Influence of the bite impression technique on reproducibility of occlusal contacts in working casts for dental implants

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The bite impression technique has been developed and applied in the fabrication of crowns. However, few reports have demonstrated its accuracy in reproducing the occlusal contacts of implant superstructures. We investigated the bite impression technique for its reproducibility of occlusal contacts on working casts for implants. Eight patients were selected who each had a single-tooth implant to replace a missing posterior tooth. A custom device was created to measure occlusal contacts and their relationship with the opposing teeth and the implant body. Image analysis was used to compare intraoral measurements from working casts made from a bite impression with those from the open tray impression technique.

Good reliability was determined for the measuring device and measurements in this study. We found that the occlusal contact points and areas on the custom measuring device were significantly better for the working casts made from bite impressions than for those from open tray impressions (p＜0.001). Furthermore, significant differences were observed in the occlusal contact areas and contact points on both teeth adjacent to the implant (p≦ 0.001), with the bite impression working casts significantly more reproducible than the open tray impression casts. Our data suggest that the bite impression technique accurately reproduces occlusal contacts for implants. (J Osaka Dent Univ 2014 ; 48(1) : 17–27)

Key words : Implant dentistry ; Bite impression technique ; Occlusal contacts

INTRODUCTION

For an implant prosthesis to function permanently and well in the oral cavity, it is necessary to consider various biomechanical factors.[1,2] Esposito *et al.*[3] reported that occlusion-induced overloads are associated with increased morbidity and poor durability of dental implants. In order to obtain appropriate occlusal contacts in prostheses, it is important to determine the reproducibility of occlusal contacts in working casts.[4] The open tray impression technique is generally employed to fabricate working casts, because of the high-level accuracy of impressions routinely obtained with this method.[5,6] On the other hand, the bite impression technique has been developed with good reproducibility of the occlusal contact relationship, and clinically applied for the fabrication of tooth-supported–type crowns.[4,7–17]

Recently, Hayashi *et al.*[14] reported that the bite impression technique is useful for the fabrication of dental casts, and has high occlusal contact reproducibility. Furthermore, Kubo *et al.*[16,17] clarified the usefulness of the bite impression technique based on a clinical evaluation of the relationship between the prosthesis and the adjacent teeth, the marginal fit, and the crown height. However, despite clinical study[18] and clinical case[19] reports using the bite impression technique to fabricate implant prostheses, as well as a study[20] addressing the positional relationship with an abutment in a working cast fabricated using this technique, no study has experimentally investigated the relationship between the implant prosthesis and opposing dentition. In this study, we investigated the reproducibility of occlusal contacts of working casts for dental implants for the bite impression technique.

MATERIALS AND METHODS

Subjects and test fixtures

The inclusion criteria were patients who : 1) visited the Department of Oral Implantology, Osaka Dental University, understood the objective of the study, and gave their informed consent to participate in the study ; 2) had no clinical abnormalities in stomatognathic function ; 3) had a single fixture placed for a posterior intermediary defect ; 4) had periodontal ligament support for the opposing dentition, regardless of the presence or absence of crown restorations ; and 5) had occlusal support in the residual molar region.

The exclusion criteria were patients who : 1) had instability of intercuspal position ; 2) the presence of defect repair with removable prosthesis other than the fixture implant ; and/or 3) were incapable of nasal breathing. Of the potential patient cohort, eight patients were ultimately included in the study, with a mean age of 52 ± 16 years. Eight fixtures were tested (Table 1). The study was designed in consideration of the protection of the rights and interests of the subjects and approved by the Medical Ethics Committee of Osaka Dental University (approval number : 100709).

Fabrication of working cast

For each patient, open tray impressions were taken and working casts were fabricated from the individual impressions. Upper and lower impressions were taken in random order with an interval of 3 min. All impressions were taken by a single specialist with 10 years' clinical experience, certified by the Japanese Society of Oral Implantology.

