Interocclusal recording for removable partial denture in bilateral mandibular distal extension were evaluated for the differences of the interocclusal recording material utilized during different impression techniques. The purpose of this study is to develop interocclusal recording utilizing occlusion rims with high accuracy.

The intraoral model with urethane rubber mucosa with 3 metallic spheres as measuring points was utilized. With the applied pressure (functional) and minimum pressure (anatomical) impression techniques, working casts were fabricated. Interocclusal recording was registered with the occlusion rim on the intraoral model unto the articulator by applying the interocclusal materials; paraffin wax (PW), ALUWAX (AW), impression paste (IP) and Exabite II (EB). Analyses were conducted with the three-dimensional analyzer and calculated for the amount of vertical and antero-posterior displacement between the intraoral model and the working cast. The results were that PW had the greatest displacement, especially with the functional impression technique, while AW had minimum displacement especially in the posterior direction. With the functional impression technique utilizing AW was revealed to minimize the amount of interocclusal displacement.

Key words: Interocclusal recording, applied pressure impression technique, bilateral mandibular distal extension, Aluwax, occlusion rim

Introduction

Intraoral evaluation of the initial placement of the fabricated removable partial denture often revealed that the vertical dimension is increased and that numerous occlusal adjustments must be made to attain the optimum occlusion. Factors that influence the vertical dimension of the removable partial denture involve multiple steps i.e.: impression recording, interocclusal recording, artificial teeth arrangement and curing procedures. Under laboratory conditions, it is possible to eliminate the error that occurs throughout the steps by adjustment made on the articulator.

But it is not possible to solve the problem of distortion that occurs in the process of making the impression and interocclusal recording, since the amount of displacement by pressure differs considerably between the remaining teeth and the residual ridge mucosa. Under functional conditions, the amount of displacement by pressure to the teeth on the longitudinal axis is approximately 30 μm to 60 μm while the amount of depression of the base plate on the residual ridge mucosa has been determined to be from about 140 μm to 350 μm with the mean being 200 μm. From these findings, the amount of displacement by pressure between the teeth and the ridge mucosa is about ten fold greater and affects their positional relationship during functional and at rest positions.
Therefore, with the assumption that the residual ridge is depressed during function, the functional impression technique by loading manipulation is routinely performed with the typical removable partial denture cases.

However, the amount of pressure applied during impression recordings and interocclusal recording with the manipulation technique and the interocclusal recording material utilized greatly influences these results. In addition, since the interocclusal recording in bilateral distal extension cases revealed that the supporting area at the molar region to be insufficient, thus reproducibility of the patient's occlusal registration is further complicated with the working casts. Although occlusion rims are utilized in such extension cases in order to stabilize the upper-lower working casts, the vertical dimension between the casts tend to increase. Intraorally, occlusal contacts of the remaining teeth were confirmed but with the working casts with occlusion rims, it was evident that a remarkable gap is often formed. Therefore, from the points of observation of impression, manipulation technique and interocclusal recording material, etc., modification and refinement of the interocclusal recording technique utilizing the conventional occlusion rims was sought.

In this study the interocclusal recording for mandibular bilateral distal extension was evaluated utilizing the different impression techniques and the different interocclusal recording materials on the simulation model, and their influences to the occlusal dimension between the upper-lower working casts were compared so that the method of interocclusal recording could be developed with high accuracy and minimum displacement.

Materials and Methods

Intraoral model and working cast

The intraoral model, mandibular bilateral distal extension model (Nissin Dental Products Inc.), utilized in this study was composed of an urethane rubber mucosa with a thickness of two millimeters and teeth fabricated with melamine. The edentulous area involved six teeth, the second premolar to the second molar on both the right and left sides of the mandible and subjected to evaluation with the maxillary intraoral model with complete dentition.

The upper-lower intraoral models were mounted to the arcon-type semi-adjustable articulator PROTAR VII (KaVo EWL Co.) and this was considered as the original prototype of the intraoral model. For the measurement of positional relation of the upper-lower jaw of the intraoral model, 3 reference points of metallic spheres for measurement were established on the lateral surface of the upper-lower intraoral model at the mid-sagittal (M) and at the left (L) and right (R) lateral surfaces corresponding to the first molar.

