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Proceedings of the 8th International Conference on Magnetic Applications in Dentistry

March 2 to 20,2009

The Japanese Society of Magnetic Applications in Dentistry

日本磁気歯科学会

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The Japanese Society of Magnetic applications in Dentistry

The 8th International Conference on Magnetic Applications in Dentistry

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Subjects:

Researches and developments related to dentistry and magnetism such as:

- Magnetic attachments for dentures
- Orthodontic appliances using magnets
- Measurement of jaw movement using magnetic sensors
- Biological effects of magnetic fields
- Dental applications of MRI
- Others

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Researches and developments related to dentistry and magnetism such as:

- Magnetic attachments for dentures
- Orthodontic appliances using magnets
- Measurement of jaw movement using magnetic sensors
- Biological effects of magnetic fields
- Dental applications of MRI
- Others

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1. The Full Mouth Reconstruction using Magnetic Attachments

Nakamura Y., Shoji K., Ando A. , Tanaka T.[1] , Okada M.[1] , Imaoka S., Ohno Y., Takada Y.,[2] Tanaka Y.

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[1]Department of Dental Laboratory , Aichi - Gakuin University Dental Hospital
[2]Division of Dental Biomaterials, Tohoku University Graduate School of Dentistry

Introduction

A magnetic attachment is a device using magnetic attractive force to provide and assist in the retention of dentures. Dentures using these special attachments have been well received by patients and treating dentists. The purpose of this paper is the case presentation of a patient who presented with chief complaints of aesthetic dissatisfaction and inability to chew. This patient underwent full mouth reconstruction using magnetic attachments as retaining elements. The following is a summary of treatment completed.

Clinical History

The patient was a 42-year-old female with chief complaints of aesthetic dissatisfaction and masticatory dysfunction. The patient had received implants on the right lower molar region in 1995, but they were failed after 3 years. The edentulous upper and lower molar regions were left untreated for many years, resulting in a distorted plane of the occlusion and a decrease in occlusal vertical dimension. Although the patient visited several general practitioners and municipal hospitals to seek aesthetic correction, she was dissatisfied with the treatment results, and then consulted with our department.

Initial Status

The patient had Kennedy Class II relationship in the upper and lower arches. There was severe molar occlusal destruction with a occlusal plane discrepancy. Also present were areas of root fracture, failing restorations with ill-fitting margins, and poor periodontal tissue health. There was severe redness and swelling of periodontal tissues around the right upper lateral incisor, and right lower first premolar areas. Radiographic examination demonstrated endodontic problems of apical radiolucencies and poor endodontic fills in other areas. Clinical examination revealed the bone torus which can be an obstacle to the restorative treatment (Fig. 1).

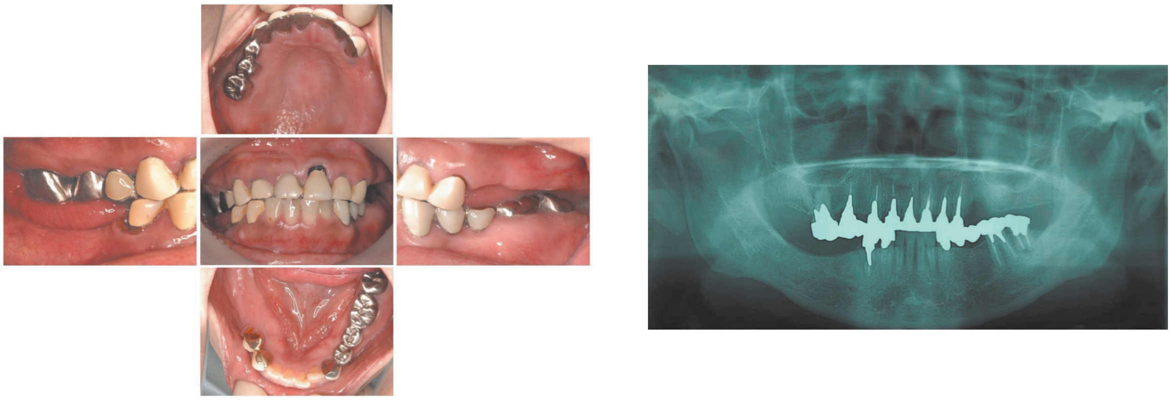

Fig.1: Oral Photo and Panoramic X-ray Photo (First examination)

Treatment Procedure

1 . Exploration

The mounted study casts were made and mounted on an articulator using face-bow transfer procedure. The diagnostic wax-up was performed to show an anticapated result and establish a restorative treatment plan showing space and dental relationship problems that might exist. The diagnostic modeling provides excellent material for patient education and demonstration (Fig. 2).

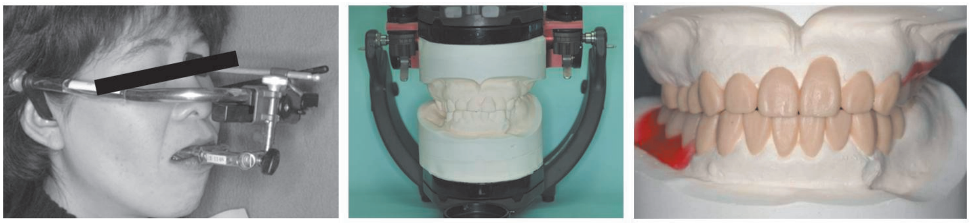

Fig.2: Face-bow transfar and Wax up for treatment

2 . Temporary Restoration and Initial Treatment Denture

The quality of the existing restorations caused a poor occlusal and periodontal environment. These were removed. Temporary restorations were placed to secure the temporary masticatory function, pronunciation, and to evaluate ane initial esthetic result, and to provide for initial periodontal and occlusal treatments stability. Temporary restorations were fabricated based on the diagnostic wax-up. In the edentulous area, treatment denture was placed to improve the occlusal support (Fig. 3).

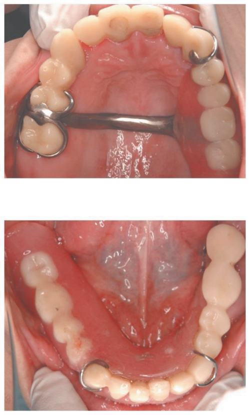

Fig.3: Temporary Restoration

3 . Provisional Restoration

After the completion of the initial periodontal treatment, resin cores with fiber posts were placed in the remaining teeth to avoid dental fracture. A provisional restoration with improved esthetics and occlusal height, and adjusted occlusal vertical dimension from the temporary restoration was fabricated (Fig. 4).

Fig.4 :Provisional restoration

4. Surgical Treatment

Maxillary bony exostosis that may interfere with final denture fabrication was surgically resected (Fig. 5).

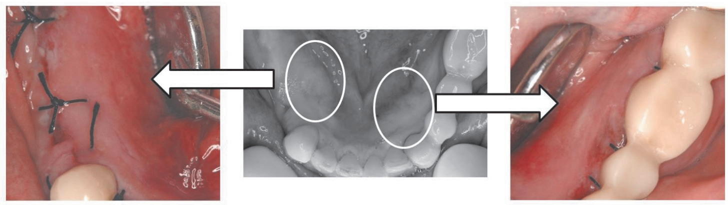

Fig.5 :Surgical Treatment

5. Preparation

To protect vital abutment teeth, preparation was performed in 3 steps with the time interval to promote the formation of the secondary dentin that protects the pulp.(Fig. 6)

Fig .6 :Preparation for Abutment Tooth

6. Final Provisional Restoration

A final provisional restoration with improved occlusion, periodontal environment and esthetics was fabricated and presented for approval by the patient. .

7. Design of Final Restoration

Maxillary denture design includes an extracoronal magnetic attachment on the distal surface of the left upper canine, slit on the distal surface of the right upper canine, and metal crowns on the right upper second premolar and first molar (Table 1).

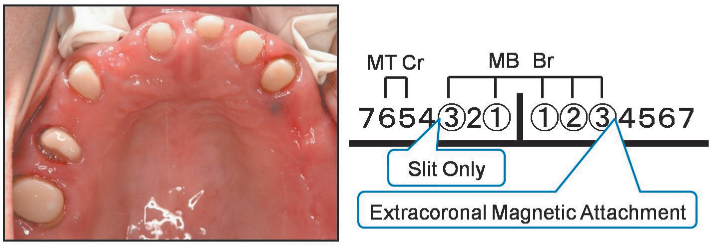

Table.1: Upper Design

Mandibular denture design includes an extracoronal magnetic attachment on the distal surface of the canines, and metal crowns on the left first and second molars (Table 2).

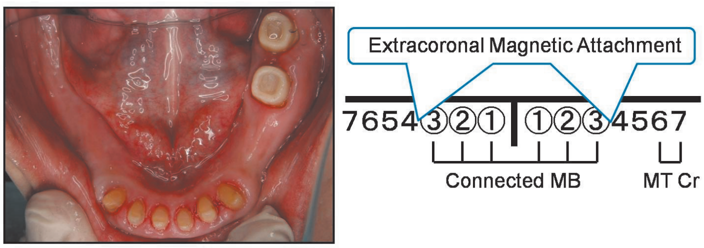

Table.2: Lower Design

8. Maxillo-mandibular Relationships and Articulator Mounting.

Cross mount transfer technique was used to preserve the original maxillo-mandibular cast relations and mounting. This procedure also preserves original diagnostic occlusal design and vertical dimension of the provisional restoration to the final restoration (Fig. 7).

Since provisional and work models are transferred on the same axis, these models can also be compared during fabrication of the final restoration to use as a reference to the opposing arch and teeth. This method simplifies the fabrication procedures such as wax-up.

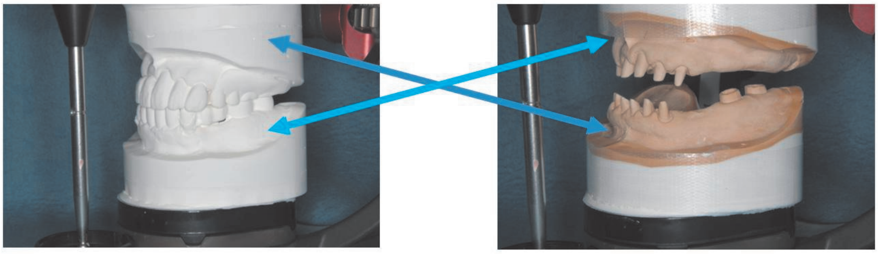

Fig.7: Cross Mount Technique

9. Trial Fitting Procedures

Trial fitting of the metal work and metal crowns was performed. Transfer impression was taken following the conventional methods after try fitting, followed by the fabrication and try fitting of the wax denture.

10. Final Restoration

Fig. 8 shows upper and Fig. 9 shows lower final restorations.

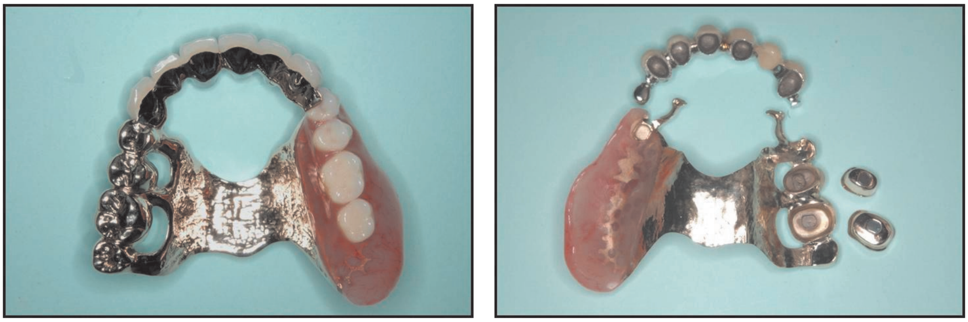

Fig.8: Upper Final Restoration

Fig.9: Lower Final Restoration

Discussion

The patient was satisfied with the esthetic results of the final restoration with magnetic attachments. The retention obtained with the attachments achieved highly satisfactory functional results. The patient was satisfied with the prosthetic retentive force (Fig. 10).

Fig.10: Oral Photo with Final Restoration

The postoperative course has been uneventful. However, the design of a final restoration is complex as the ideal combination of esthetics and functionality is difficult to obtain. It is important that regular maintenance is obtained. (Fig. 11).

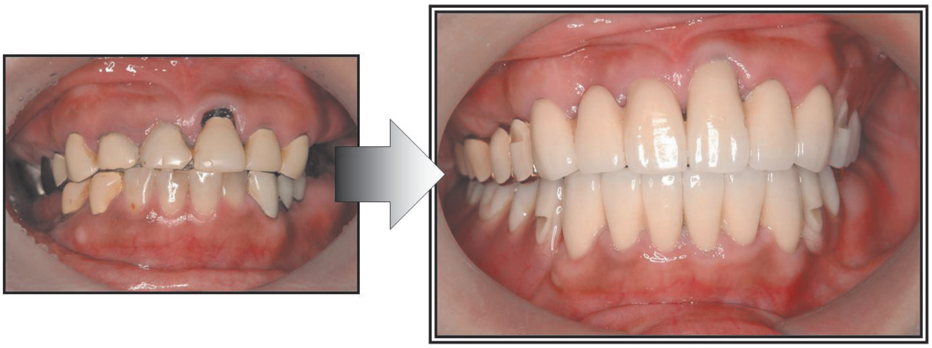

Fig . 11 Comparison Before Treatment with After

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2. Longitudinal Study on Metal Plate Denture with Magnetic Attachments

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Introduction

At present, magnetic attachments have been applied clinically in various cases.
It's useful to carry out postoperative investigations and to confirm results, as it shows the criterion of the clinical application. Thus, we can use magnetic attachments safely.
From this point of view, postoperative investigation on 252 magnetic attachments which were applied to 105 metal plates in Aichi-Gakuin University Dental Clinic over the 10 year period from 1993 to 2003, were carried out. The results of this investigation were reported in 2003.
In this study, a further 5 years were researched to compose a longitudinal study over approximately 15 years.

Methods and Results

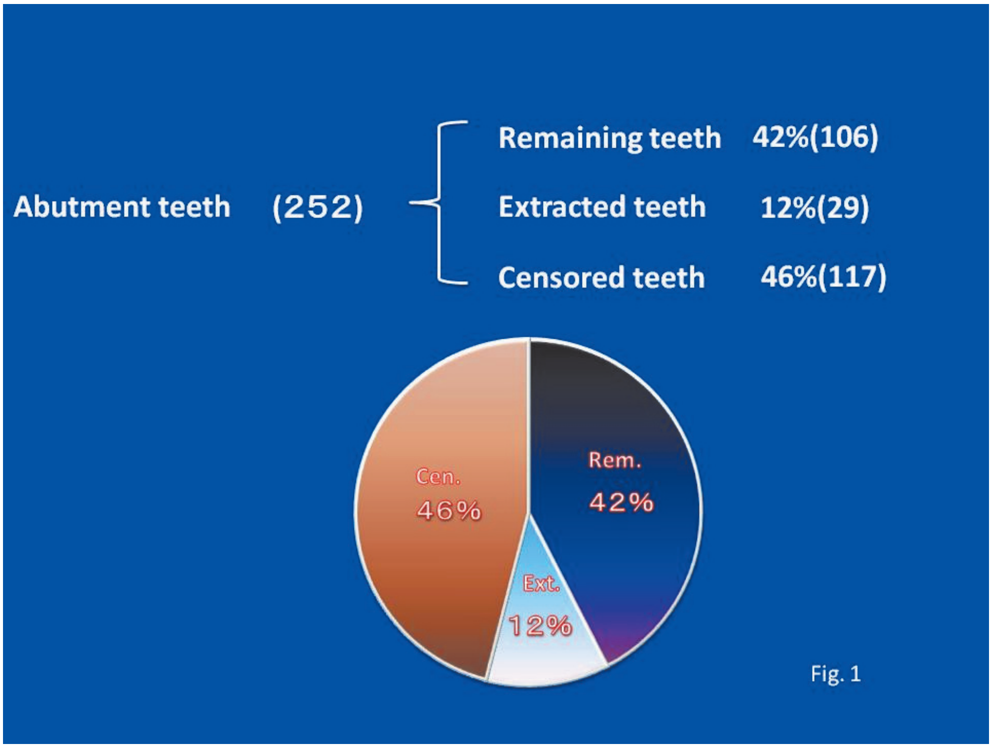

Fig. 1

Fig.1 shows the transition of the conditions of all abutment teeth over the 15 years period 1993 to 2008.
The numbers of extracted teeth were 29, censored teeth were 117 and the remaining teeth were 106.

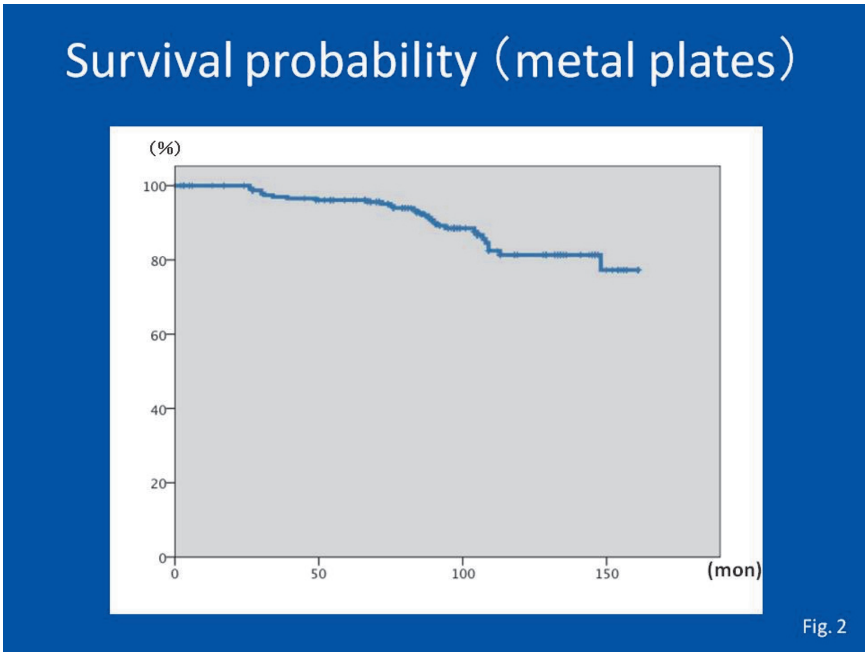

Fig.2 shows the survival probability of all abutment teeth using a Kaplan-Meier analysis.
After 10 years, the cumulative survival rate was 88% and after 15 years the cumulative survival rate fell to 77%.