For the bite impression technique, a unilateral impression was taken using a tray for dental impression-taking (Triple Tray®, Premier Dental, PA,

Table 1 Implant site

Jaw	First premolar	Second premolar	First molar
Upper	1	3	1
Lower	0	0	3

(n = 8)

USA) and a plastic implant impression coping (Implant Impression Coping Closed Tray, Nobel Biocare, Tokyo, Japan) for the impression coping. After attaching the impression coping to the fixture in the oral cavity, the bite impression tray was tried-in to confirm occlusion in the intercuspal position. The head position was adjusted with the patient in the sitting position so as to set the Frankfort horizontal plane parallel to the floor. To specify the clenching strength for bite impression-taking in the intercuspal position, a surface electrode (EMG Sensor DE-2.1, Delsys, Boston, MA, USA) was applied to the center of the masseter on the implant side in the direction of the muscle fibers, and the muscle electrical activity was measured through a bipolar lead.

The measured surface electromyography (SEMG) signal was digitized using an EMG Evaluation System (Bagnoli-2, Delsys) and a data collection system (UAS-108B, Unique Medical, Tokyo, Japan), with the time constant set to 0.03 seconds, the sampling frequency to 1 KHz, the amplification to 1,000 times, and the high cut-off frequency to 1 KHz. The data were then displayed as root mean square (RMS) rectified waveforms on a monitor using biological information analysis software (Unique Acquisition ver.2.11.0.10, Unique Medical) to visually feed back the data to the subject. Taking the maximum voluntary clenching (MVC) in the intercuspal position as 100% MVC, the clenching strength for bite impression-taking was set at 10% MVC. Prior to bite impression-taking, the subjects practiced clenching with 10% MVC in the intercuspal position with the bite tray inserted in the mouth.

Block out was applied to the undercut region of the dentition using cotton wool. After applying adhesive and allowing it to dry (Adhesive, GC, Tokyo, Japan) on the bite tray, a light-bodied addition curing silicone rubber impression material (Examixfine Regular, GC) was poured into the tray. The impression material was infused around the impression coping using a syringe, and the bite tray was inserted so as to include the ipsilateral canine. The subject immediately clenched with 10% MVC in the intercuspal position and maintained this jaw position for 3 min for setting of the impression material. The tray was then re-

moved from the mouth, washed in running water, disinfected with sodium hypochlorite solution[21] and left standing at room temperature for 60 min.

We used the method reported by Rosenstiel *et al.*[22] to fabricate working casts from the bite impression, which was then mounted onto a twin-stage articulator (Verticulator, Jelenko, NY, USA). After trimming the impression, an implant analogue (Implant Replica, Nobel Biocare) was attached to the impression coping, and a small amount of a polyether rubber impression material for artificial gingiva preparation (GI-Mask, Yoshida, Tokyo, Japan) was infused around it. The DI-Lok® Tray (DI-Lok® Trays Quadrant Size, Ootaki, Nagoya, Japan) was attached to the maxillary frame of the articulator using a type IV gypsum (Moderock II, Shofu, Kyoto, Japan), followed by infusion of the type IV gypsum on the implant side of the impression and into the DI-Lok® Tray. After solidifying, the impression and articulator were placed upside-down, and the type IV gypsum was infused on the opposite side of the impression and into the mandibular frame of the articulator. While the type IV gypsum was solidifying, screws were fixed on the lateral parts of the articulator to prevent lifting. After the type IV gypsum had solidified, the impression was removed from the articulator.

In the open tray impression technique, an individual full-mouth impression tray and impression coping (Implant Impression Coping Open Tray, Nobel Biocare) were used on the implant side. An individual tray was fabricated using an autopolymerizing resin (Tray Resin II, Shofu), and two sheets of paraffin wax (Paraffin wax, GC) were used as a spacer. Stops were set on the inner surface of the tray at 4 sites : the bilateral canine cuspids and bilateral nonfunctional cusps of the residual molars. Blockout was applied to the undercut region of the dentition. Conventional impression-taking procedures were employed.[4, 5] For impression-taking of the opposing dentition, a commercial aluminum tray for the whole jaw (Alginate Impression Tray, Komatsu, Tokyo, Japan) and addition polymerization type silicone rubber impression material were used. Blockout was applied to the undercut region of the dentition using cotton wool.