Impression recording of the intraoral model was determined with the applied pressure impression technique as a functional impression and the minimum pressure impression technique as an anatomical impression utilizing a custom tray fabricated with the self-curing acrylic resin. The custom tray was fitted on the remaining teeth with a stopper and the incisal stopper was modified in a hinge-shaped manner in order for the tray to be placed in the proper position.

With the applied pressure impression technique, the custom tray was fabricated to cover the residual ridge without wax spacers whereas with the minimum pressure impression technique, 2 sheets of baseplate wax as the spacer were utilized. In order to determine the impression recording of both the intraoral area and reference points of the lateral surface of the upper-lower intraoral models, the tray was fitted by extending its adjacent margin to cover the reference points. For the insertion of the tray to its proper position a guiding plane was attached for orientation.

As for the impression recording material, the condensation reaction polyvinylsiloxane silicon elastomer, Coltex (Colten Co.) was utilized and for the applied pressure impression the medium type and for the minimum pressure impression the fine type were utilized. In the applied pressure impression, the weight of 1 kg was placed on the tray after insertion while for the minimum pressure impression technique, there were the minimum stress loaded by manipulating the tray with both hands for evaluation of impression record. After setting of the impression, identical metallic spheres specified in the intraoral model were also fixed to the corresponding impression surfaces and then high strength dental stone; Fujrock (GC Dental Products Co.) was poured for the fabrication of the working cast.

Impression recording of the upper intraoral model was determined with the same minimum pressure technique that was applied to the lower one.

On each working cast, the base plate of the occlusion rim was fabricated with light-cured base plate resin and the wax rim was fixed to the base plate with magnetic attachment in order for it to be exchanged. The outline of the occlusion rim was determined along the
line 0.5 mm upper from the bottom of the buccal and lingual sulcus of the residual ridge and the lingual cervical line of the remaining dentition of the working cast.

**Measurement and analysis methods**

Four types of interocclusal recording material utilized were the paraffin wax (PW, GC Dental Products Co.), Aluwax (AW, ALUWAX Co.), impression paste medium (IP, GC Dental Products Co.) and addition reaction polyvinylsiloxane interocclusal recording material, Exabite II (EB, GC Co.). Interocclusal recording was registered by setting the occlusion rim to the intraoral model and by applying the 4 types of interocclusal recording materials to the occlusal surface of the removable wax rim on the articulator which was limited to only the hinge movement.

For the applied pressure impression technique, the occlusal surface of the removable wax rim was adjusted so that slight contact of the superior cusp of the opposing tooth is registered, and as for the minimum pressure impression, the wax rim was adjusted so a small clearance is formed. Five separate interocclusal recordings were determined for each material on each occlusal surface.

The coordinate system of measurement was established with three reference points for measurement on the lateral surface of the maxillary intraoral model which consisted of the M point corresponding to the upper inter-incisor and the R and L points corresponding to the upper first molars. The M point was defined as the origin and the line that intersects the equilibrium point of the 3 maxillary reference points and the origin was the X (antero-posterior) -axis and the plane that intersects the 3 reference points was the X-Y plane, the Z (vertical) -axis was the line that intersects the X-Y plane vertically at X-Z plane and the Y-axis was the line that horizontally intersects the origin according to the right-handed coordinated system (Fig 1).

In order to adjust the difference of the coordinate system between the intraoral model and working cast, the maxillary intraoral model and working cast were overlaid on top of each other, the equilibrium point of the 3 reference points, G and G' were matched, and the X-axis were aligned on top of one another.

Fig. 1. Coordinate system of measurement was established with three reference points on the maxillary intraoral model. In order to adjust the coordinate system between the intraoral and working cast, the maxillary intraoral model and working cast were overlaid on top of each other, the equilibrium point of the 3 reference points, G and G' were matched, and the X-axis were aligned on top of one another.

