−2.33[a]	0.27[a]
	(SD)	5.82	0.08

Abbreviation: SD, standard deviation.
[a] Significant difference between optical and physical within the same preparation group ($p<0.05$).

implemented based on the partial optical bite registration.

For multiple unit preparations, the optical method was significantly less precise in the dimensional accuracy of the interarch relation of the prepared teeth in comparison with the conventional method. Therefore, the result did not support the hypothesis of this study. As a result of the full coverage or the occlusal coverage in onlay preparations, the morphometry of the abutments was considerably simplified from that of the intact teeth. With multiple preparations, the optical impression was less informative for a good match when merging with the antagonist. The results of the current study support recent literature[14] that did not recommend preparation and optical impression of all molars and premolars at the same time when the posterior occlusal support was lost. Instead, the restorations should individually be constructed, with retention of occlusal support by the neighborhood intact teeth.

The optical impression and bite registration method can preclude the use of various materials for fabrication of restorations. The use of an impression material and working cast potentially introduces dimensional errors into the completed restorations. When mounting the casts on the articulator with the physical method, expansion of the plaster[17] as well as technical errors[18] may deteriorate the accuracy of the interarch relationship. Although environmental factors such as optical interference by saliva may potentially cause dimensional errors with the optical system,[19] it is suggested that the method was effective, especially for a single posterior restoration, and further development of this new and promising technology is strongly encouraged.

CONCLUSIONS

The hypothesis that the optical method increases the accuracy of interarch registration was not supported by the results of this study. However, in a single posterior restoration, the optical method provides better dimensional accuracy in the interarch relationship in comparison with the conventional physical registration.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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