Using two sheets of paraffin wax as a spacer, the primary impression was taken with a putty-type impression material, followed by addition of a light-bodied material onto the putty. The impression was taken after thoroughly drying the dentition. Mouth opening during solidification was set at a distance of one fingerwidth. On maxillomandibular registration, the head position was adjusted with the patient in a sitting position so as to set the Frankfort horizontal plane parallel to the floor, with curing silicone rubber impression material added for bite-taking (Exabite II, GC). The clenching strength was set to 10% MVC. The subjects practiced homogenous clenching in the intercuspal position on bilateral sides. The bite impression material was infused in the bilateral molar regions, and the maxillomandibular relationship, excluding the anterior teeth, was recorded. The impression was removed from the mouth, disinfected,[20] and left at room temperature for 60 min.

An implant analogue was attached to the impression coping of the impression, and a small amount of the polyether rubber impression material for artificial gingiva preparation was infused around it. A working cast was fabricated using the type IV gypsum. A twin-stage articulator was used for the articulator, and the maxillary and mandibular casts were attached to it using type IV gypsum and the cast technique. The maxillomandibular registration material was used only as a reference for the jaw position.[23] While the type IV gypsum was solidifying, the screws of the lateral parts of the articulator were fixed to prevent lifting of the working casts. Manufacturers' instructions were followed for all impression methods and cast materials.

Fabrication of measuring device

A measuring device was fabricated for each subject in order to compare the relationship between the implant prosthesis and the opposing dentition under three conditions : in the intraoral cavity (intraoral, Io) ; on the working casts fabricated using the bite impression technique (Biwc) ; and on the working casts fabricated using the open tray impression technique (Otwc). The measuring device was fabricated from the bite impression technique separately from that used for Biwc by a dental technician with 30 years' clinical experience, certified by the Japanese Society
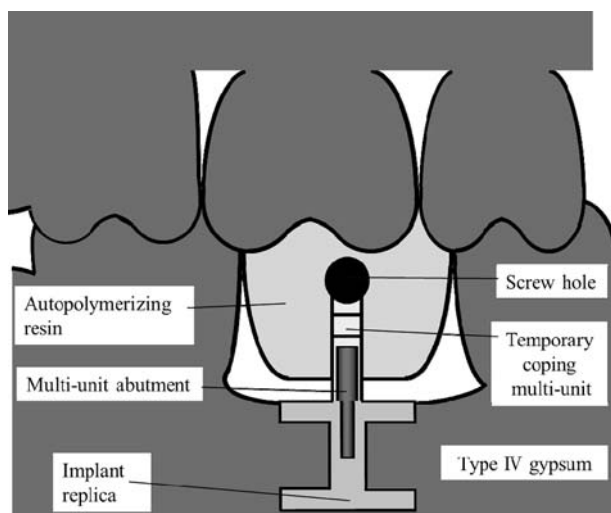
Fig. 1 The custom measuring device.

of Oral Implantology. A screw fixation-type temporary abutment (Temporary Abutment Engaging, Nobel Biocare) was fixed at a torque functionality of 35 Ncm to an implant analogue on the cast using a torque wrench. In cases where the screw hole was open on the occlusal surface, a screw fixation-type multi-unit abutment (17° Multi-unit Abutment NobRpl NP 3 mm, 30° Multi-unit Abutment NobRpl RP 5 mm, Nobel Biocare) and temporary cylindrical multi-unit (Temporary Coping Multi-unit, Nobel Biocare) were used instead of the temporary abutment to avoid the occlusal surface.

After applying white Vaseline (Propeto®, Maruishi Pharmaceutical, Osaka, Japan) to the opposing dentition as a separating agent, a room-temperature curing resin (Unifast III, GC) was built-up on the temporary abutment or temporary cylinder multi-unit to register the inner and outer inclines of the opposing functional cusp. The proximal contacts were registered following the standard implant prosthesis fabrication methods.[24] A jig to set the direction of the measuring device attachment was fabricated using dental hard resin (Estenia® C&B, Kuraray, Tokyo, Japan) (Fig. 1). The fabricated jig was used to attach the measuring device to both the oral cavity and the subject's working cast.