Measurements were conducted on the intraoral model and working cast, the M, R and L reference points of the maxilla and mandible were three-dimensionally determined with the manual direct contact three-dimensional analyzer, QM-Measure 353 (Mitutoyo Co.). The center position of each metallic sphere was calculated by the direct three-dimensional method in triplicate and the mean value were converted coordinately, then the 3 reference points of the intraoral model and the working cast of the maxilla were overlaid on top of each other, for determining the vertical (V) and antero-posterior (A-P) displacement, M-M', R-R' and L-L' in relation to the mandible (Fig 2).

Analyses conducted were the amount of V displacement along the Z-axis and the amount of A-P displacement along the X-axis of the intraoral model and the working cast. While for the horizontal lateral displacement along the Y-axis, due to its limitation to only
the hinge movement of the articulator during interocclusal recording, it was not considered for evaluation and analysis. Each measurement was subjected to the one-way ANOVA test and Sheffe’s F test was utilized for evaluating each interocclusal recording material.

Results

The difference in the displacement between the intraoral model and the working cast for each impression technique is shown in Fig 3-6.

1. Comparative analysis of the difference in displacement between the reference points

1) Vertical direction (Z) (Fig 3)

(1) Applied pressure (functional) impression technique

At all reference points PW revealed to have the greatest displacement and showed the largest value with 587 $\mu$m at the M point. At the R and M point IP had the smallest displacement with 96 $\mu$m(R), whereas at the L point AW had the smallest with 24 $\mu$m. On both the R and L points, PW was revealed to have similar amount of displacement while as for the other interocclusal recording materials, the amount of displacement obtained at the L points was demonstrated to be smaller.

(2) Minimum pressure (anatomical) impression technique

At the M and L points PW had the greatest amount of displacement with 260 $\mu$m. EB had relatively greater amount of displacement at the L point with 306 $\mu$m than the other reference points.

2) Antero-Posterior direction (X) (Fig 4)

(1) Applied pressure (functional) impression technique

Evaluation on the amount of displacement for AW was the smallest at all reference points and showed 13 $\mu$m at the M point while the amount of displacement for PW was the greatest at all reference points especially at R point with 271 $\mu$m. AW, IP and EB revealed increased amounts of displacement at the R and M points with greater amounts of displacement at the L point.

(2) Minimum pressure (anatomical) impression technique

The measured amount of displacement of all materials at the M point had negative values, a forward displaced position, while the R and L point in PW and the L point in EB revealed a posterior displacement. The average value of displacement at each point revealed to be within 100 $\mu$m.

2. Comparative analysis of the mean value of each reference point

The mean value, the distribution of each material and the amount of displacement of the 3 reference points (R,M,L) were evaluated for each impression technique in Fig 5 and 6. The displacement along the Z and X-axis for each impression and each interocclusal recording material were determined with the one-way ANOVA test. As to the results, interocclusal recording materials were of significance and subjected to Sheffe’s F test with a risk percentage of 5%.

1) Vertical direction (Z) (Fig 5)

Overall, positive values were attained with both the applied and minimum pressure impression techniques with an increase in the interocclusal distance. PW revealed the greatest amount of displacement with both the applied and minimum pressures impression with a significant difference when compared with the other materials evaluated ($p < 0.05$). The mean values of each material except PW with the applied pressure impression revealed to be approximately from 70 to 170 $\mu$m smaller than that with the minimum pressure impression.

2) Antero-Posterior direction (X) (Fig 6)
Fig. 3. The displacement in the vertical (V) direction with the applied (functional) and the minimum pressure (anatomical) impression techniques at each reference point; R (right), M (mid-sagittal) and L (left). The positive (+) value was defined as an increase in the vertical dimension of the upper-lower working cast.

Fig. 4. The displacement in the antero-posterior (A-P) direction in the applied (functional) and the minimum pressure (anatomical) impression techniques. The positive (+) value defined that the mandible of the working cast was displaced posteriorly.

Fig. 5. The displacement in the V direction was compared with the mean value of each interocclusal recording material during the applied and the minimum pressure impression techniques.
With the applied pressure impression, all materials evaluated were posteriorly displaced and PW had the greatest amount of displacement and the smallest for AW, the value of the 4 materials was significantly different from each other (P < 0.05).