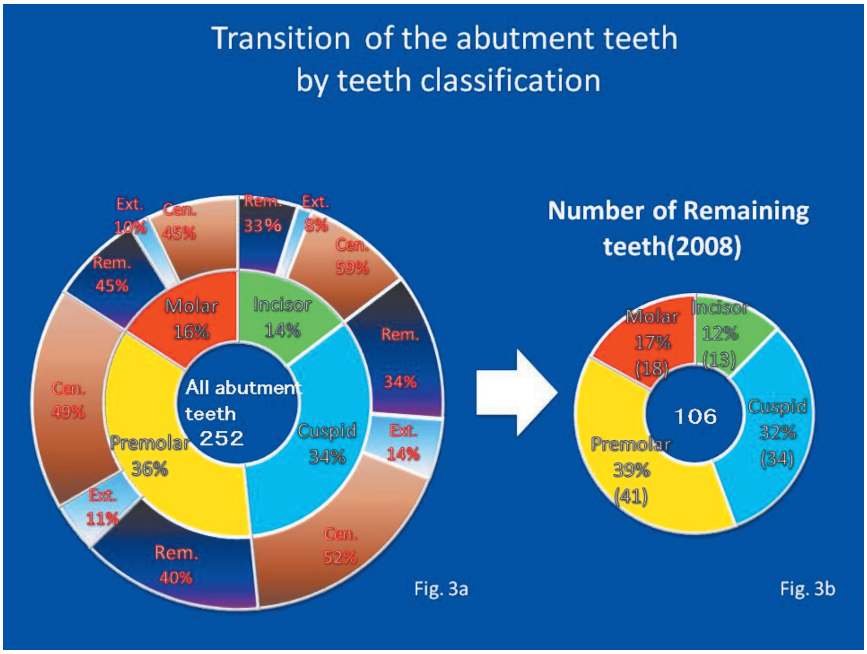

Fig.3 shows the transition of abutment teeth by tooth classification, and classified the teeth as incisors, cuspids, premolars or molars. The inside of Fig.3a are the conditions when the research was started. The outside portion of the graph in Fig.3a was the transition.
Fig.3b was the rate of the remaining teeth by tooth classification. No large changes could be seen from the start of the study. 3 incisor teeth, 11 cuspid teeth, 11 premolar teeth, and 4 molar teeth were extracted.

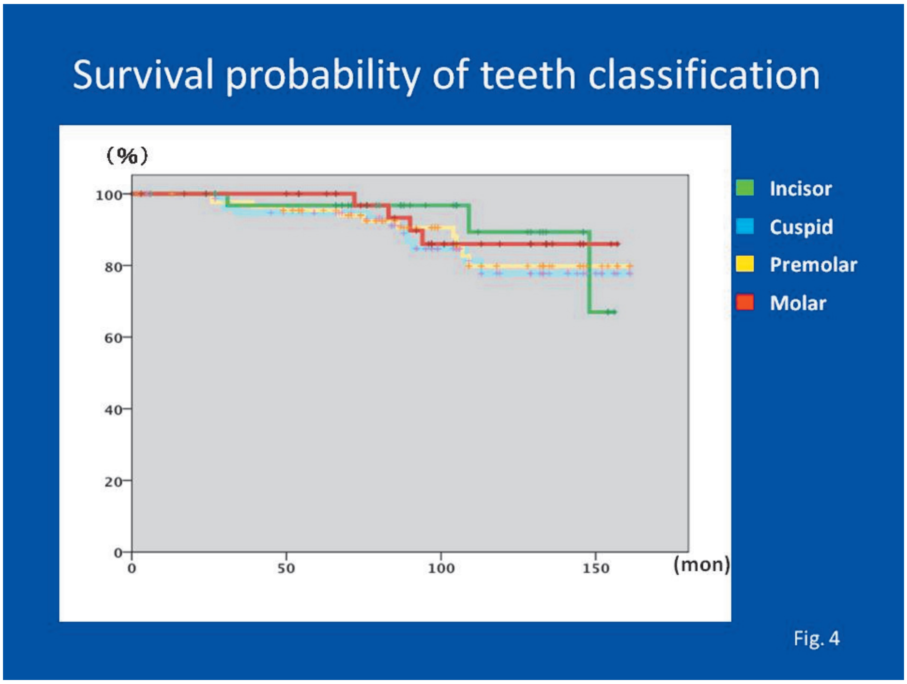

Fig.4 shows the survival probability of the tooth classification. The survival rate of incisor teeth was 67%, cuspid teeth was 78%, premolar teeth was 80% and molar teeth was 86%. But no significant differences were found (log-rank test : spss statistics 17.0).

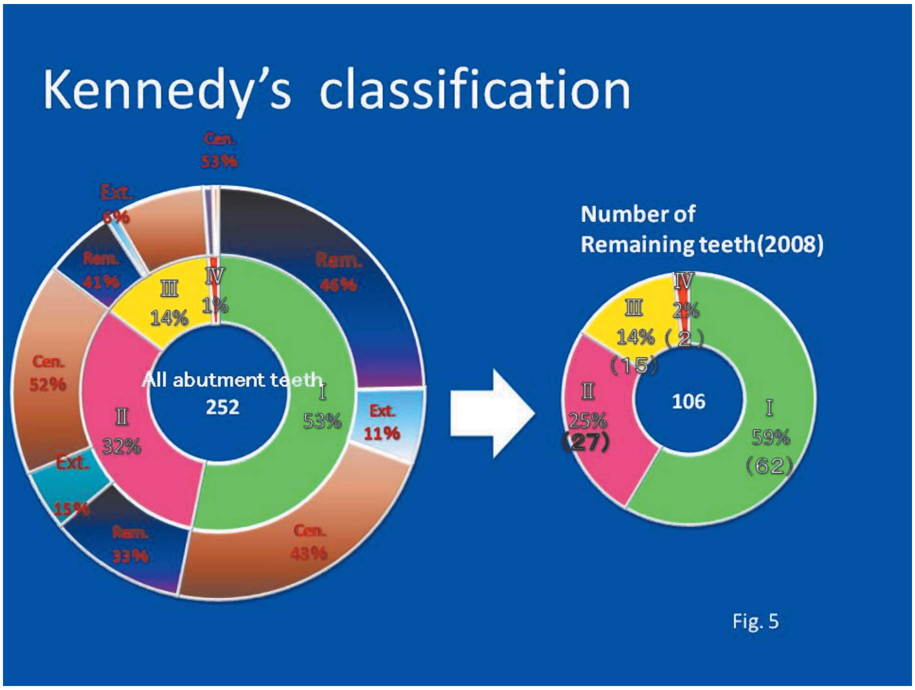

Fig.5 shows transition of the condition using Kennedy's classification. No large changes were found from the start of the study. The number of extracted teeth of Class Ⅰ were 15, Class Ⅱ were 12, Class Ⅲ were 2 and Class Ⅳ were 0.

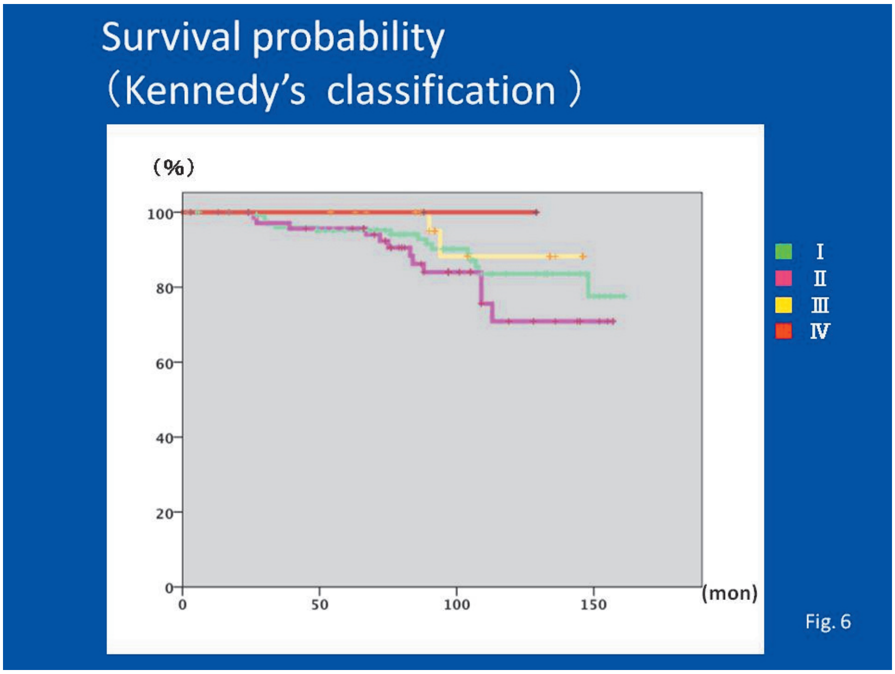

Fig.6 shows the survival probability of the Kennedy's classification. The survival rate of Class Ⅰ was 78%, Class Ⅱ was 71%, Class Ⅲ was 88% and Class Ⅳ was 100%. But no significant differences were found.

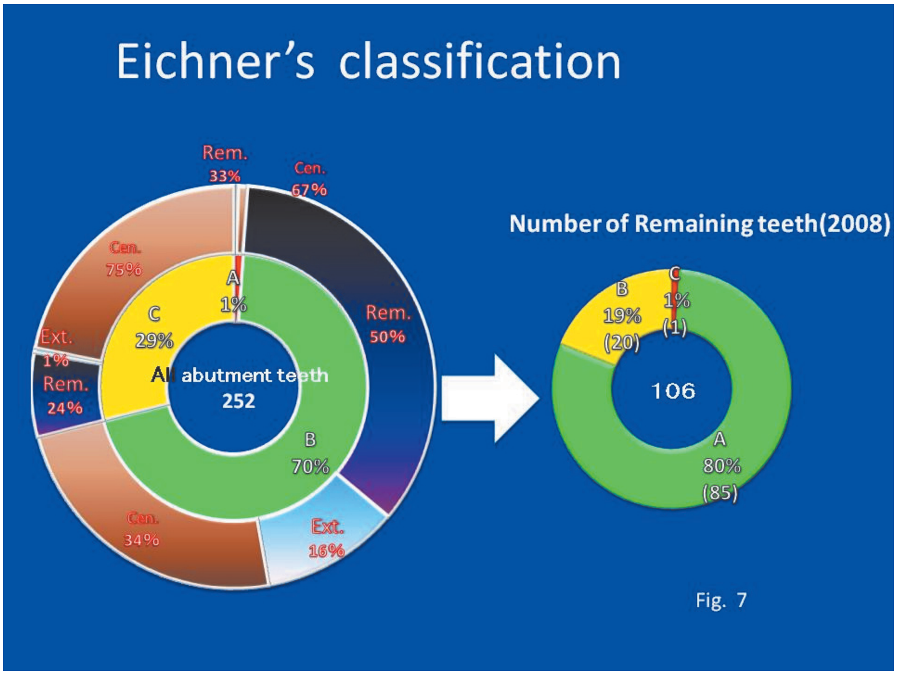

Fig.7 shows the transition of the condition by Eichner's classification. The rate of remaining teeth of class B were looked to have increased for 15 years, because of a large number of Class C that were unsored. The number of extracted teeth of Class A were 0, Class B were 28, and Class C were 1. Extraction was concentrated in Class B which lost one part of the four occlusal supports.

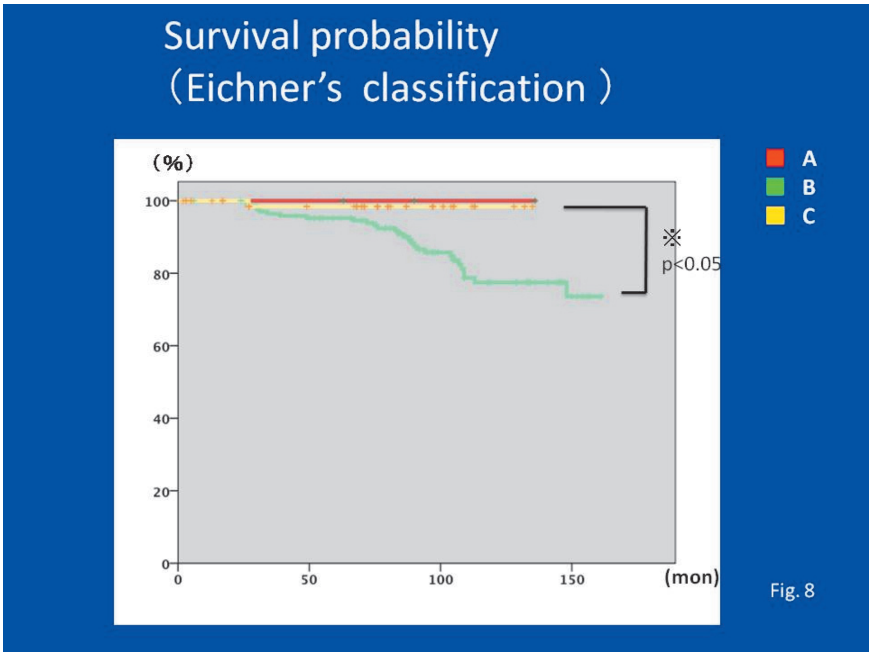

Fig.8 shows the survival probability of the Eichner's classification. The survival rate of Class A was 100%, Class B was 74%, and Class C was 98%. A significant difference was found between Classes B and C.

We also researched magnetic attachments which were applied to acrylic resin plates and compared these with those attached to metal plates. Magnetic attachments were applied to 1133 teeth and 111 of these teeth were chosen for this study.

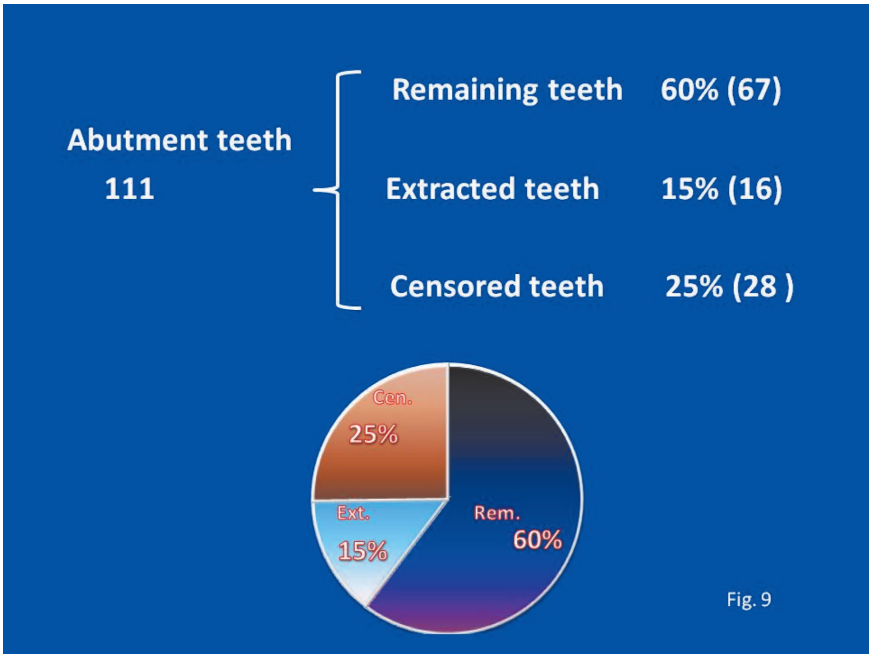

Fig.9 shows the transition of the conditions of abutment teeth of resin plates.
The numbers of extracted teeth were 16, remaining teeth were 67, and censored teeth were 28.

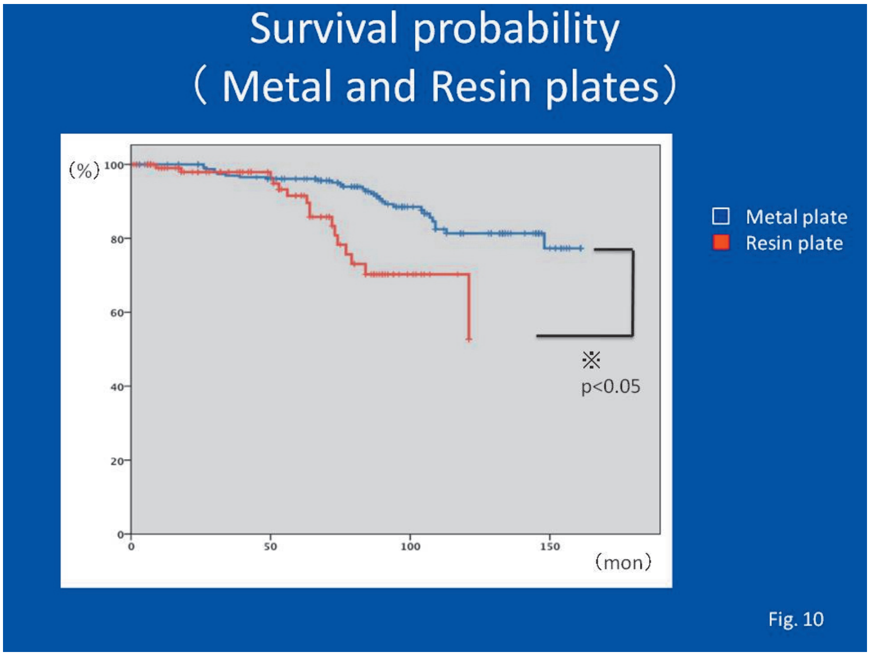

Fig.10 shows a comparison of the survival rates between metal plates and resin plates.
After 7 years, the cumulative survival rate of resin plates was about 70% and after 10 year it fell to 53%. A significant difference between resin plates and metal plates was found.