Record of occlusal contact relationship

To record occlusal contacts under the three measure-

ment conditions (Io, Biwc and Otwc), the measuring device was first fitted and adjusted in the subject's oral cavity. To confirm that occlusal contacts of the residual dentition were not altered after attaching the measuring device, the contacts of the residual dentition were recorded for each subject using occlusal registration material (Bite-Checker, GC). The clenching strength was 10% and 30% MVC. The measuring device was tried-in, and the relationship between the mesial and distal adjacent teeth was adjusted so that a 110-μm contact gauge, but not a 150-μm contact gauge, could be inserted. The occlusal surface of the measuring device was adjusted so as to make occlusal contact during clenching with 30% MVC undetectable with 12-μm occlusal film (Articulating Film, GC), but detectable with 30-μm occlusion paper (Articulating Paper, GC). After occlusal surface adjustment, the abutment was fixed at 35 Ncm using a torque wrench, and the measuring device was attached using the jig. After attachment, Records of the occlusal contact relationship were taken with 10% and 30% MVC using occlusal registration material, and the absence of any change from the previous occlusal contact record of the residual dentition was confirmed before measurement.

After adjustment, the measuring device was attached and occlusal contacts were recorded using occlusal registration material under the three measurement conditions. In Io, the clenching strength was set to 10% MVC. In Biwc and Otwc, after the measuring device was attached, a wax separating agent (GC-sep, GC) was applied to the dentition of the working cast and thoroughly dried. The occlusal registration material was poured onto the occlusal surface of the mandibular dental cast on the articulator, and the cast was immediately fitted applying finger pressure. After confirming that the maxillary and mandibular casts were fully fitted, screws of the lateral parts of the articulator were fixed to maintain this condition, and a 1-kg load was added to the upper frame of the articulator. After setting, the occlusal registration material was removed from the cast and trimmed. The occlusal contacts were recorded twice under each condition.

Occlusal contact reproducibility

Occlusal contact reproducibility was investigated by measuring changes in the number of occlusal contact points and occlusal contact area. Image processing software (Image Hyper II ver 5.3, Science-eye, Saitama, Japan) was used to quantify the occlusal contacts. The number of occlusal contact points and occlusal contact areas in the region with an inter occlusal surface distance of 30 μm or less were calculated. The number of occlusal contact points was determined by counting the number of cells calculated by the image processing software.[25] The measurement region was set on the measuring device and both adjacent teeth (the mesial and distal teeth). Under each condition, imaging analysis of the two occlusal registration materials was performed three times, respectively. The mean measured value of the six measurements was adopted under each condition.

Statistical analysis

Intra-rater reliability of the measured values was investigated. The intraclass correlation coefficient (ICC)[26] of each parameter was calculated to check reliability of the average measurements. An ICC value of 0.75 or greater is regarded as 'good reliability', and, for measurement, 0.9 or greater is regarded as 'ensures reasonable validity'.[26] Null hypotheses of differences under the measured values of the number of occlusal contact points and the area under the three conditions were tested. The null hypotheses were : 1) there is no difference in the number of occlusal contact points on the measuring device among the three conditions, 2) there is no difference in the occlusal contact area on the measuring device among the three conditions, 3) there is no difference in the number of occlusal contact points with both adjacent teeth among the three conditions, and 4) there is no difference in the occlusal contact area with both adjacent teeth among the three conditions.

For these null hypothesis tests, repeated measures one-way layout analysis of variance (ANOVA) was performed regarding the conditions of occlusal contact recording as factors. Prior to ANOVA, the sphericity was investigated using Mauchly's test.[27] When no sphericity was established, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε).[28] In addition, to judge the practical significance, the effect size (ω^2_p)[29–32] was calculated for each parameter. When a significant difference was detected with ANOVA, Bonferroni's multiple comparison was performed.[33] The significance level was set at 5%. Statistical analysis was performed using analysis software (IBM SPSS Statistics Base 19.0, IBM SPSS Advanced Statistics 19.0, IBM, NY, USA).

RESULTS

Reliability

For the number of occlusal contact points on the measuring device, the point estimation of ICC(1,6) was 0.947 or greater under all conditions, and the lower limit of the 95% confidence interval (CI) was 0.860 or greater. For the area, the point estimation was 0.967 or greater, and the lower limit of the 95% CI was 0.914 or greater (Table 2). For the number of occlusal contact points on the two adjacent teeth, the point estimation was 0.991 or greater under all conditions, and the lower limit of the 95%CI was 0.976 or

Table 2 Reliability of the measurements on the custom measuring device

Condition	Contact	ICC (1,6) (95% CI)
Io	P	0.947 (0.860–0.988)
	A	0.984 (0.957–0.996)
Biwc	P	0.980 (0.947–0.995)
	A	0.967 (0.914–0.992)
Otwc	P	0.995 (0.988–0.998)
	A	0.998 (0.994–0.998)

P : Occlusal contact points, A : Occlusal contact areas, ICC : Intraclass correlation coefficient, CI : Confidence interval.