While with the minimum pressure impression, PW had the largest absolute value in comparison to other materials, the difference between IP and AW was significant (p < 0.05).

Discussion

The subjects for this study were enrolled from the mandibular bilateral distal extension cases with 6 teeth missing and diagnosed to the Kennedy Class I classification or to the Eichner Class B2 group. The mandible of our study subjects was supported only in the premolar region vertically at the intercuspal position and with the upper-lower working casts it is extremely difficult to accurately reproduce the interocclusal jaw relationship.

The intraoral model was fabricated with a mucosa ridge made of urethane rubber with a thickness of 2 mm which was referred to by Uchida\textsuperscript{6} who reported the mucosa of the residual ridge in mandibular edentulous cases has a thickness range of 1.45 to 1.58 mm in the stress-bearing region.

The displacement of the interocclusal jaw relationship between the intraoral model and the working casts was determined from the 3 metallic spherical reference points at the lateral surfaces of each model. Present methods utilize an articulator with an inspection gauge or a recording grid and stylus\textsuperscript{7,12} or a three-dimensional optic analyzer for measurement\textsuperscript{13-16} but in conditions where the displacement is greater than 100 μm, their reliability and accuracy are unsatisfactory. Okubo\textsuperscript{17} utilized metallic sphere for their reference point and reported that their precision of measurement was about 5 μm. Our study revealed that the displacement of measurement at the center point of the metallic sphere was less than 1.5 μm at each reference point. With the method of transferring the metallic spheres between the intraoral model and the working cast we were able to obtain accuracy with displacements within 50 μm for the X, Y, Z-axis which was considered to be sufficient.

Recently, with accurate and reliability of the impression materials under clinical conditions, additional reaction polyvinylsiloxane has been widely accepted and utilized. But with such impression material, the setting curve sharply elevates, thus indicating that ideal flow condition of the material rapidly sets and makes it difficult to for pressure loading. On the other hand, the condensation reaction polyvinylsiloxane, the setting curve is smooth and gradual\textsuperscript{18-20} and it is easier to conduct pressure loading procedures, thus we selected the condensation reaction type material for our study.

With the applied pressure impression technique, PW had the greatest amount of displacement at all reference points. This result is postulated to be due to or involvement of setting shrinkage after heating, characteristic dimensional changes in respect to time of PW, pressure applied for making the impression and difference in movement of the occlusion rim attained during interocclusal recording. Müller et al.\textsuperscript{21} fabricated working casts with interocclusal recording materials and mounted the cast unto the articulator and determined the amount of displacement for each material evaluated. Their reported findings revealed that three-dimen-

Fig. 6. The displacement in the A-P direction was compared with the mean value of each material during the applied and the minimum pressure impression techniques. □ was defined to be a significant difference (P < 0.05) from the other materials.
sionally PW had a displacement of greater than 200 $\mu$m at 30 minutes and after a day, the displacement observed in the V direction was 460 $\mu$m. At approximately 30 minutes after interocclusal recording, measurements of each reference point were conducted resulting in a difference in findings than those reported by Müller et al.\textsuperscript{21}, this is postulated to be due to the fact that our study subjects were distal extension cases. In addition, with the minimum pressure impression, PW was revealed to have the greatest amount of displacement at the M and L point in comparison to other interocclusal recording materials but when compared to the applied pressure impression the amount of difference was smaller. We postulate that this is due to the fact that with the applied pressure impression during pressure application for making the impression and interocclusal recording, the locomotive and multifactorial involvement or influence to the suitability of the material to the mucosa surface of the occlusion rim, occlusal pressure, etc. are involved compared to the minimum pressure impression.

Findings of other 3 interocclusal recording materials for applied and minimum pressure impression revealed that there was a significant difference in the V direction only between IP and EB in the applied pressure technique. Thus, it is suggestive from our findings that AW, IP and EB may be evaluated to be similar in respect to its ability in vertical reproducibility.