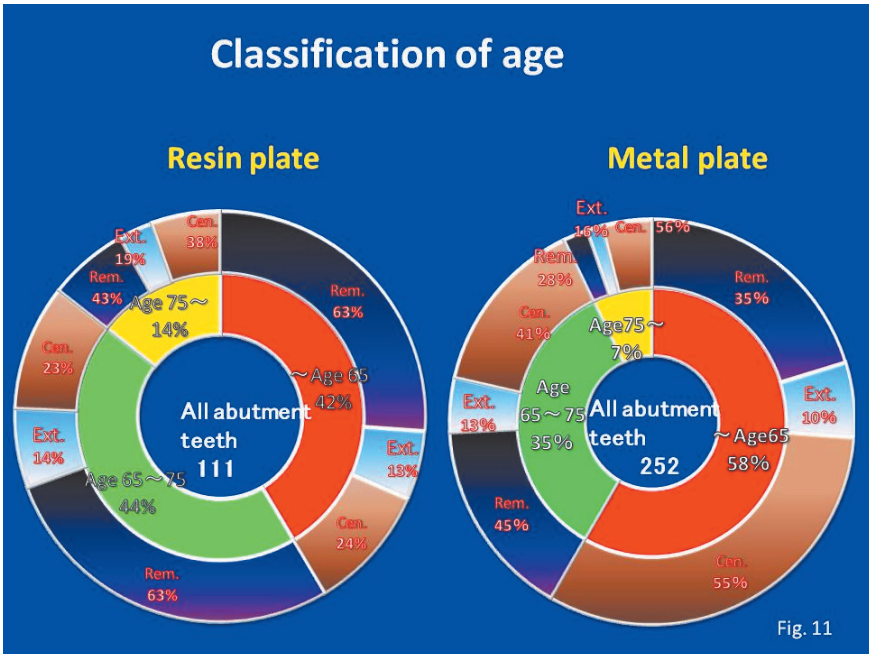

Fig.11 shows a comparison by age groups when attachments were applied. We divided the case to 3 groups, the group of ~65, the group of 65~75 and the group of 75~. The rate of abutment teeth of the group of ~75 for metal plates was higher than that for resin plates.
The rate of censored teeth was high in the group of ~75 for metal plates. On the other hand, it was low in the group of ~75 for the resin plate.

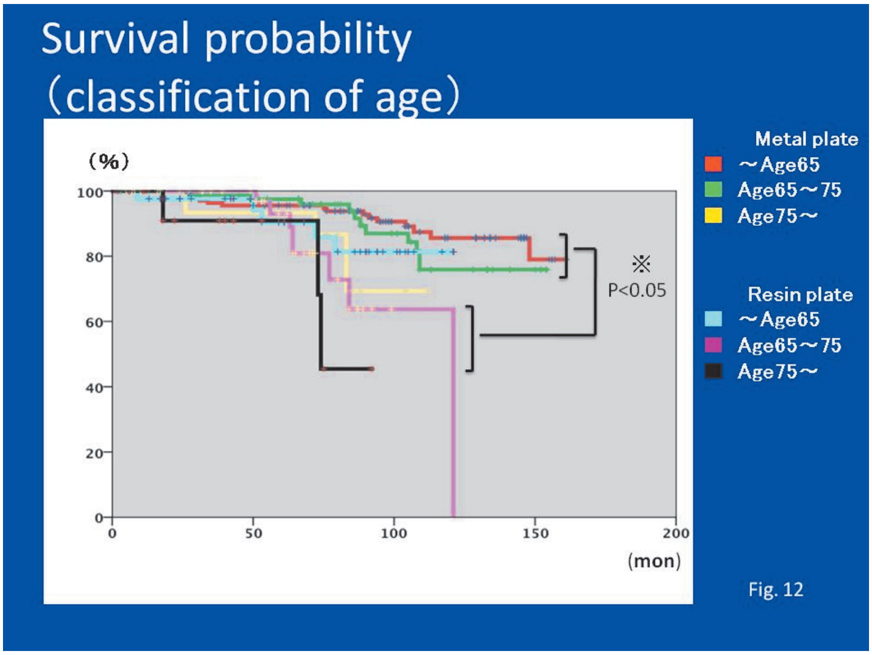

Fig. 12

Fig.12 shows the survival probability of the age classification. The survival rate of metal plates was 79% for the group of ~65, 76% for the group of 65~74, and 69% for the group of 75~. The survival rate of resin plates was 81% for the group of ~65, 64% for the group of 65~74 , and 46% for the group of 75~. Significant differences were found between the 2 groups of metal plates for the groups under 75 and the 2 groups of resin plates for the groups over 65. This shows the survival rate is high for the group of ~75 of metal plates.

1. The survival rate of abutment teeth of metal plates was 77% after 15 years and of resin plates was 53% after 10 years.

2. There were many extractions of abutment teeth in Class 1 and 2 of Kennedy classification. On the other hand, there were few extractions in Class A and C of Eichner's classification where no occlusal support or all occlusal support existed.

3. No significant difference could be found between different plate materials of plate by age classifications. However, there were difference of the survival rate between the group of age over 65 of resin plates and the groups of age under 75 of metal plates. This shows the survival rate of metal plates for ages under 75 is high.

Discussion

A significant difference in the survival rate between metal plates and resin plates was found. One of the reasons is design of denture. Metal plates allow for great latitude in design and enable the design of an ideal partial denture. Another major reason for the survival rate of metal plates is that the major connectors are solid.
The major connectors of resin plates can be strained by the occlusal force as abutment teeth are moved badly.
A significant difference was found between Class B and C of Eichner's classification.
Even within class B, the survival rate of abutment teeth that have few occlusal supports is high . If the plate has many occlusal supports, strong occlusal force is added to the part with no occlusal support. As bearing of the abutment teeth increases it may cause periodontisis.
A significant difference could be found between the group of age under 75 with metal plates and the group of age over 75 with resin plates. This is the same reason of comparison of denture material. However, there are few cases in the group of age over 75,and it's essential to look at further cases in future.

3. Evaluation of Swallowing Movement by Posture Change Using a Magneto-Impedance Sensor

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Introduction

The objective of this study is to develop a device using a magneto-impedance sensor to screen dysphagia. Video Fluorography (VF) is effective for the diagnosis of swallowing difficulties. However, this diagnosis method is not effective for every patient because of the hazard associated with radiation exposure, the expense, and the time required for the diagnosis[1)]. Generally, more simple method, such as the Repetitive Saliva Swallowing Test (RSST), is used for screening of dysphagia.

In this study, we developed a screening device to automate the RSST using a Magneto-Impedance sensor (MI sensor). And we tried to determine whether it was possible to measure any movement associated with swallowing by using a screening device. In addition, we evaluated any influence of posture change on swallowing. The measurement results varied according to changes in the subject's posture. We examined the posture that was appropriate for swallowing by analyzing the measurement results.

However, it is difficult to obtain sufficiently accurate results with the screening device because the body moves when swallowing occurs. In the course of this experiment, we conducted measurements using a three-dimensional MI sensor to overcome this problem.

Materials and Methods

The Repetitive Saliva Swallowing Test (RSST) is a safe and simple method to screen difficulties associated with swallowing. It is performed by counting swallowing in 30 seconds. When the count of swallowing is less than 3 times/30 seconds, the subject is identified for further investigation for functional dysphagia by RSST [2)].

We developed a screening device to automate the RSST. The screening device consists of an MI sensor and a magnet, as shown in Figure 1. Figure 2 shows the layout of the screening device on a patient. A magnet was attached to the larynx, and an MI sensor was attached to the breastbone. The movement of the magnet, which was the movement of the larynx according to swallowing, was detected by the MI sensor as a change in the magnetic field. The output signal from the MI sensor shows the movement of the larynx with swallowing.

This time, we measured the swallowing movement by this method in healthy subjects and senior adult subjects. The screening device measured the swallowing movement in healthy subjects (Figure 3). However, it was difficult to obtain sufficient results in older adults (Figure 4) because the MI sensor moved when older adults swallowed. A MI sensor detects geomagnetism in addition to the swallowing movement [3)].

Consequently, we examined the influence of a subjects' posture on swallowing by multiple measurements. We anticipated that body movement during swallowing would be suppressed by the procedures used to measure it. In this time, we measured it by five kinds of posture of standing position, dorsal position, seated position, and cervix part bent position (the angle is 30 and 60 degrees). The subjects were measured in five types of posture: while standing, dorsal position, sitting, and bending his head at an angle of 30 and 60 degrees.

In addition, we developed a screening device using a three-dimensional MI sensor as a countermeasure for geomagnetism caused by bodily movement. Figure 5 shows the layout of the screening device using a three-dimensional MI sensor. This screening device can detect swallowing movements in three directions. However, it is necessary to switch the axial direction using a control program when measuring because only one output pin is mounted on this MI sensor. This time, we performed two kinds of measurements. One changed axis every 5 seconds, and the other, every 1 millisecond.

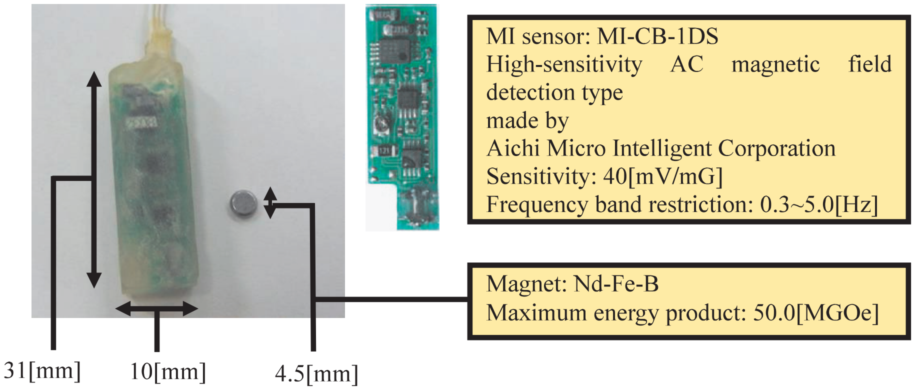


Figure 1: The MI sensor and magnet

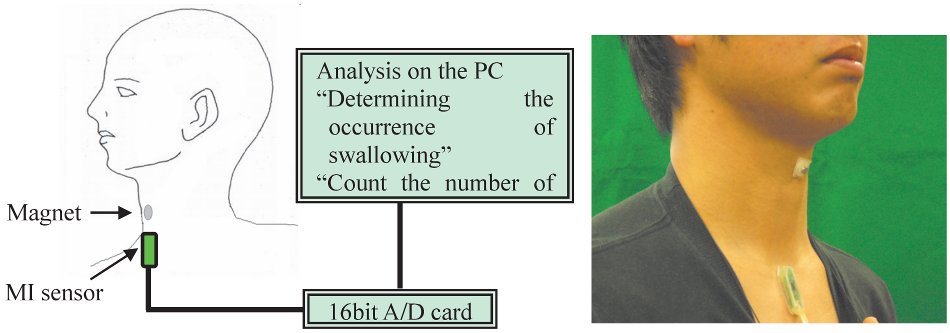
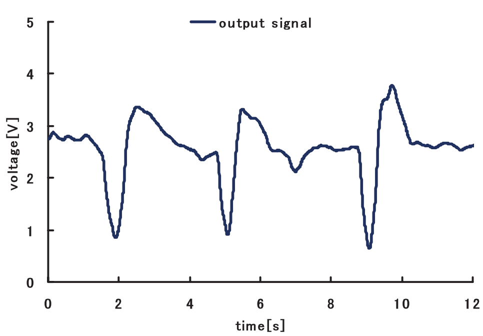


Figure 2: Layout of the screening device



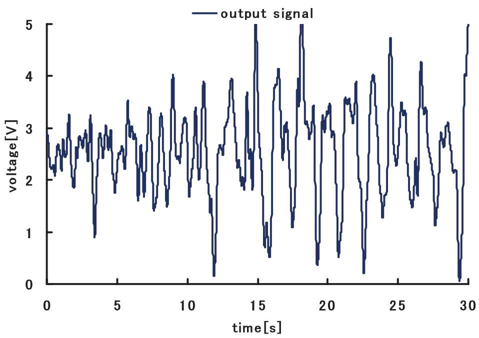


Figure 3: Swallowing three times (healthy subject, male, 22 years old)

Figure 4: Swallowing eight times (senior adult, male, 77 years old)

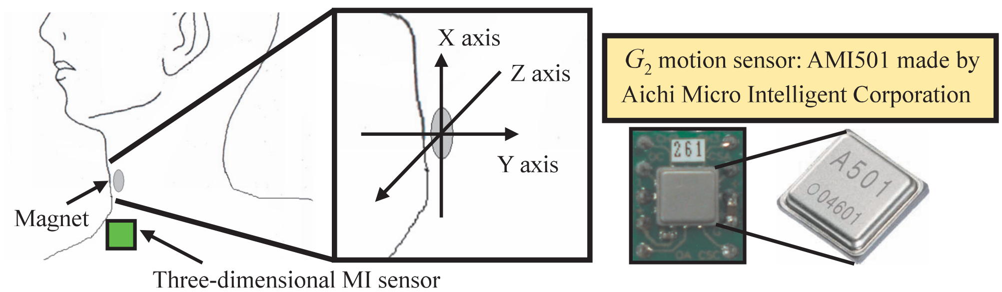


Figure 5: Layout of the screening device (using the three-dimensional MI sensor)

Results

Figures 6 to 9 show the measurement results of a 24-year-old male swallowing in five postures (refer to Figure 3 for the results from a seated position). The MI sensor did not accurately detect the swallowing movement when the subject was standing or when the measurement was obtained from a dorsal position (Figures 6 and 7). On the other hand, the MI sensor accurately detected swallowing movements when the subject was sitting and bending his head (figure 8, figure 9). Comparable results were obtained from measurements of several other healthy subjects.

Figure 10 shows the measurement result of using a three-dimensional MI sensor when the axis changed every 5 seconds (Figure 11). The larynx moved differently in each axis. Figures 12 and 13 show the measurement results when the axis changed every 1 millisecond (Figure 14). The screening device made the geomagnetism by the sensor movement constant by calculating the absolute value of the output (Figure 15).