Table 3 Reliability of the measurements from the teeth adjacent to the implant

Condition	Contact	ICC (1,6) (95% CI)
Io	P	0.991 (0.976–0.988)
	A	0.994 (0.985–0.992)
Biwc	P	0.995 (0.988–0.999)
	A	0.995 (0.988–0.999)
Otwc	P	0.994 (0.985–0.999)
	A	0.992 (0.980–0.995)

greater. For the area, the point estimation was 0.992 or greater, and the lower limit of the 95%CI was 0.980 or greater (Table 3).

Number of occlusal contact points with the custom measuring device

In the Io condition, occlusal contact points were detected in all subjects (mean : 4.83 points, 95%CI [4.00–5.66]). With Biwc, occlusal contact points were detected in all subjects, and the number was decreased compared with that measured in the Io condition (mean : 2.81, 95%CI [1.84–3.78]). With Otwc, the number was generally lower than that in Biwc, and no contact was detected in four of the subjects (mean : 1.13, 95%CI [0.00–2.26]) (Fig. 2). With Mauchly's sphericity test, no significant difference was noted (p = 0.487). Using ANOVA, a significant difference was noted (p < 0.001), and ω^2_p was 0.86 (Table 4). For the

multiple comparisons test, significant differences were noted between the conditions with all combinations (p = 0.004, p < 0.001, and p = 0.016, respectively) (Fig. 2).
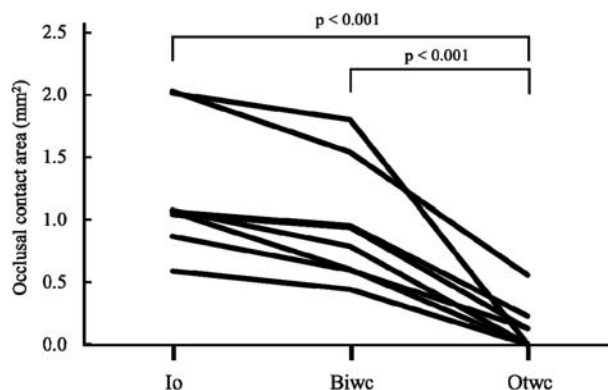
Occlusal contact areas with the custom measuring device

In the Io condition, occlusal contact areas were detected in all subjects (mean : 1.22 mm², 95%CI [0.78 –1.66]). With Biwc, occlusal contact areas were detected in all subjects, and the areas decreased compared with those in the Io condition (mean : 0.96 mm², 95%CI [0.56–1.36]). With Otwc, the area was generally narrower than that seen with Biwc, and no contact was detected in four subjects (mean : 0.13 mm², 95%CI [−0.03–0.29]) (Fig. 3). With Mauchly's sphericity test, no significant difference was noted (p = 0.520). A significant difference was noted using the
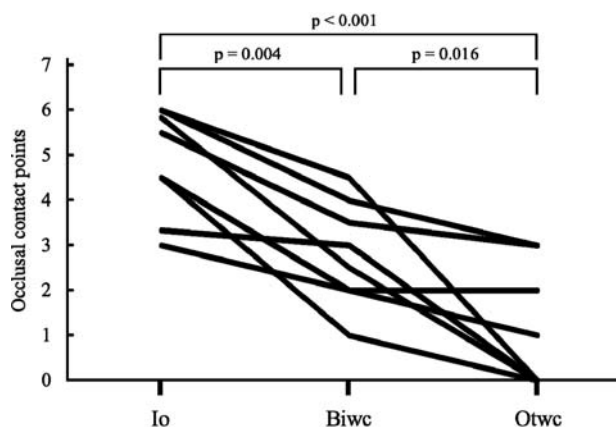
Fig. 2 Comparison of occlusal contact points on the measuring device (n = 8)
Io : Intraoral, Biwc : Working casts made bite impression technique, Otwc : Working casts made with open tray impression.

Fig. 3 Comparison of occlusal contact areas on the measuring device (n = 8).