Positive values were obtained at all reference points for all materials evaluated for the amount of V displacement, the value of interocclusal dimension for the working cast was revealed to be greater than that of the intraoral model.\textsuperscript{22} The mean values of the interocclusal recording materials with the exception of PW was 143 $\mu$m and with the minimum pressure impression the mean value was 261 $\mu$m (excluding PW), an overall difference was 118 $\mu$m. Thus when applied and minimum pressure impression techniques were comparatively analyzed the V displacement was smaller and was revealed to be approximately 100 $\mu$m and it is possible to postulate that due to the influence in distribution of pressure to the residual ridge mucosa the interocclusal dimension is decreased.

When referring to the A-P displacement (X) with the applied pressure impression, PW was revealed to have the greatest amount of displacement in the A-P direction at all reference points as well as in the vertical direction and it revealed a tendency to be retruded (Fig 7). On the other hand, AW when comparatively analyzed with other interocclusal recording materials it was revealed to have the smallest amount of displacement and at the R point, protrusion was observed. With the minimum pressure all interocclusal recording materials were revealed to have smaller amounts of displacement of measurement and protrusion was observed at the M point (Fig 7). The tendency of retrusion of the working cast during application of pressure is the fact that the residual ridge mucosa was depressed in the postero-inferior direction against the remaining dentition or during interocclusal recordings even distribution of vertical force to the occlusal rim was not attained, thus the occlusion rim was pushed posteriorly and rotated and the depression that results is postulated to be the causative factor. In other words, between the impression technique and interocclusal recording, the direction of the pressure loaded to the mucosa differed resulting in anterior or posterior displacement.

As for the minimum pressure impression technique, it is postulated that there is practically no pressure loaded to the mucosa, position relationship of the tooth and ridge mucosa, tooth and occlusion rim, thus it can be accurately reproduced and anterior or posterior translocation was less observed than the applied pressure technique. In comparison to the applied pressure impression, elevation of the posteriorly located occlusion rim was observed and with the minimum pressure impression, relatively the mandible was revealed to be slightly rotated in the anterior direction and located anteriorly at the M point (Fig 7). However PW showed retrusion at the R and L point and had slight negative value at the M point which was within the range of measuring deviation, we postulated that slight posterior translocation was performed in PW with the minimum pressure impression.

While with the applied pressure, slight posterior translocation was identified for AW and was postulated that it is possible to conduct interocclusal recording during application of pressure for obtaining the impression. Aluwax is the product of refinement to solve the problems encountered with wax, modification with the addition of aluminum as filler, thus distortion after setting was minimized and the fitting of the opposing dentition was satisfactory. The results for EB were revealed to be similar with those of IP and AW in respect to vertical displacement with high reproducibility but in respect to A-P displacement the amount of displacement increased. Igari et al.\textsuperscript{23} reported that the additional reaction polyvinylsiloxane interocclusal recording material has endogenic stress and that during interocclusal recording these materials become distorted and elastic stress occurs. EB contains an abundant amount of fillers and possesses a
moderate amount of fluidity and does not flow into the interdental space and has satisfactory fitting to the opposing dentition but possesses the characteristic property of endogenic stress of elastic materials thus it is postulated that A-P distortion occurs.

**Clinical significance of this study**

Mandibular bilateral distal extension model with artificial ridge mucosa was subjected to impression techniques and interocclusal recordings and was evaluated on their influences to the interocclusal registration. As to the results, under all conditions the interocclusal distance in the V direction had positive values and confirmed the possibility in fabricating a removable partial denture with a high vertical dimension. With applied pressure impression technique the V displacement was revealed to be approximately 100 μm smaller than that with minimum pressure impression technique. On the other hand, under applied pressure impression technique the A-P displacement was observed significantly and the mandibular working cast was demonstrated to be retruded in all interocclusal recording materials with the exception of AW. Impression technique for removable partial dentures are conducted under the assumption of function and conventionally the applied pressure impression technique is conducted. It is suggested to be the appropriate method with the applied pressure impression technique utilizing occlusion rims with AW as an interocclusal recording material in order to minimize the amount of interocclusal displacement.

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