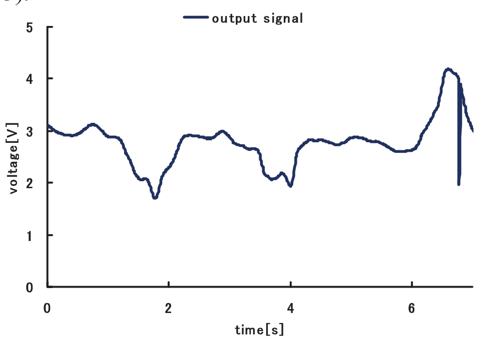


Figure 6: Result from a standing position

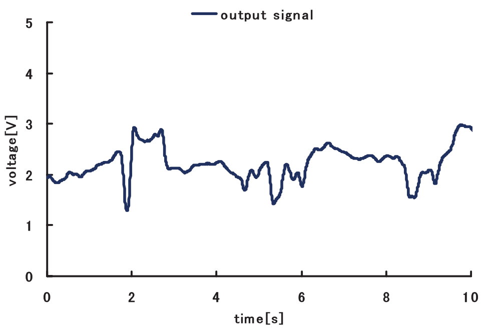


Figure 7: Result from a dorsal position

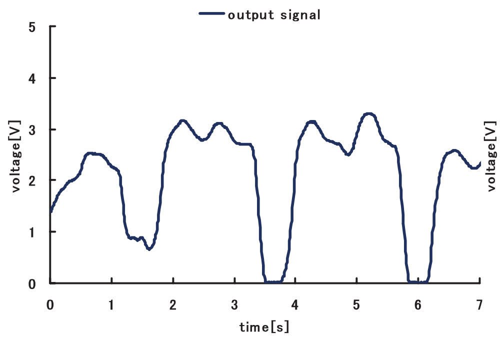


Figure 8: Result from a sitting position (head angle: 30 degrees)

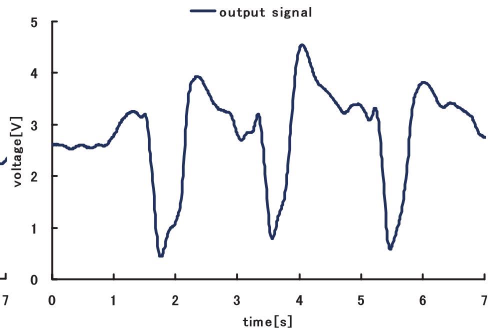
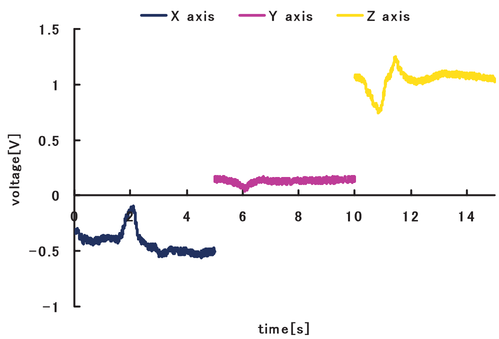


Figure 9: Result from a sitting position (head angle: 60 degrees)



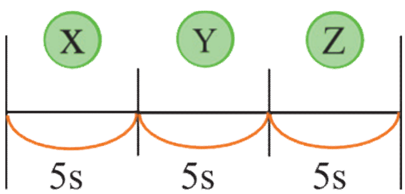


Figure 11: The axis changed every 5 seconds

Figure 10: Result when the axis changed every 5 seconds

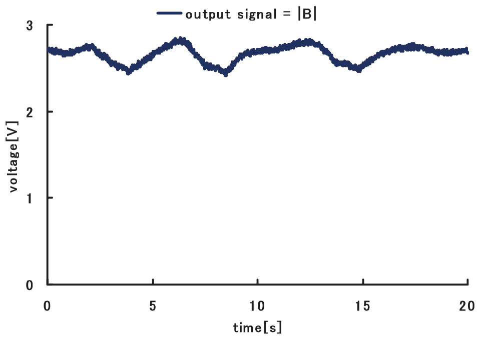


Figure 12: Swallowing three times (when body did not move)

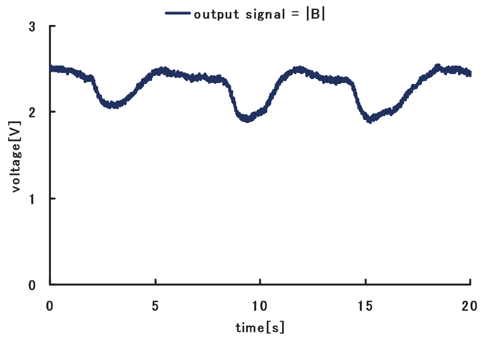


Figure 13: Swallowing three times (when body did not intentionally)

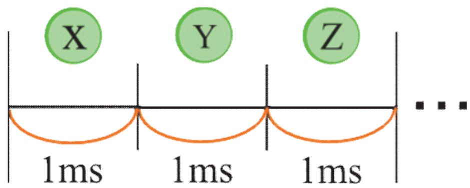


Figure 14: The axis change every 1 millisecond

Value of terrestrial magnetism: B_0

Value of magnet movement: B_m

Value of output of sensor:

$$B = B_0 + B_m = B_X + B_Y + B_Z$$

Final output: $|B| = \sqrt{B_X^2 + B_Y^2 + B_Z^2}$

Figure 15: Calculation of the absolute value

Discussion

The analysis indicated that significant movement was associated with swallowing when the subjects were bending his/her head forward (Figures 8 and 9). One possibility for this result was that the subject's esophagus was expanded by the gravitation. Another possibility was that the subject's trachea was narrowed by gravitation [4)]. For these reasons, the best position for swallowing was determined to be when the subject was bending his/her head.

In addition, the larynx moved significantly in the direction of the z-axis (Figure 10). This occurred because the epiglottis moved dramatically in the direction of the z-axis when the subject swallowed.

The three-dimensional MI sensor did not influence bodily movement when swallowing, as demonstrated in Figures 12 and 13. Reason of this result was that the three-dimensional MI sensor measured components of the magnetic field so fast that the influence of the terrestrial magnetism was suppressed effectively.

Conclusions

For this study, we developed a device that uses a magnet-impedance sensor for screening of dysphagia. We confirmed that the device could measure any movement associated with swallowing. In addition, we examined the influence of a subject's posture on swallowing movements. The results presented in this paper indicate that the most suitable posture for swallowing is when the subject is bending his/her head forward.

However, the screening device did not appear to yield sufficiently accurate results in cases when the patients moved while swallowing. To overcome these obstacles, we measured the movements associated with swallowing with the use of a three-dimensional MI sensor, and the terrestrial magnetism that occurred by moving the sensor was made constant.

In the future, a high-precision analysis method that can be used to measure senior adults will be required.

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4. Influence of the heating on the attractive force of a magnetic attachment -Part 2. Study of Denture Based Resin Curing-

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Introduction

A magnetic attachment has achieved excellent clinical results, and has been recognized as a useful tool with numerous advantages compared with a conventional mechanical retainers[1-3].

A Neodymium (Nd) magnet, recently available on the market, has a reported characteristic the temperature-related of magnetic force loss at low relative temperatures. This is considered as one disadvantage of a Nd magnet use.

The clinical use conditions including the effect of temperature relationship and laboratory processing should be evaluated.

Objective

We investigated the influence of the difference in curing methods and thickness of denture-base resin on the attractive force of a magnetic attachment on the assumption that magnetic assemblies were incorporated into the work model during polymerization temperatures.

Materials and Methods

1) Materials

Specified magnetic assemblies and keepers were used as samples in this study (GIGAUSS D 600 (GC) and PHYSIO MAGNET 35 (Hitachi Metals)). Five samples for each product were evaluated(Fig. 1).

Fig. 1: Magnetic attachments

2) Methods

The influence of two different resin curing protocols were tested on magnetic attachment attractive force: 1. microwave curing method and 2.wet heat curing method.

Resin curing protocol with magnetic attachments followed the following techniques. Microwave technique resins were cured in a specified microwave oven at 500 watts for 3 minutes. Wet heat resin curing protocol were cured at 70°C for 60 minutes, and then 100°C for 30 minutes, followed by cooling at room temperature for 24 hours. Following use of either curing method, tested magnetic assemblies were removed from resin samples, and attractive force was measured. Attractive forces before and after polymerization for each curing method were compared to investigate the influence of polymerization on the attractive force. We also investigated the change in the attractive force for 3 different resin thicknesses.

3) Sample preparation

Molded paraffin wax was invested in a flask using ADVASTONE (GC) based on the conventional method, followed by wax elimination. A magnetic assembly was adhesively stablized with alpha-cyanoacrylate adhesive (Aron Alpha) into the space created by wax elimination. Acron MC Live Pink no. 8 was packed into a flask in the rapid heat cure method, and Acron Live Pink no. 8 was packed in the wet heat cure method. A magnetic assembly was removed from the resin plate after polymerization, and used as a sample (Fig. 2). Resin plate samples were 35 x 60 mm in width, and 5, 10, and 15 mm in thickness (Fig. 3).

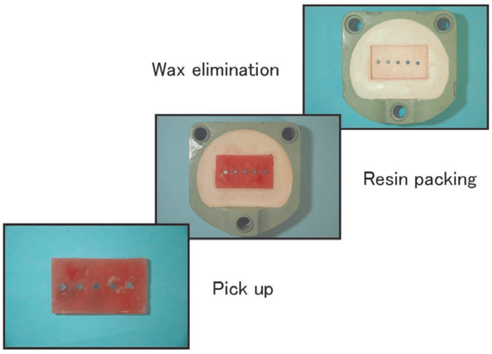

Fig. 2: Process of sample fabrication

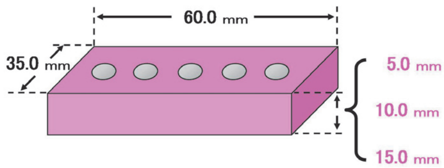

Fig. 3: Resin plate size

4) Attractive force measurement

Attractive force measurement was conducted using EZ test, compact tabletop material tester, with a 5 kgf load cell and 5 mm/min crosshead speed. Attractive force was measured 10 times for each magnetic assembly, and the average was taken as a result. Attractive forces before and after each experiment were compared. The custom made jig devised in our department was used to accurately measure the attractive force (Fig. 4).

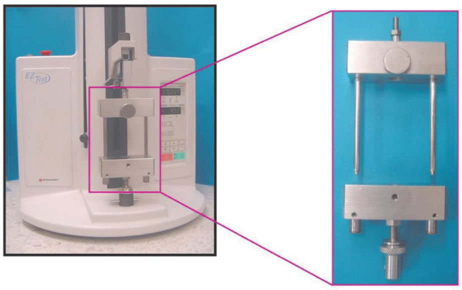

Fig. 4: Measuring device and custom made jig

Results

In the rapid heat cure method, magnetic attraction forces decreased with both in GIGAUSS D 600 and PHYSIO MAGNET 35 after completion of polymerization procedures. The evaluation of resin thickness on the attraction forces demonstrated a decrease in measured attraction force with the resin plate thickness of 10 mm compared to a 5mm sample. No significant difference was found for the 10 and 15 mm samples (Fig. 5).

The wet heat curing method showed similar results as the rapid heat curing method regarding the influence of curing methods and resin thickness (Fig. 6).

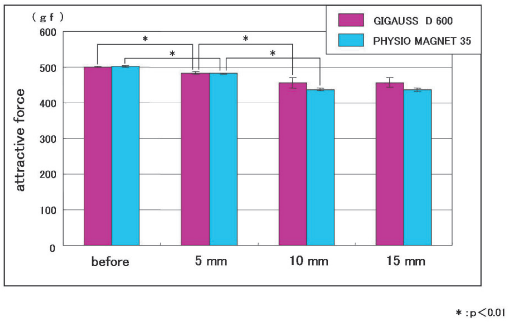

Fig. 5: Rapid heat curing

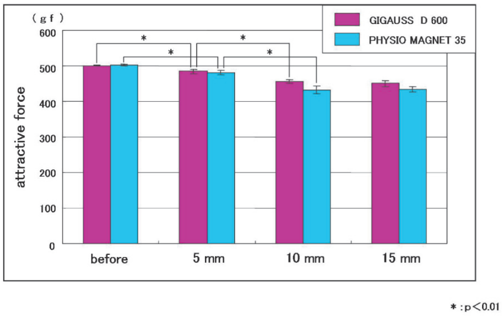

Fig. 6: Wet heat curing

Discussion

The present study was performed on the basis that magnetic assemblies are incorporated into working models during higher polymerization temperatures. Magnetic assemblies were directly bonded with a heat-curing resin. Since this method does not require autopolymerized quick cure resin, it offers advantages such as improved mucosal surface denture esthetics, and improved adhesive attachment between a magnetic assembly and resin. Dentures made using this procedure offer several advantages and improved physical properties with greater material stability.

The influence of polymerization on the resulting magnetic attachment attractive force properties is significant. Attraction forces decreased both with the rapid heat curing method and wet heat curing method after polymerization. This finding suggests a significant heat-related material changes after polymerization.

The magnetic attachment attraction forces are also affected by enclosing denture resin base thickness. Further investigation in the relationships of heating on the magnetic assembly units is recommended. The mechanisms of heat generation and polymerization on the attractive force are not clearly understood. It is also unclear as to the influence of electromagnetic microwave generation on magnetic assemblies and metal components.

Conclusion

The influence of two different denture resin curing protocols of the denture base resin, and the effect of resin thickness on the attraction force was evaluated.

1. Both the microwave and wet heat curing methods showed a decrease in the attraction force after polymerization.
2. The attractive force decreased by 4% in a resin plate 5 mm in thickness, and by 10% in a resin plate 10 mm in thickness. No difference was found between resins 10 and 15 mm in thickness.
3. No significant difference in the attractive force of a magnetic assembly was found between rapid and wet heat resin curing techniques.

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5. Effects of Dental Alloys and a Magnetic Keeper on MRI. Part 2 Relationship between Cast Crowns and Artifacts of Axial Plane Images

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Introduction

Various metal alloys have been applied to dental treatment, for example, orthodontic wires, claps, inlays, crowns, denture frames, and implants, depending of their properties. In addition, magnetic attachments (MA) are developed and used as the retainers of conventional or implant-supported overdentures. Since the 1990s, MA have become popular in Japan even though they are less well known in Europe and the U.S.A. Nevertheless, with the magnetic field of Magnetic Resonance Images loss of signal occurred in the head and neck region by the used of dental alloys. To compare the signal intensity generated, crowns of different dental alloys and a pre-fabricated magnetic keeper were used, and the distribution of their signal intensity was compared from the same distance.

Objective

MRI artifacts generated by dental alloys have caused some problems due to their magnetic characteristics depending on whether they were diamagnetic, ferromagnetic, or paramagnetic substances. The aim of this study was to examine the artifact area around the specimens by analyzing MRI dicom data and comparing the Coefficient variance (CV) values of the signal intensity among dental alloys.

Materials and Methods

1. Samples

Four clinical dental alloys and one pre-fabricated magnetic keeper were selected (Table 1). The former were cast into a similar lower first molar using the same shell crown (Mesiodistal width: 8 mm; buccolingual diameter: 7.5 mm). An identically shaped acrylic resin crown was used as a control. Five samples for each material (a total of 20 crown shapes and 5 magnetic keepers) were investigated (Fig. 1).

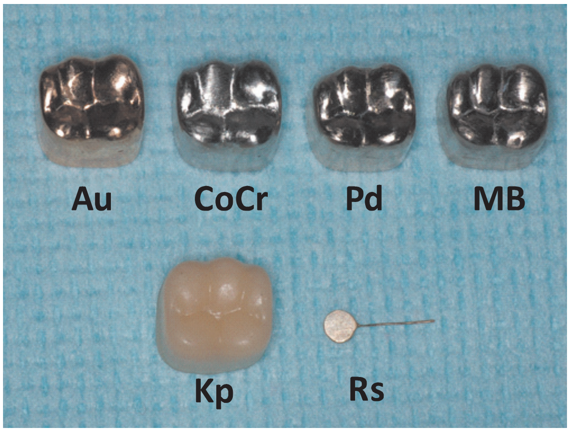

Fig. 1 Samples

Dental casting	Abbreviation	Composition (%)	Manufacturer
Magnetic Keeper	Kp	Fe 58.8, Cr 19, Mo 2	Hitachi, Japan
Sankin Ortop Type 3	Au	Au 75, Pt 4, Ag 6, Cu 12, Others 3	Hitachi, Japan
Cobalt Chromium	CoCr	Co 64, Cr 30, Mo 6, MN, Si, C, N	Pentron, USA
Gold-Silver-Palladium	Pd	Au 12, Ag 46, Pd 20, Cu 20	GC, Japan
Gold Porcelain Alloy	MB	Au 65, Pd 25, In<9, Ir, Ga, Ag	Pentron, USA
Resin Control	Rs	Resin Acrylic	GC, Japan

Table 1

2. Phantom and Agar

A cubic phantom (Fig. 2) was used. To fix the sample in the phantom, a reversible hydrocolloid, agar, was used. The agar was first melted using the Colloid Bath ST-600 (Sankin Corp., Tokyo, Japan) at 80 degrees C for 120 minutes. The agar was then poured until the half of the cubic phantom, about 70 mm from the base. After the agar gelled, the sample was placed in the middle of the phantom. Finally, a second layer of agar was then poured to entirely fill the phantom (Fig. 2).

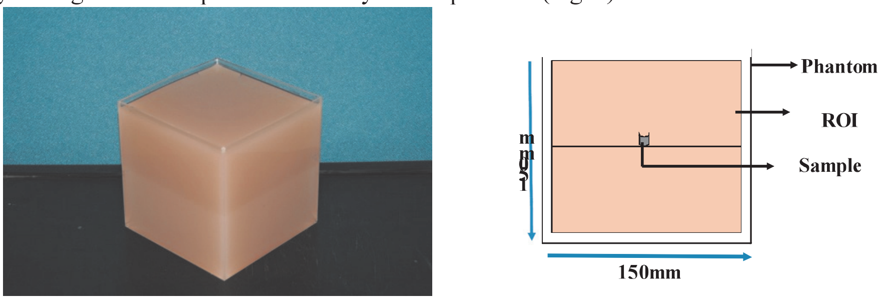

Fig. 2 Cubic Phantom (150mm × 150mm × 150mm)

3. MR Imaging

The phantom was placed in a head-and-neck coil on the table of a 1.5-Tesla MRI apparatus (Fig. 3) (Magnetom Vision, Siemens, Germany). To investigate a sequence of artifact images in the axial, coronal, and sagittal planes, a T1-weighted spin-echo sequence (550 msec/14 msec, repetition time TR /echo time TE) and a T2-weighted turbo spin-echo sequence (3400 msec/90 msec TR/TE) were used with an acquisition time (TA) of 03:33. All images were taken with the following parameters: Number of acquisitions (AC), 3; Number of Slices, 19; Thickness, 5 mm; Pixel size, 0.9 mm x 0.9 mm; Matrix size, 256 x 256. FOV, 230/mm; Scan time, 6 min 10 sec.

Fig. 3 MRI apparatus table and Axial, Coronal, Sagittal planes

4. Data and Statistical Analysis

The Digital Imaging and Communications in Medicine (DICOM) data from MR images of each sample were analyzed with Image J software (Bethesda, Maryland, U.S.A.), and a region of interest (ROI) was drawn around square images for data acquisition. The mean and standard deviation (SD) of the signal intensity (SI) were obtained from the pixels within ROI images, and the mean coefficient of variation (CV) for each sample was calculated and evaluated with one-way ANOVA and Dunnett's test. $P<0.05$ was considered significant.

Results

1. Artifacts in MR Images

Artifacts from the center (0 mm) are shown in axial T1-WI images. With Au, MB, and Pd, artifacts appeared as a black gap. With Kp and CoCr, a white area was observed. In the Rs image, the crown's shape can be clearly seen (Fig. 4).