Table 4 Results of repeated measure one-way ANOVA for occlusal contact points on the custom measuring device and the effect size

Source	Sum of squares	df	Mean squares	F-value	P-value	Effect size (ω^2_p)
Measurement conditions	55.155	2	27.578	26.237	<0.001	0.86
Subject	17.628	7	2.518	2.396		
Error	14.715	14	1.051			
Total	87.498	23				

df : Degrees of freedom.

Table 5 Results of repeated measure one-way ANOVA for occlusal contact areas on the custom measuring device and the effect size

Source	Sum of squares	df	Mean squares	F-value	P-value	Effect size (ω^2_p)
Measurement conditions	6.025	2	3.013	29.638	<0.001	0.88
Subject	2.544	7	0.363	3.576		
Error	1.423	14	0.102			
Total	9.992	23				

ANOVA (p<0.001), and ω^2_p was 0.88 (Table 5). For the multiple comparisons test, significant differences were noted between Io and Otwc, and between Biwc and Otwc (p<0.001, respectively) (Fig. 3).
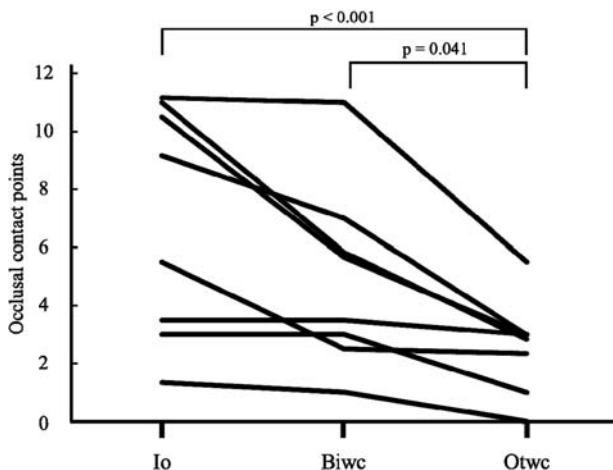
The number of occlusal contact points on both adjacent teeth

In the Io condition, occlusal contact points were detected in all subjects (mean : 6.90 points, 95% CI [3.54–10.26]). With Biwc, occlusal contact points were detected in all subjects, and the number was decreased compared with that in the Io condition (mean : 4.94, 95%CI [2.30–7.58]). With Otwc, the number was generally lower than that seen with Biwc, and no contact was detected in one subject (mean : 2.58, 95%CI [1.22–3.94]) (Fig. 4). With Mauchly's sphericity test, no significant difference was noted (p=0.310). Using ANOVA, a significant difference was noted (p=0.001), and ω^2_p was 0.76 (Ta-

ble 6). For the multiple comparisons tests, significant differences were noted between Io and Otwc, and between Biwc and Otwc (p<0.001 and p=0.041, respectively) (Fig. 4).

Occlusal contact areas on both adjacent teeth

In the Io condition, occlusal contact areas were detected in all subjects (mean : 10.10 mm², 95%CI [5.25 –14.95]). With Biwc, occlusal contact areas were detected in all subjects, and the areas were decreased compared with those in the Io condition (mean : 5.91 mm², 95%CI [2.73–9.09]). With Otwc, the area was generally narrower than that seen with Biwc, and no contact was detected in one subject (mean : 1.83 mm², 95%CI [0.51–3.15]) (Fig. 5). With Mauchly's sphericity test, a significant difference was noted (p =0.038). Using ANOVA with Greenhouse–Geisser ε, a significant difference was detected (p<0.001), and ω^2_p was 0.84 (Table 7). For the multiple compari-

Fig. 4   Comparison of occlusal contact points on the two teeth adjacent to the implant (n=8).
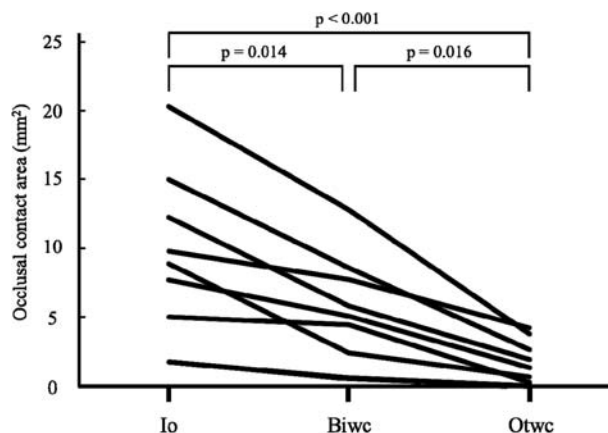
Fig. 5   Comparison of occlusal contact areas on the two teeth adjacent to the implant (n=8).