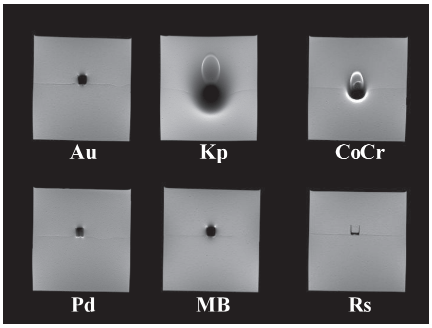

Fig. 4 Axial T1-WI MRI images from the center of the sample. Artifacts in the ROI.

2. SI and Pixel Numbers

Judging from the histograms, the SI for Kp and CoCr is widely distributed. The histograms for Au, MB, and Pd showed a narrow SI distribution (Fig. 5).

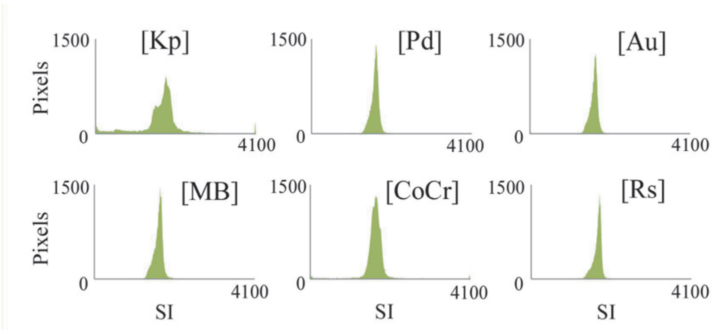

Fig. 5 Histogram from axial T1 - WI

3. Coefficient of Variance

As for CoCr, in coronal plane, the CV of SI was significantly different up to 40 mm but had a gap of non-signal from 15 to 30 mm.

As for Kp, the CV was significantly different in axial plane T1-WI up to 70 mm until the edge of the ROI.

As for MB, in coronal plane, a significant difference in SI was seen up to 5 mm.

As for Pd and Au, compared to Rs at 0 mm, Au and Pd did not show any significant difference in any of the coordinate planes (Table 2).

Table 2 Comparison of Rs to dental alloys

Discussions

Dental alloys are more often used in dentistry prosthodontics than resin due to their properties, including higher life expectancy and maintenance of good condition.

[CoCr]	Axial		Coronal		Sagittal	
	T1-WI	T2-WI	T1-WI	T2-WI	T1-WI	T2-WI
0 (mm)	*	*	*	*	*	*
5	*		*	*	*	*
10	*		*	*	*	*
15	*					*
20	*	*				
25	*					
30						
35			*			
40			*			
45						

[Kp]	Axial		Coronal		Sagittal	
	T1-WI	T2-WI	T1-WI	T2-WI	T1-WI	T2-WI
0 (mm)	*	*	*	*	*	*
5	*	*	*	*	*	*
10	*	*	*	*	*	*
15	*	*	*	*	*	*
20	*	*	*	*	*	*
25	*	*	*	*		*
30	*	*		*		*
35	*	*		*		*
40	*	*	*	*		
45		*		*	*	*
50				*	*	*
55	*			*	*	*
60	*			*	*	*
65	*					
70	*					

* $p<0.05$

[MB]	Axial		Coronal		Sagittal	
	T1-WI	T2-WI	T1-WI	T2-WI	T1-WI	T2-WI
0 (mm)			*	*	*	
5			*			
10						
15						
20						

[Au] [Pd]	Axial		Coronal		Sagittal	
	T1-WI	T2-WI	T1-WI	T2-WI	T1-WI	T2-WI
0 (mm)						
5						
10						
15						
20						

Au, MB, CoCr, and Pd are widely used for fixed prostheses in dental clinics. In addition, magnetic attachments have been proved to be a concrete solution to eliminate the lateral force to the abutment, and the manipulation of the denture is easy even by handicapped patients.

Nevertheless, to avoid artifact areas, the dental keeper can also be removed from the oral cavity. As it is situated in the mouth, it is not a disturbance in other parts of the body that may need to be exposed to MRI.

Conclusions

Compared to Kp and CoCr, the artifacts generated by Au, MB, and Pd alloys were fewer than those generated by a keeper from 0 to 20 mm.

Mean SI per pixel for Kp in axial images was significant in all samples.

CoCr showed a significant difference in all the specimens in T1 WI from 0 mm to 25 mm. In T2 WI, no significant difference was registered for CoCr with Au, Pd, and MB except with Rs at 0 mm T2 WI.

The coefficient of variation of the signal intensity might be a practical way to calculate the artifacts generated by metallic abutments.

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6. Evaluation of Leakage Flux out of Foreign Dental Magnetic Attachments

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Introduction

The tissues in the mouth may be exposed to the magnetic flux leaking out of magnetic attachments for a long time. Therefore, it is important to discuss their biological effects.

Objective

The objective of this study is to evaluate the effects on the human body of the leakage flux out of foreign dental magnetic attachments.

Materials and Methods

Table 1 shows the seven types of foreign dental magnetic attachments analyzed. Dyna Magnet, Titanmagnetics, Microplant, and Multipurpose Magnet systems are open magnetic circuit types of magnetic attachments. On the other hand, the Maxi Magnet, Magnedisc 800, and Smart Kit are closed magnetic circuit types of magnetic attachments. Many of them are used for implant overdentures.

Table 1 Product names, manufacturers, and magnetic circuits of each attachment.

	Product	Manufacturer	Magnetic circuit
1	Dyna WR Magnet	Dyna Dental Engineering	Open type
2	Titanmagnetics	Steco system technic	Open type
3	Microplant	Gebr.Brasseler	Open type
4	Multi Purpose Magnet System	Technovent	Open type
5	Maxi Magnet	Technovent	Sandwich type
6	Magnedisc 800	Attachment International	Cup type
7	Smart Magnet Sytem	Preat Corporation	Sandwich type

Figure 1 shows the analysis models of foreign magnetic attachments. These models were made with reference to internal structures that were reported in the 17^{th} Conference on Magnetic Application in Dentistry.[1)]

Titanmagnetics, Microplant, and Multipurpose Magnet systems, which are open types of magnetic attachments, have a magnet in the keeper and are attracted to each other by both magnetic forces. Magnedisc 800 has a magnetic circuit of a cup type. Maxi Magnet and Smart Kit are sandwich types of magnetic attachments. However, in Fig. 1, (5) and (7) show the ways in which the magnetic circuits differ from the Japanese sandwich type.

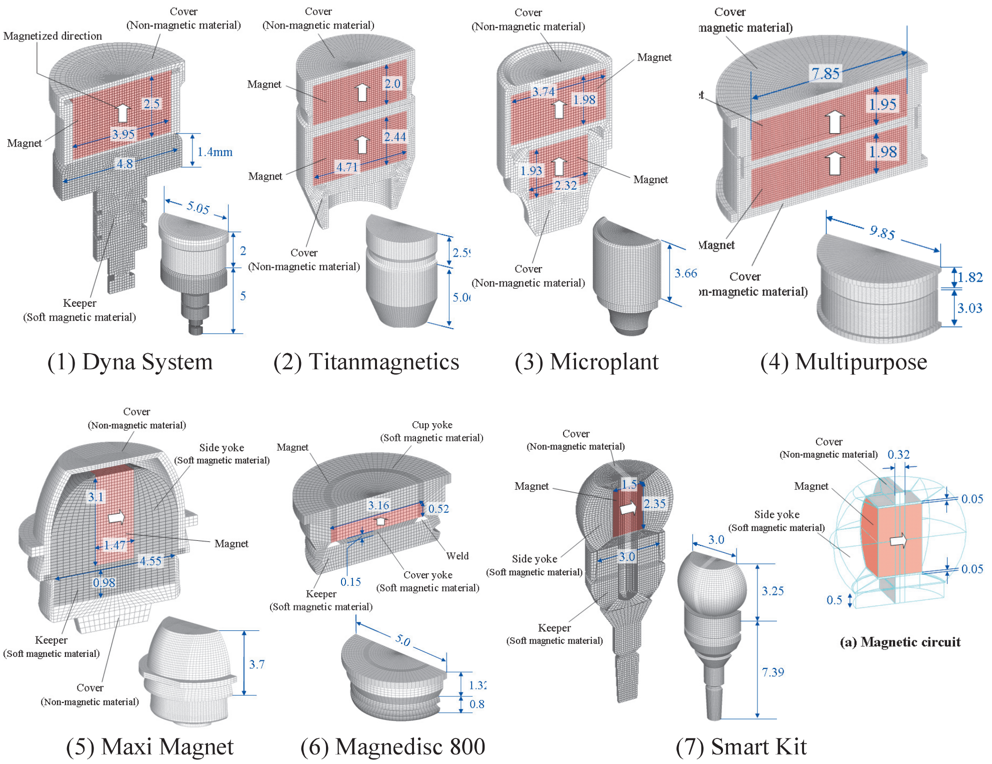


Fig. 1 Structures of each magnetic attachment.

The construction materials for the keeper and yoke were a rare-earth magnet and a soft magnetic stainless steel with high corrosion resistance. The properties of each material and software used in the analysis are given below.

- Magnet: Rare-earth magnet (Nd-Fe-B), Magnetization J = 1.3 T
- Soft magnetic material: Stainless steel, B_s =1.6 T, μ_r=5000
- Software: Modeling (FEMAP, NST, Co., LTD., Japan),
  Finite Element Method (μ-MF, μ-TEC Co., Ltd., Japan)

The leakage magnetic flux is evaluated by comparison of the FEM analysis and guidelines proposed by ICNIRP and WHO. According to the guidelines, the static magnetic field strength of general public exposure is up to 40mT.[2)]

Results and Discussion

1. Magnetic attraction

A magnetic attachment may have a small gap between the magnetic assembly and the keeper in long-term use. Figure 2 shows the magnetic attraction with the gap varied from 0mm to 0.2mm.

In case of the 0mm gap, Magnedisc 800 has the largest magnetic attraction. However, it decreases rapidly when the gap length becomes large. The Multipurpose Magnet system shows attractive force above 830[gf]. The other open magnetic circuit types have small magnetic attraction at the 0mm gap. However, Titanmagnetics, Microplant, and the Multipurpose Magnet system retain more than 90% of the attractive force of the maximum value when the gap length is 0.1mm. The magnetic attractions of Maxi Magnet and Smart Kit decrease to 80% and 10% of the maximum value at the 0.1mm gap, respectively.

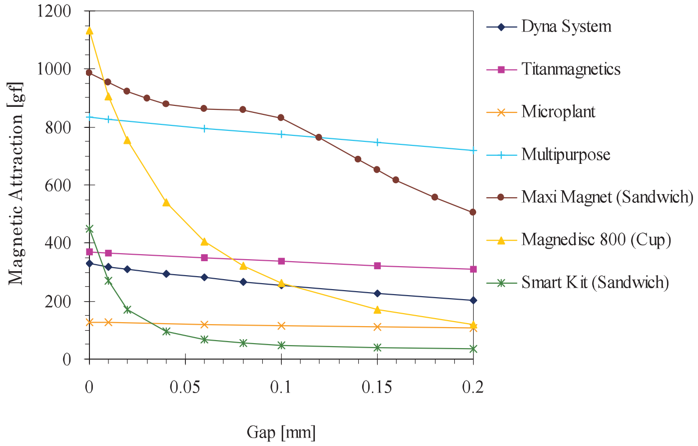


Fig. 2 Air gap and magnetic attraction.

2. Leakage magnetic flux density

Figure 3 shows the leakage magnetic flux of foreign magnetic attachments at the 0mm gap and the length to the WHO's guideline value from the surface of the magnetic attachment. This figure shows that the leakage magnetic flux of the open magnetic attachment is leaking out of the magnetic attachment.

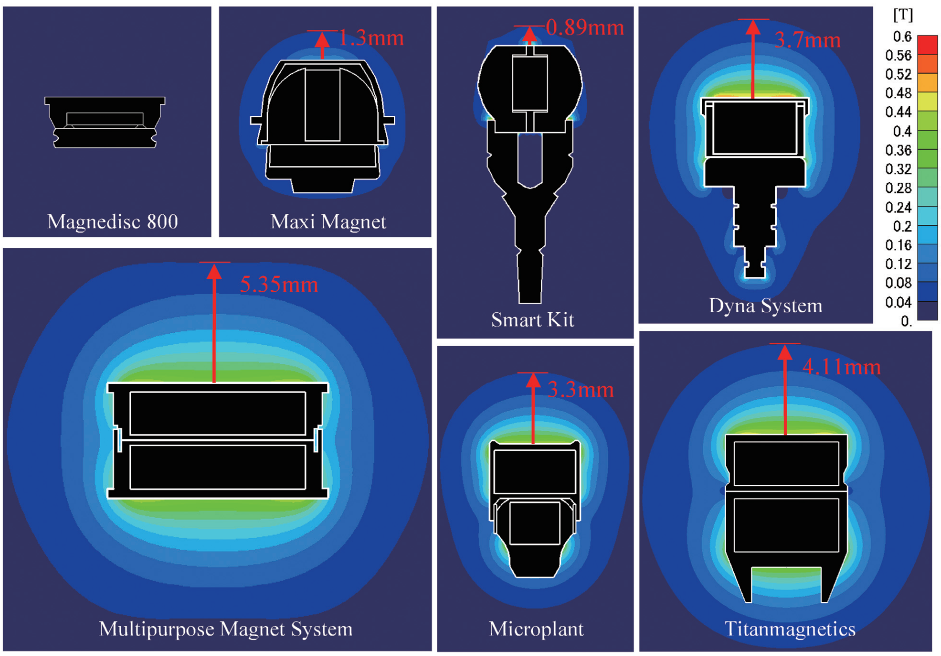
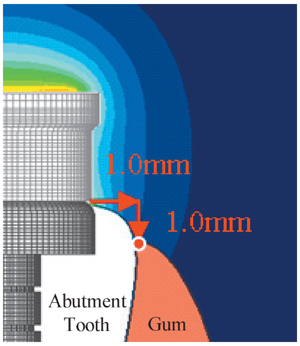


Fig. 3 Leakage magnetic flux density distributions of each magnetic attachment.

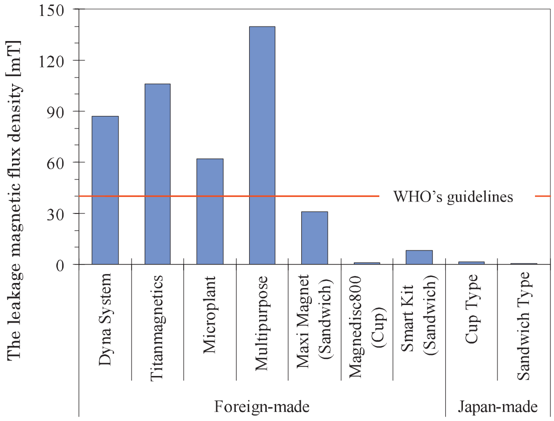
3. Leakage magnetic flux at the tissue in the mouth

In Fig. 4 (a), it is assumed that the distance from the magnetic attachment to the tissue of the alveolar ridge is 1.0mm in the horizontal and vertical directions. Figure 4 (b) shows the leakage magnetic flux density for its position. The leakage magnetic flux of the Japanese magnetic attachments (cup type and sandwich type)[3)] is shown for the comparison.

As a result, the leakage magnetic flux of open magnetic circuit types exceeds the WHO guidelines, i.e., 40mT. It is particularly large in the Multipurpose Magnet system, in which the magnet is in the keeper and the diameter of the magnet is large. Three types of closed magnetic circuit and Japanese magnetic attachments do not exceed the 40mT limit at the tissue in the mouth.



(a) Position of the tissue in the mouth



(b) Leakage magnetic flux of the position

Fig. 4 Leakage magnetic flux density of the tissue around the magnetic attachment.

The leakage magnetic flux against the air gap is shown in Fig. 5. The leakage magnetic flux of all the open types is above 40mT. However, that of the closed types is below 40mT, and the gap length is 0.2mm.

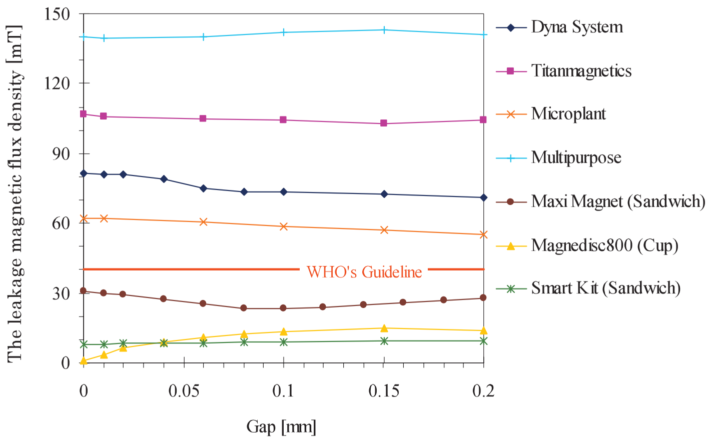


Fig. 5 Air gap and leakage magnetic flux density.

4. Leakage magnetic flux of the keeper

It is necessary to investigate the leakage magnetic flux out of the keeper because the Multipurpose Magnet system, Titanmagnetics, and Microplant have magnets in the keeper.

Figure 6 shows the leakage magnetic flux of the keeper including a magnet. Red points shows the tissue positions as shown in Fig.4 (a) and the length represents the distance from the surface of the keeper where the leakage magnetic flux is same strength to the WHO's. As a result, their leakage magnetic flux is less than the results shown in Fig. 3. However, the leakage magnetic flux at the tissue in the mouth exceeds 40mT. That of the Multipurpose Magnet system is 110mT, that of Titanmagnetics, 105mT, and that of Microplant, 42.3mT.

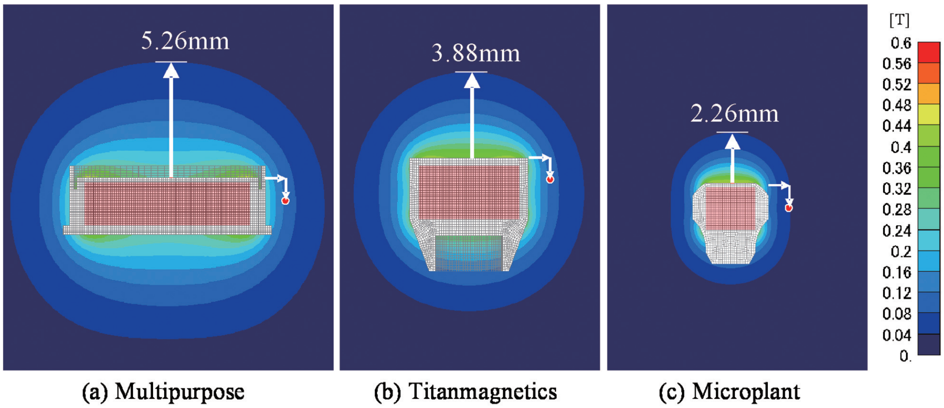


Fig. 6 Leakage magnetic flux density distributions of the keeper.

Conclusions

Under the analytical conditions presented here, the results of this paper indicate that the leakage magnetic flux of all the open types of foreign magnetic attachments exceeds the WHO guidelines. However, the closed types satisfy the WHO guidelines at the position of the tissue in the mouth.

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7. Application of a Split-Type Obturator Retained by Magnetic Attachments

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Introduction

Maxillary-defects following tumor resection are often broad, making it very difficult to correct defects with dento-maxillary prostheses. [1)]This is because it is difficult to attach a prosthesis in the mouth or to place and remove a large obturator. Here, the use of a split obturator and dento-maxillary prosthesis in a patient with a broad maxilla-defect solved the problem with favorable results.

Case

Patient: A 76-year-old male
Chief complaint: Visited the University Dentistry Hospital for the first time in March 2007 complaining of an inability to eat because his denture would not stay in place.
History of present illness: The patient underwent surgery to remove a maxillary sinus cancer in 1988, after which he received radiotherapy. The patient has since been wearing a dento-maxillary prosthesis.
Present illness: The maxilla was edentulous (Aramany class I). No teeth were missing from the mandible (Fig. 1).

Figure 1
Intraoral view at the first visit

Denture preparation

Impressions of the denture and obturator sections were taken separately. For the obturator section, a tubular custom tray was made using resin. A Denture Aid LC (GC, Japan) was then applied in the mouth as widely as possible and cured to complete the tray.[2)]For impression-taking, a silicone impression material (Fusion mono-phase type, GC, Japan) was used. A wash-type impression material was used to take an impression of finer areas (Fig. 2).

After an interocclusal record and trial fitting, a resin was poured into the denture section and obturator (Fig. 3). The impression of the junction between the denture and obturator was taken inside the mouth. First, the obturator section was attached in the mouth. The silicone impression material (Fusion mono-phase type,GC, Japan) was poured, and the patient was instructed to bite gently (Fig. 4). The junction between denture and obturator was set near the denture basal surface, and a circumferential groove was formed (Fig. 5).As retainers, physio-magnets (Nisshin, Japan) were used, with 4.8-mm diameter magnets placed in the anteroposterior regions, 3.0-mm diameter magnets placed in the left-right regions, and keepers placed on the obturator to complete the denture (Figs. 6 and 7).

Figure 2 Precise impression of the obturator section

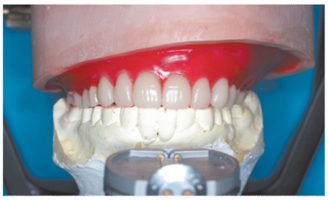

Figure 3 Finished wax denture

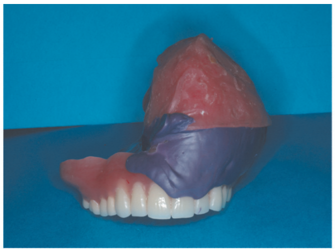

Figure 4 Impression of the junction

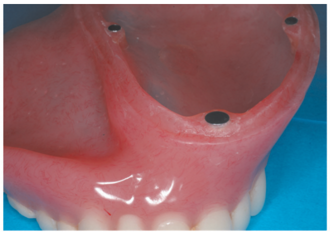

Figure 5 Finished dento-maxillary prosthesis and magnetic attachment

Figure 6
Creation of a circumferential grove at the junction

Figure 7
Finished dento-maxillary prosthesis

Results and Discussion

The retentive force of the dento-maxillary prosthesis was sufficiently high, and the chief complaint of dentures falling out while eating was resolved. Masticatory and speech disorders were also improved, and esthetically favorable results were obtained. The patient is now able to easily put on and take off the dento-maxillary prosthesis independently, and oral hygiene has remained favorable. Functional evaluation of the denture have shown that functions with the new denture are markedly improved relative to those with the old denture.

Functional assessment

After attaching the new denture, various function tests and surveys were conducted, and therapeutic effects were assessed.[3)]

Masticatory function

Maximum bite force

Using Dental Prescale 50H/R type (Fuji Film, Japan), the maximum bite force was measured using the old and new dentures, and the results were compared.

The maximum bite force for the old and new dentures was 207.8 and 418.1 N, respectively.

Masticatory scores

The mastication ability was measured using the table of Yamamoto's masticatable foods. Most scores were better when compared to those achieved with the old dentures (Fig. 9).

	New Denture			Old Denture		
Fo	Can Bit	Can't F	Don't	Can ite	Can't ite	Don't at
Pickled radish		×			×	
Peanut	○				×	
Hard-baking rice cracker	○				×	
Boiled rice cake	○				×	
Beefsteak	○				×	
Vinegared octopus		×			×	
Sagittated calamary		×			×	
Rice Cracker	○					—
French bread		×			×	
Steamed rice with red beans	○				×	
The sashimi of the cuttlefish		×			×	
Ham	○				×	
Kamaboko	○				×	
A tubular fish meat		×			×	
Rice	○			○		
The sashimi of the tuna	○			○		
Kabayaki	○			○		
Hanpen	○			○		
Boiled fish	○					—
Rice porridge	○			○		
Tofu	○			○		

Figure 9 Comparison between new and old dentures according to Yamamoto's masticatable foods

Patient subjective satisfaction

Figure 10 shows the results of the patient's subjective satisfaction for denture and oral functions.

The level of satisfaction was high for all items.

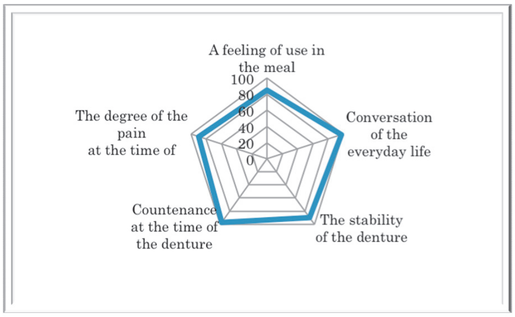

Figure 10 Subjective satisfaction

Conclusions

In the present patient, a split-type obturator was used, achieving large retentive force. Cleaning inside an obturator is often difficult with a dento-maxillary prosthesis, but cleaning in this case was very easy because the patient was able to take the prosthesis apart independently and the design is simple. In addition, a circumferential groove was added to the junction between the obturator and denture to prevent water from invading the obturator.

In the present method using a split obturator, the location of the split and the magnet retentive force need to be examined.

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8. Effect of Crosshead Speed on Magnetic Retentive Force

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Introduction

There have been many reports regarding magnetic retentive force. However, in these reports, the crosshead speeds for which the magnetic retentive force has been measured are not the same. The purpose of this study is to evaluate the retentive force of a magnetic attachment for different crosshead speeds.

Materials and Methods

GIGAUSS D600 (GC, Japan) magnets were used as test samples (n=5) and square acrylic resin pillars (10×10×30 mm) (Tokyo Giken, Japan) were prepared. The magnetic attachment was installed at the center of the acrylic resin. The retentive force of the magnetic attachment was measured using a customized testing jig and a universal testing machine (EZ-Test, Shimadzu, Japan)(Fig. 1). The crosshead speed was set to 43 different levels in the range between 0.5 mm/min and 500 mm/min. This testing jig was constructed with a linear ball slide (THK company, Tokyo) to prevent the sidewise movement of the specimen during traction. Statistical analysis was performed by using the Dunnett test (p=0.05).

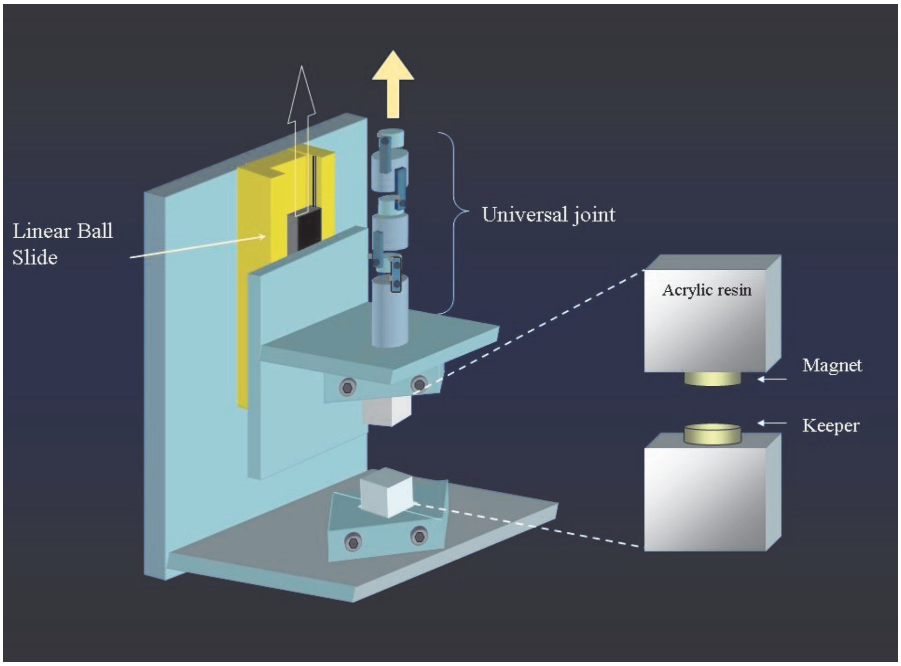

Fig. 1 Testing jig

Results

The retentive force for crosshead speeds in the range between 0.5 mm/min and 500 mm/min is shown in Fig. 2. It was found that the retentive force of GIGAUSS D600 magnets was 5.12 N at crosshead speed of 0.5 mm/min, 4.99 N at 5.0 mm/min, 4.96 N at 6.0 mm/min, and 4.41 N at 20 mm/min.

Figure 3 shows the retentive force for crosshead speeds in the range between 0.5 mm/min and 20 mm/min.

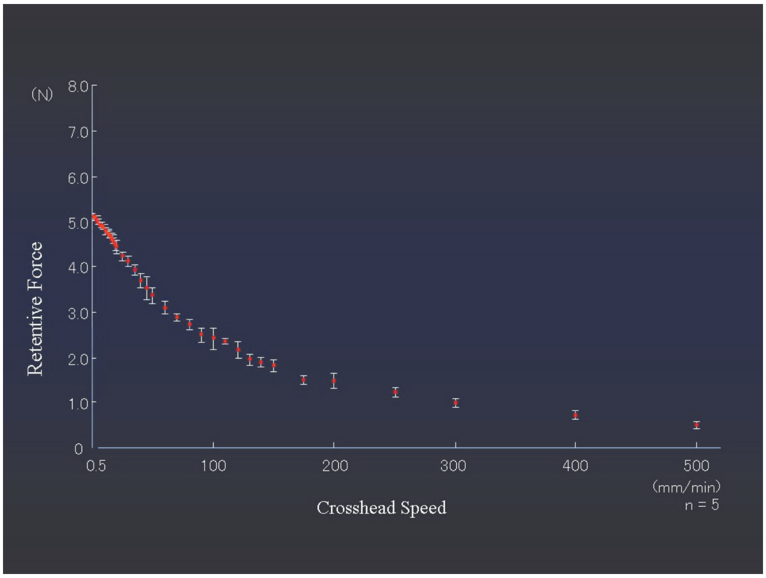

Fig. 2 Retentive force of magnetic system for various crosshead speeds

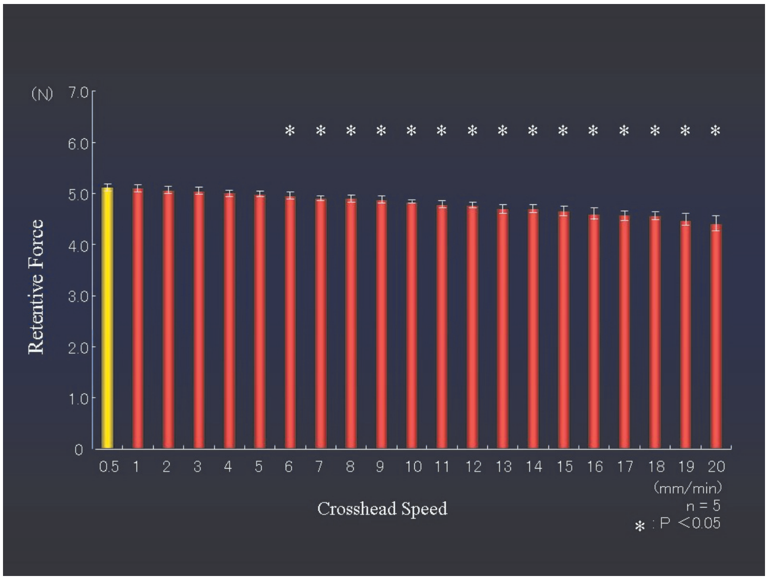

Fig. 3 Retentive force of magnetic system for crosshead speeds in the range between 0.5 mm/min and 20 mm/min

Discussions

There have been many reports regarding magnetic retentive force. However, in these reports, the crosshead speeds for which the magnetic retentive force has been measured are not the same. This experiment was performed in order to establish the influence of the crosshead speed on the magnetic retentive force.

Conclusions

1. The strongest retentive force was observed when the speed was lowest.
2. The retentive force of GIGAUSS D600 magnets decreased as the crosshead speed of magnetic attachment increased.
3. There was no statistically significant difference in retentive force between crosshead speed=0.5 mm/min and crosshead speed=5.0 mm/min, whereas statistically significant difference in retentive force was observed between crosshead speed=0.5 mm/min and crosshead speed=6.0 mm/min ($p=0.05$).

Acknowledgment

This study was supported in part by Grant from Dental Research Center, Nihon University School of Dentistry.

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9. The Inclination Angle on the Axial Surface of Coping Affects the Stress Distribution of the Abutment Tooth for Overdentures

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Introduction

In case of minority residual teeth, the overdenture is designed for the maintenance of the abutment tooth and the residual ridge and stability of occlusion. When a coping is applied to the abutment tooth for an overdenture, the shape of the coping may affect the stress distribution of an abutment tooth and the circumferential tissue. In this study, the interaction between the difference of the inclination angle on the axial surface and the stress distribution and displacement direction on the abutment tooth under a vertical load was examined using a three-dimensional finite element method.

Materials and Methods

A complete overdenture model with a coping set on the mandibular right canine was evaluated. The abutment tooth was set of inclined 15 degrees from occlusal plane. The outline of the abutment tooth and mandible was modeled on the basis of data from a multi-detector CT (Asteion Super4 Edition, Toshiba, Japan). A periodontal ligament, cortical bone, cancellous bone, and alveolar mucosa shapes were modeled with reference to anatomical measurements. The analysis models constructed were tooth, cortical bone, cancellous bone, periodontal ligament, alveolar mucosa, denture base, and coping. For this study, Rhinoceros (Version 1.0, Robert McNeil & Associates, U.S.A.) and ANSYS (Version 11.0, Ansys Inc., U.S.A.) were used.

Table 1 shows the Young modulus and Poisson's ratio. Three inclination angles (0, 30, and 45 degrees) on the axial surface of the coping were designed. The height of the coping was 1 mm from the lingual alveolar crest, and the top surface was set parallel to the occlusal plane (Fig. 1). The loading condition set up the vector of muscular contraction of the chewing movement.

Material	Young's modulus (MPa)	Poisson's ratio
Dentin	11721.1	0.30
Cortical bone	10414.7	0.30
Cancellous bone	88.3	0.30
Denture base	1896.3	0.30
Au-Ag-Pd alloy	110815.1	0.30
Periodontal membrane (The first load)	0.049	0.49
Periodontal membrane (The second load)	0.7	0.49
Alveolar mucosa	0.045	0.49

Table 1

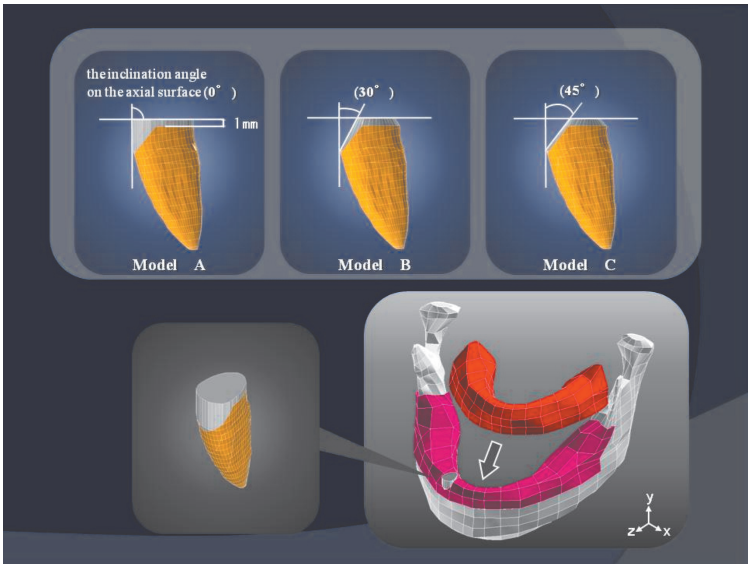

Fig.1

Table 2 shows the loading conditions.