Table 6   Results of repeated measure one-way ANOVA in occlusal contact points on the teeth adjacent to the implant and the effect size

Source	Sum of squares	df	Mean squares	F-value	P-value	Effect size (ω^2_p)
Measurement conditions	74.600	2	37.300	13.405	0.001	0.76
Subject	161.815	7	23.116	8.308		
Error	38.956	14	2.783			
Total	275.371	23				

Table 7   Results of repeated measure one-way ANOVA in occlusal contact areas on the teeth adjacent to the implant and the effect size

Source	Sum of squares	df	Mean squares	F-value	P-value	Effect size (ω^2_p)
Measurement conditions	271.691	2	135.845	22.224	<0.001	0.84
Subject	268.751	7	38.393	6.281		
Error	85.576	14	6.113			
Total	626.018	23				

sons test, significant differences were noted between the conditions with all combinations (p = 0.014, p < 0.001, and p = 0.016, respectively) (Fig. 5).

DISCUSSION

Methods

Patients were selected following the guidelines stating that it is desirable for the bite impression technique to be used for a single abutment tooth with healthy adjacent teeth on both sides and healthy opposing dentition.[7,8] Patients with a posterior intercalary defect were thus selected to reliably mount the open tray impression working casts on the articulator, employing the cast technique with occlusal support from the posterior molars. Furthermore, bite impressions were taken to include the canine in the cast, because this allows accurate reproduction of the dentition in the cast.[7,8] For the tray, a plastic bite tray was used because these casts have been reported to be the most accurate.[20] For the impression coping, a short snap-on-type plastic coping was used and adjusted to a length that did not interfere with intercuspidation, as detailed previously.[17,18]

To clarify differences between the impression techniques, the impression, casting materials and the articulator were kept constant between the experiments. To evaluate the intercuspal position, we used the verticulater as the articulator because it closes and opens the mouth in the normal direction of the occlusal plane and prevents early contact. Although different impression copings were used for the impression techniques, this is likely to only have a small effect on the results. This is because the impression coping used in the bite impression technique was a snap-on-type picked up by the impression, and we omitted the step wherein we would return it to the impression in the closed tray technique ; this is reported to reduce the accuracy of the impression.[34]

We also used the same type of device to measure the occlusal contact relationship for all three tests, because morphological differences in the adjacent and occlusal surfaces measured using different devices may influence the results. With this measuring device, an angle was added to the screw hole so as to open it on the buccal side to avoid the occlusal sur-

face. The occlusal surface of the measuring device was fabricated by registering the inner and outer inclines of the functional cusp of the opposing dentitions. This was based on specific criteria that were independent of the type of opposing tooth to prevent the measuring device from having a non-physiological influence on the opposing dentition while recording the occlusal contact.[35] A measuring device employing screw fixation was fabricated, and the torque on the attachment was set at 35 Ncm to prevent lifting of the device. In addition, a jig was used to fix the attachment direction of the device to inhibit its rotation.

The clenching strength was specified during the bite impression technique and intraoral occlusion recording, because others have reported the influence of different clenching strengths on the occlusal contact area and number of contact points.[36] Weak clenching is recommended for the bite impression technique ;[14-16] therefore, clenching strength was set at 10% MVC, because this corresponds to subjective weak clenching in healthy dentulous subjects.[37] Intraoral occlusal contact recording and bite impression-taking using the surface electrode were consecutively performed on the same day in each subject, because the removal and re-application of the surface electrode may reduce reproducibility even within the same subject, even though the clenching strength is the same.