		Node number		Load	
		Right side	Left side	Right side	Left side
Masseter muscle	Superficial part	15	15	190.4	190.4
	Deep part	7	7	81.6	81.6
Medial pterygoid muscle		16	16	132.8	132.8
Temporal muscle	Anterior belly	19	19	154.8	154.8
	Middle belly	14	14	91.8	91.8
	Posterior belly	19	19	72.6	72.6

Table 2

Figure 2 shows the loading directions with arrows. Ten occlusal stops at the intercuspal position and the upper part of the condyle bilaterally were completely restrained on the designed models. Figure 3 shows the restricted positions with circles. Stress levels were calculated under the minimum principal stress on the surface of cortical bone. The vector of the movements was calculated on the six points of the surface of the abutment tooth.

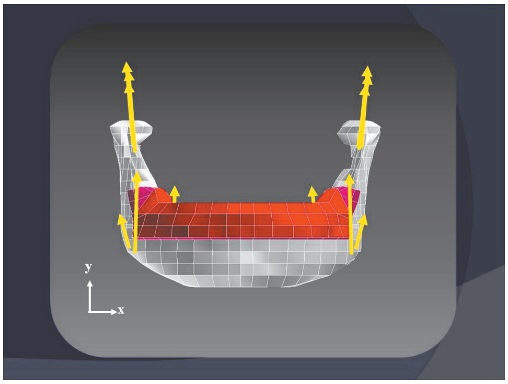

Fig.2

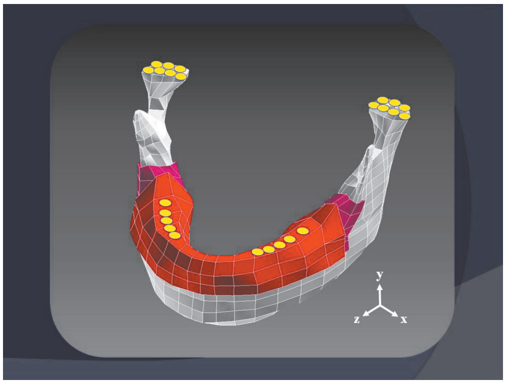

Fig.3

Results

Figure 4 shows the stress distribution of the abutment tooth (2D stress contour plots) and the stress distribution graph of the top surface of cortical bone. The stress concentration was detected on the labial and lingual side of the abutment tooth, but there were no significant differences regarding the stress distribution and displacement direction among three kinds of analysis models. The displacement of the abutment tooth, which correlated the elevated inclination angle on the axial surface, was slightly increased.

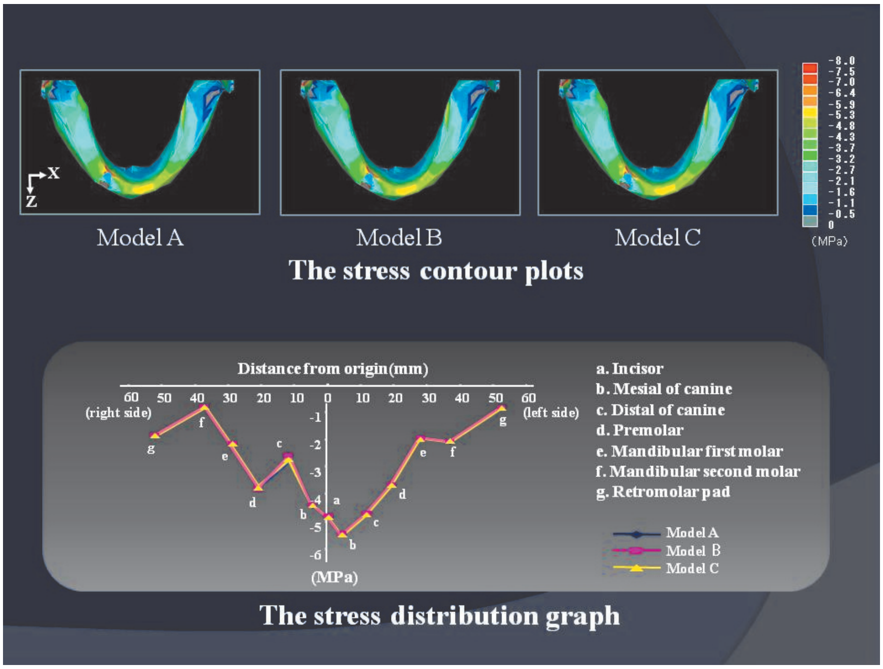

Fig. 4

Discussion

The influence of the difference of the inclination angle on the axial surface of the coping was not apparent because the load was vertical for the attractive surface of the coping and the height of the coping was short.

Conclusions

According to the results, there were no significant differences in the stress distribution and displacement direction on the three inclination angles (0, 30, and 45 degrees) on the axial surface of the coping under a vertical load.

Acknowledgements

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10. Hardening time of Self-curing resin for Installing Magnets and Removing Denture

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Introduction

The self-curing resin is widely used for installing a magnet into the denture base. Ideally, after the resin have completely hardened, the denture with the magnet is taken out the intraoral. The self-curing resin that flow into undercuts may cause difficulty in removing the denture. On the other hand, because the polymerized resin have insufficient hardness, magnets cannot be fixed adequately. In this study, we evaluated the optimal hardening time of the self-curing resin for installing a magnet and removing the denture safely.

Materials and Methods

1. Production of resin block

For the production of a resin block, a gypsum spacer (GC, Tokyo, Japan) was adhered to the base of a rubber frame and then the self-curing resin (UNIFAST III LIVE PINK, GC) was filled on top of the rubber frame. After the self-curing resin have hardened, the resin block was taken out the rubber frame, and a spillway was made (Fig. 1).

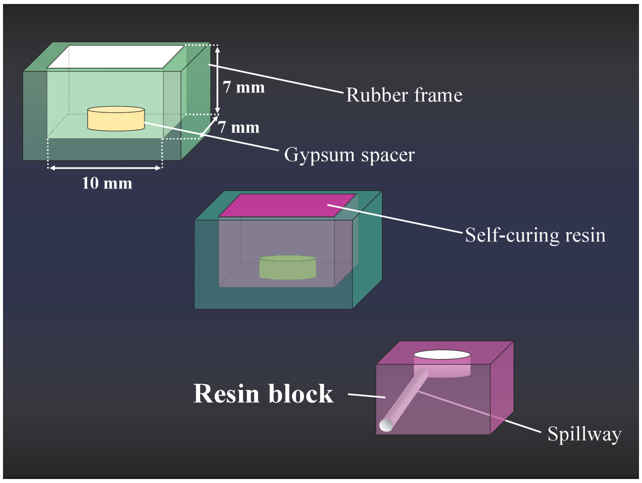

Fig. 1

2. Installing the magnets

A retentive force testing jig was made using a linear ball slide (THK Company, Tokyo, Japan) set on a universal testing machine (EZ-Test, Shimadzu, Kyoto, Japan) (Fig. 2). A keeper was attached to the acrylic prism of the jig traction compartment and then the magnet was adsorbed to the keeper. The fabricated resin block was bonded to another acrylic prism of the jig fixation compartment. Thereafter a self-curing resin was brushed-on to the resin block and the magnet was then installed. The cross-head speed was 100mm/min to remove the keeper (Fig.3).

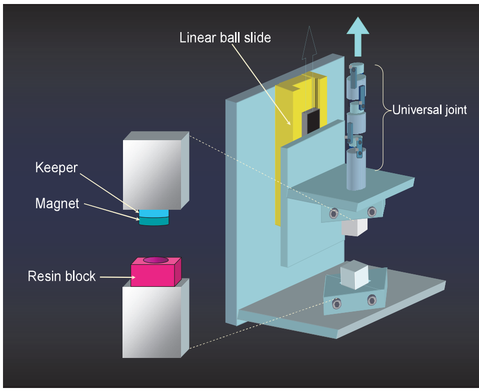

Fig. 2

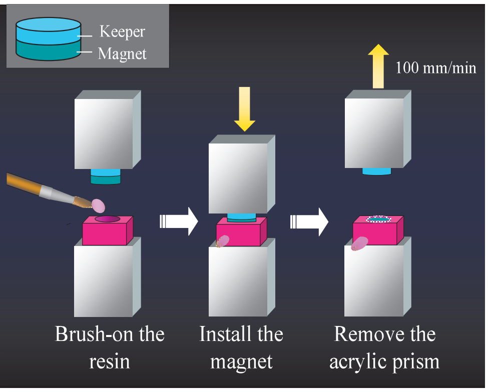

Fig. 3

3. Experimental conditions

Five samples of each of three sizes of magnets (GIGAUSS D400, D600 and D800, GC) were used and each magnet was measured five times in this study. The magnets were installed for 40, 50 or 60 seconds. Moreover, 9 removal times (90, 100, 110, 120, 130, 140, 150, 160 and 170 seconds) were evaluated. The measurements of installing and removal times were started after the self-curing resin was brushed-on (Fig. 4).

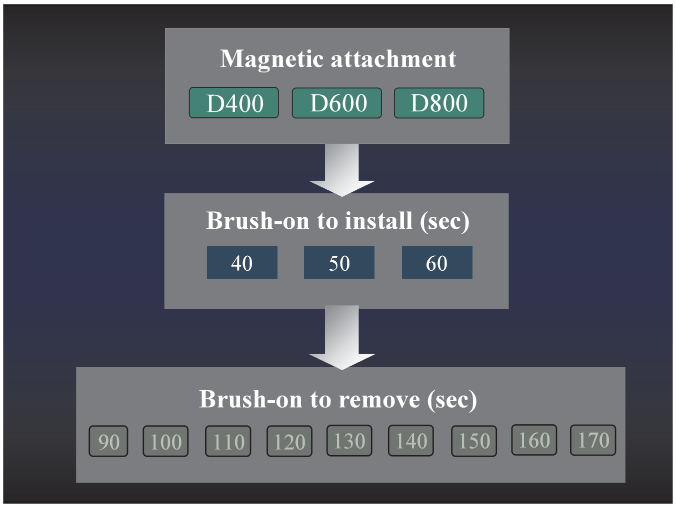

Fig. 4

4. Feasibility of installing the magnet and removing the resin block

The three conditions considered to cause failure of setting a magnet are as follows:

(1) The magnet is left on the keeper at the time of keeper removal.
(2) Hardening of the self-curing resin is incomplete.
(3) The magnet is not installed in a good position.

Measurement of retentive force was performed at a 5 mm/min of the cross-head speed, except under the three conditions mentioned above. The retentive force stated by the manufacturer was considered to be the index of the success or failure of assessing installing feasibility.

Results

Figures 5, 6 and 7 show the number of success in installing the magnets and its relationship to removal time. The most successful timing for installing the three types of magnet tested was 50 seconds, and the adequate removal times were 130 seconds for D400, 140 seconds for D600 and 160 seconds for D800. Resin hardening was incomplete at the time of magnet installation of 40 seconds. There was also a case in which resin stiffened at a magnet installation time of 60 seconds.

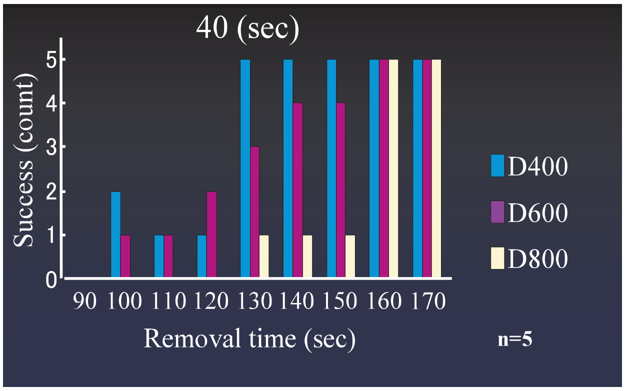

Fig. 5

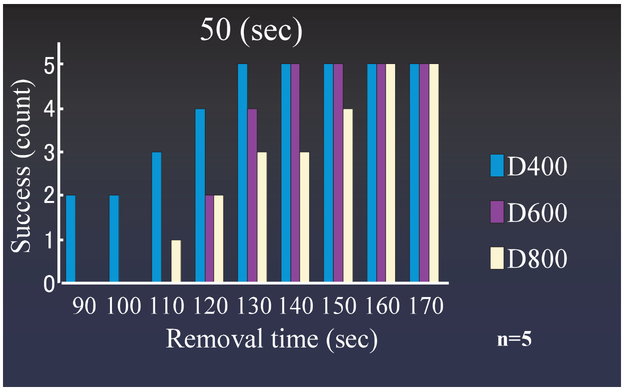

Fig. 6

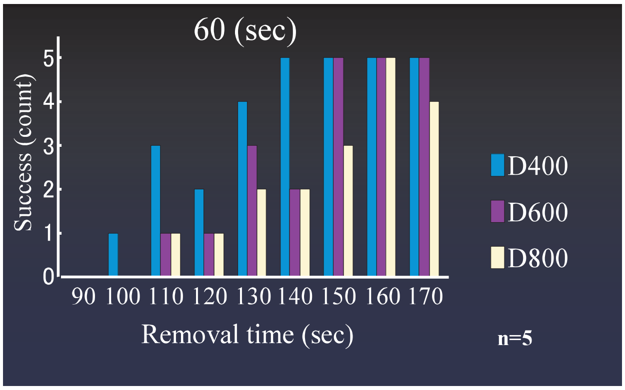

Fig. 7

Conclusions

The optimal time for installing the magnet was 50 seconds, and the adequate removal times were 130 seconds for D400, 140 seconds for D600 and 160 seconds for D800. In the case of installing a magnet with strong attractive force, a tendency for a longer removal time was noted.

Acknowledgement

This study was supported in part by Grant from Dental Research Center, Nihon University School of Dentistry.

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11. The Effect of Abutment Tooth Connection with Extracoronal Attachment using the Three Dimensional Finite Element Method - Part 2. The Construction of Finite Element Model from CT Data -

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Introduction

An extracoronal magnetic attachment retainer design for partial denture prosthetic applications has been developed. Restorative limitations of space and physiologic function requirements may complicate esthetic placement of attachments in a partial denture design. Our previous reports have presented the advantages of an extracoronal magnetic attachment design for extracoronal applications with vital teeth. The traditional retainer design requirements satisfying retention and resistance form and while providing an applications that is esthetic has shown good patient feedback[1-3].

In a distal extension partially edentulous treatment, a patient may refuse to wear bilateral denture for several reasons, including esthetic concerns and satisfactory hard and soft tissue adaptation and fit.

In applications of distal extension and cantilever, an extracoronal attachment has potential to cause overload. The optimal and proper use of any remaining teeth adjacent to the edentulous area for use as supporting abutments is of great concern. Any decision in the selection of abutment number or interconnected splinting of supporting abutment teeth is based on the best knowledge based upon comprehensive dental evaluation. However, there are clinical situations where minimal supporting information exists to appropriately render these decisions.

Finite Element Method (FEM) has been well applied in stress evaluations for prosthodontic dental studies. We have previously reported the use of two-dimensional models of prosthodontic treatment situations. This study utilized the application of three dimensional modeling to evaluate the applications and stress distribution patterns for extracoronal magnetic attachment retainers for partial dentures.

Objective

The aim of the present study was to fabricate three-dimensional finite element model from actual patient data. We investigated the effect of interconnected abutment number in case of unilateral use of extracoronal magnetic partial denture retainers using the FEM model.

Materials and Methods

1. Materials

A subject was selected from patients who were diagnosed and treated in the department of implant dentistry at our university hospital. The selected patient was given informed consent before the study. The CT data at diagnosis and the study model were used in the present study (Fig. 1).

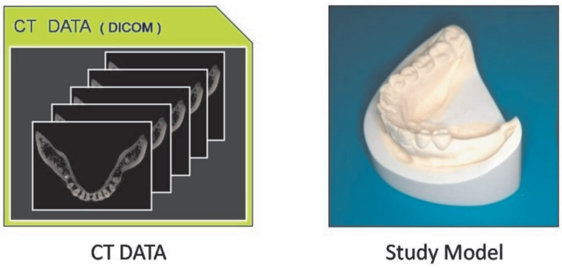


Fig . 1 Materials

The patient was a 42-year old woman who visited our implant department due to the left mastication disorder. At first visit, lower left first and second molars were missing, and no problem was found in the bone and periodontal tissue.

2. Methods

1) Geometry data formation

Table.1 shows the flow chart of the geometry data formation.