Both adjacent teeth were added to the measurement site, in addition to the measuring device, to not only investigate the relationship between the implant prosthesis and the opposing dentition, but also to compare the intercuspal position to confirm whether the overall dentition showed a similar tendency. Indices of occlusal contact reproducibility include changes in the number of occlusal contact points, the contact areas, and their positions. In this study, we assessed changes in the number of occlusal contact points and the contact areas. Objective evaluation is possible using these two types of quantitative data. Quantitative evaluation of the occlusal contact positions remain to be investigated in the future. The number of occlusal contact points and the contact area were calculated in a region with a 30-μm or smaller distance between the occlusal surfaces, because the

acceptable range of the occlusal height in the stomatognathic system has been reported to be 30 μm or less.[38]

We used a novel measurement method, and the reliability of the measured values was evaluated using ICC. The mean of six values measured by a single rater was adopted as the measured value on each cast. ICC(1,6), which represents intra-rater reliability, was calculated. An ICC value of 0.75 or greater is regarded as 'good reliability', and, for measurement, 0.9 or greater is regarded as 'ensures reasonable validity'.[26] In addition to the null hypothesis tests to determine statistical significance, practical magnitude among the measured values were also analyzed by determining the effect size.[29–32] ω_p^2 was calculated in the repeated measures one-way layout analysis of variance. Using this value, a bias can be corrected when the sample size is small.[32] Cohen's index was used for the interpretation of ω_p^2 : 0.01, 0.09 and 0.25 or greater are regarded as 'small', 'medium', and 'large', respectively.[29]

Results

The mean of six measured values was calculated to measure the indices under each condition. This was done to reduce random errors. Regarding the reliability of the mean values taken using the measuring device, the point estimation was 0.947 or greater and the lower limit of the 95%CI was 0.860 or greater in all parameters. This was judged as showing 'good reliability'. On both adjacent teeth, the point estimation was 0.991 or greater and the lower limit of 95%CI was 0.976 or greater in all parameters. This was judged as 'ensures reasonable validity'. The reproduction of the occlusal contact condition of the mesial and distal teeth on the measuring device was also favorable, showing that the parameters were measured in a stable intercuspal position. Particularly, the specification of the clenching strength using SEMG visual feedback in the intraoral occlusion recording was favorable. The ICC of both the number of occlusal contact points and contact area measured at two sites was close to 1, ensuring the high-level reliability of this experimental method.

In the Biwc and Otwc conditions, the occlusal contact area was significantly larger on the measuring device, whereas the number of contact points was significantly greater on both adjacent teeth. These results may have been caused by differences in the occlusal surface morphology between the natural teeth and measuring device, which was fabricated based on specific criteria, independent of the type of opposing dentition. This was done to closely investigate occlusal contact reproducibility.

In Otwc, the values were significantly decreased compared with those for the Io and Biwc conditions, regardless of the measurement site and index of occlusal contact reproducibility. Taking the number of occlusal contact points on the measuring device in Io as 100%, the rates of change in the measured values of the two impressions were 58% and 27% in Biwc and Otwc, respectively ; this result showed that the reproducibility of the bite impression technique was about 2.1 times greater than that of the open tray technique. Similarly, 79% and 11% of the occlusal contact area were reproduced in Biwc and Otwc, respectively, indicating that reproducibility of the bite impression technique was about 7.2 times greater than that of the open tray technique. Since the effect size on the ANOVA was 'large' in all indices, these findings demonstrated a practical difference in reproducibility between these two impression techniques.

Two factors likely influence this reproducibility : biological and technical factors. For instance, when mouth opening is unavoidable during impression-taking, the mandibular arch width is decreased by the masticatory muscles and muscles around the floor of the oral cavity.[39–44] In the open tray impression technique, a working cast is fabricated under conditions that are different to normal occlusion, and, thus, the intercuspal position in the working cast may be different from that in the oral cavity, reducing the reproducibility of the occlusal contacts. In contrast, for the bite impression technique, the working cast of the intraoral intercuspal position may have been fabricated well because the interocclusal registration was performed at the same time as impression taking. In addition, the uniform clenching strength during intraoral occlusion recording may further increase the reproducibility of the bite impression technique because displacement

of the teeth and jaw bones depends on the clenching strength.[45] As a technical factor, the occlusal relationship may be more accurately reproduced on the articulator with the bite impression technique because the fitting of working casts by the technician is omitted, unlike the situation with the open tray impression technique.

In this study, we clarified that the relationship between the implant prosthesis and opposing dentition as well as the overall dentition of the intraoral cavity (Io) are effectively reproduced in Biwc compared with Otwc. Thus, our results show that the bite impression technique demonstrates better occlusal contact reproducibility than the open tray impression technique.

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