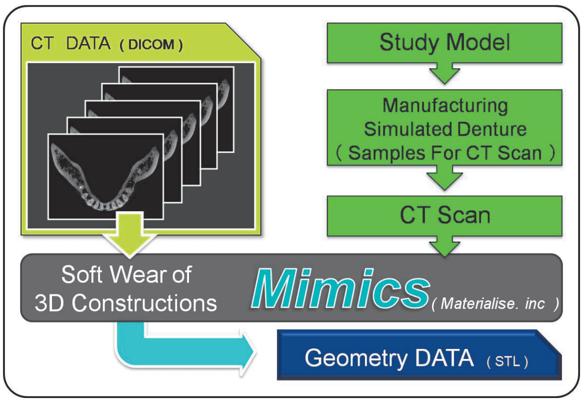


Table . 1 Flow Chart untill The Geometry DATA

(1) CT data process

The DICOM data obtained from CT was processed using three-dimensional image processing and editing software (Mimics, Materialise), and geometry was extracted from CT concentration value. Segmentation of the teeth, cortical and cancellous bones was performed. Constructed 3D geometry data was output as a STL format (Fig. 2).

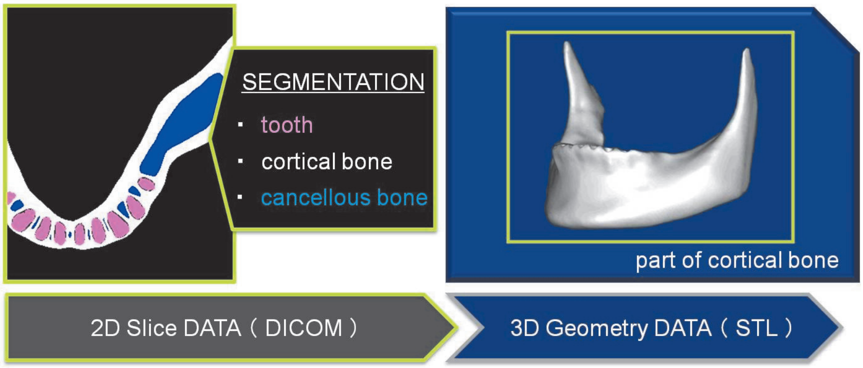


Fig . 2 Managements of CT DATA

(2) Fabrication of a sample for CT scan

A sample for CT scan was fabricated to reproduce complex geometry such as extracoronal attachment and denture. The following is a fabrication process:

① Fabrication of a copy model

A copy model of the study model made at diagnosis was fabricated, and used as a work model (Fig. 3).

Simulate fabrication of a denture and crowns were performed on this work model representing an oral cavity.

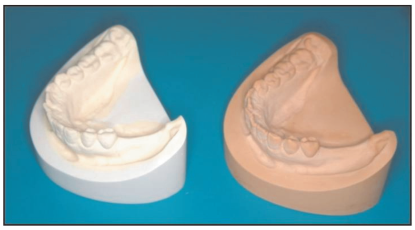


Fig . 3 A copy of Study Model

② Simulate preparation of abutments and fabrication of resin crowns

Simulate preparation of abutments was performed on the work model (Fig. 4-a), followed by the build-up of resin crowns (Fig. 4-b). Scanning resin (Yamahachi Dental MFG, Co.) was used to fabricate a sample. This radiopaque quick cure resin is suitable for reading the geometry since radiopaque contrast agent is homogenously dispersed.

a . preparation

b . resin crown

Fig . 4 Simulate Preparation

③ Placement of an attachment

The EC keeper tray plastic pattern was duplicated with scanning resin, and was placed on the distal part of the second premolar following the conventional method. Milling was performed on the lingual surface of the second premolar, and the male part for an interlock was created between the lingual surface of the second premolar and the crown of the first premolar (Fig. 5).

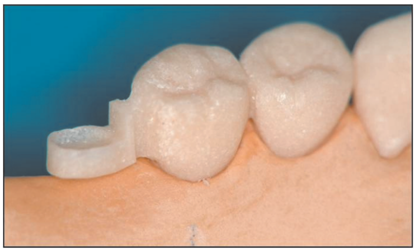


Fig . 5 Complete of Part of Male

④ Build-up of a metal frame

A removable metal frame that fits into the placed attachment was fabricated (Fig. 6).

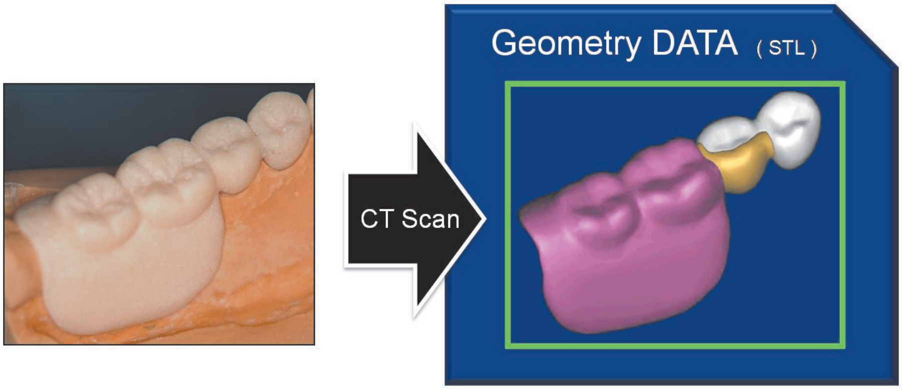
Fig . 6 Part of Metal Flame

⑤ CT scan and three-dimensional construction

A sample was scanned with Micro-focus X-ray CT (Shimazu Corp.) in Tiff format. The data was then processed using three-dimensional image processing and editing software (Mimics, Materialise), and geometry was extracted (Fig. 7-a).

⑥ Build-up of a denture base

A denture base part was built-up on the metal frame part, and its morphology was modified (Fig. 7-b).



a . Part of Removable Denture b . 3D Constructions (MIMICS)

Fig . 7 Complete of Sample and 3D Constructions

2) Finite element Modeling

All geometry data was imported into Patran (MSC Software Corp.) The cervical margin of the crown obtained from CT data and the cervical margin of the fabricated crown were adjusted to coincide in good balance in the three-dimensional space based on the occlusal plane and panoramic radiography (Fig. 8).

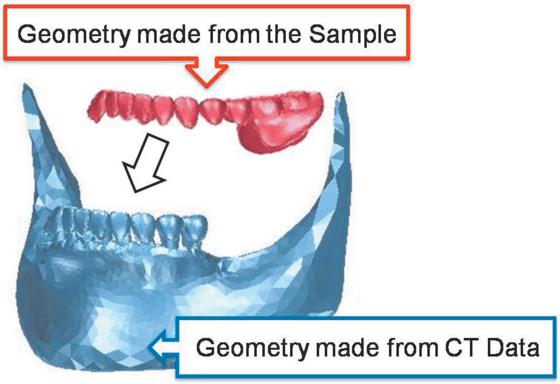


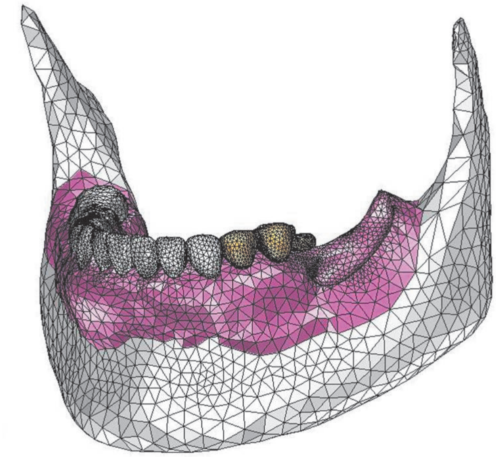
Fig . 8 FEM Modeling

3) Analysis

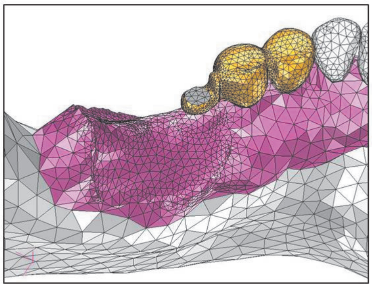
Mechanical property value was input into the constructed finite element model. The boundary condition was applied, followed by the calculation of an analysis solver (Marc2005r3, MSC Software).

(1) Analysis model

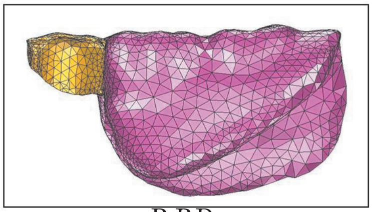
Fig. 9 shows an overall view of the FEM model. Four models with #4-5, 3-4-5, 2-3-4-5, and 1-2-3-4-5 interconnected abutments were constructed. Element and nodal point numbers are shown in Table.2.



a . Perspective



b . Attachment



c . R.P.D

Fig . 9 FEM Model

Model	elements	nodes
45 interconnected	117,943	27,030
345 interconnected	118,085	27,038
2345 interconnected	118,104	27,030
12345 interconnected	118,329	27,043

Table . 2 Number of Elements and Nodes

(2) Analysis condition

Contact conditions were introduced between a denture and the mucosa, and an abutment and attachment. Friction type was Coulomb friction, and the friction coefficient μ was set at 0.01. Analysis type was linear elastic stress analysis, and three-dimensional tetrahedron and pentahedron element were employed. DELL PRECISION 470 (DELL) was used for the analysis.

Mechanical Properties

	Young's Modulus (MPa)	Poisson's Ratio
periodontal ligament	1.00	0.45
oral mucosa	0.10	0.45
cortical bone	11,760	0.25
cancellous bone	1,470	0.30
tooth	11,760	0.35
metal	94,080	0.30
denture	2,450	0.30

Table . 3 Components and Mechanical Properties

① Components and mechanical properties

Table. 3 shows components and mechanical properties of the model. Same mechanical property value was applied for a crown, attachment, and metal frame. For the periodontal membrane and mucosa, a preliminary experiment was performed so that the vertical displacement of teeth against the applied load is close to the known value.

② Constraining and loading conditions

Lower bilateral coronoid processes was a complete constraint. A total of 10 N of vertical loads to the occlusal plane was applied on the occlusal surface of denture teeth (Fig. 10).

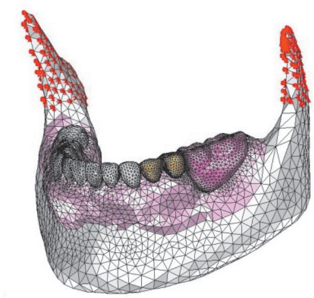
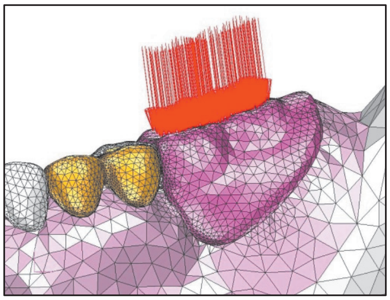



Fig . 10 Fix and Load Conditions

Results

1 . Distributions

Stress distribution pattern demonstrated con Mises equivalent stress distribution.

1) Abutment

Abutments from the tooth #1 to 4 were extracted from the analysis model. Figures.11a-d show the stress distribution of each model. All models showed stress concentration in the crown margin of the most posterior abutment. However, stress distribution was observed extensively in the #4-5 interconnected model when focusing on the root of the most posterior tooth #5. The models include the tooth #3 as an abutment demonstrated little change in the stress distribution although slight stress relaxation was observed.

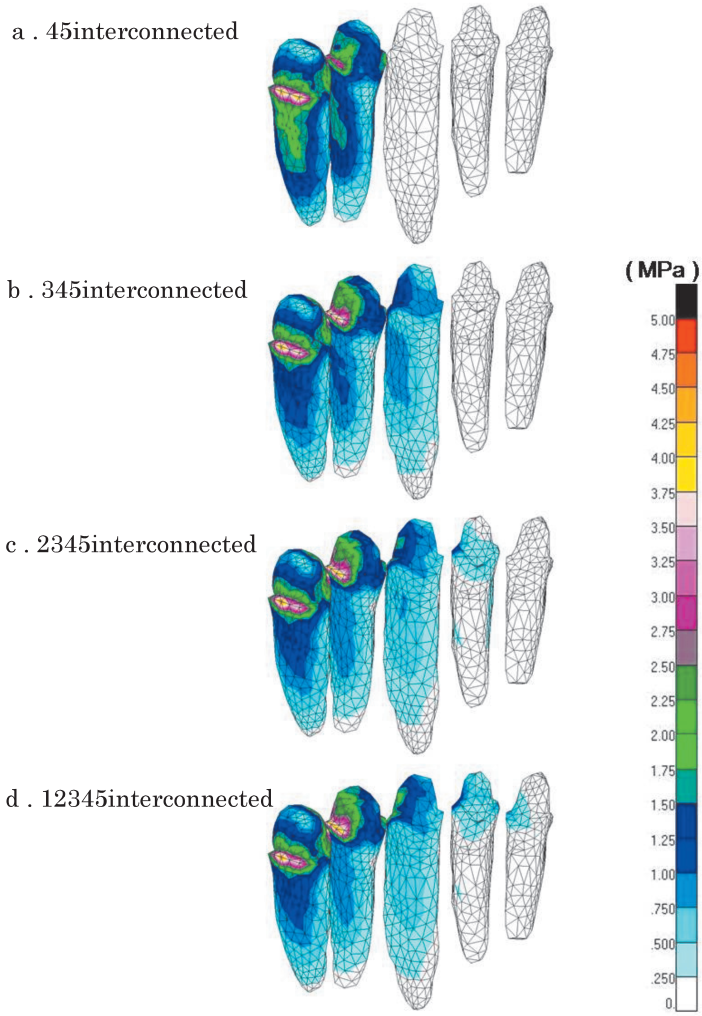


Fig . 11 Stress Distributions of Abutment Tooth

2) Cortical bone

Figures 12 a-d show stress distributions of the cortical bone. The data of the cortical bone was extracted from the model. In the 4-5 interconnected model, stress concentration was observed throughout the compact bone around abutment teeth. As the number of abumtment teeth increased, stress distribution was shifted towards the mesial area.

a . 45interconnected

b . 345interconnected

c . 2345interconnected

d . 12345interconnected

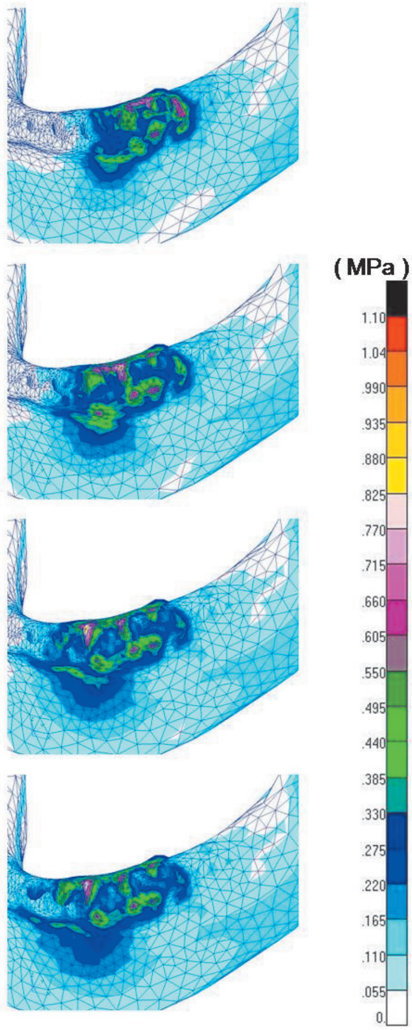


Fig . 12 Stress Distributions of Cortical Bone

2 . Displacement

1) Abutment

Figure. 13 shows the distal displacement of abutments. Measuring points were cusp tips of the most posterior abutments. The results showed a decrease in the displacement as the number of interconnected abutment increased, especially in the models including the tooth #3 as an abutment. The 3-4-5 interconnected model demonstrated a decrease by 50% compared with the 4-5 model.

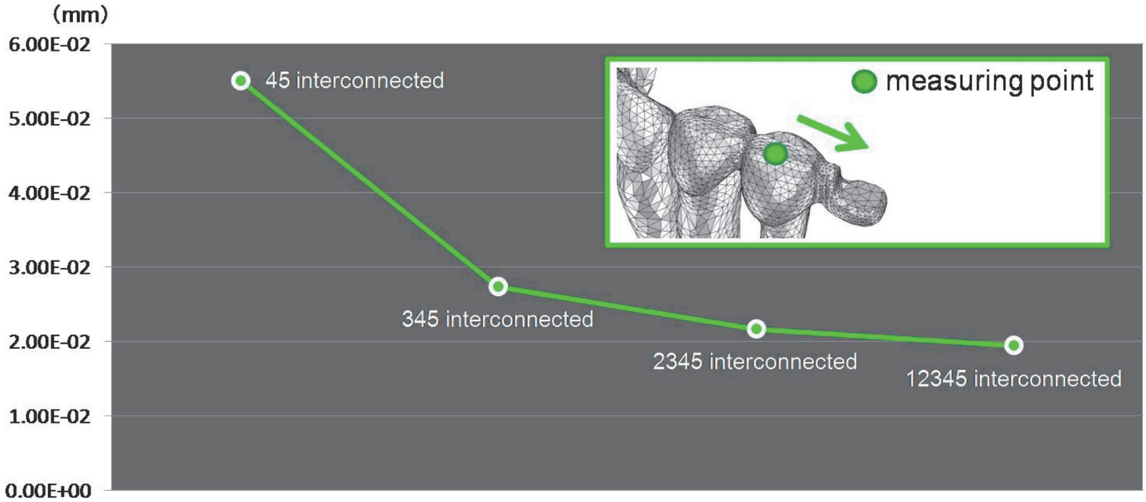


Fig . 13 Displacement of abutment

2) Denture

Figure. 14 shows the vertical displacement of a denture. The measuring point was posterior margin of a denture. The vertical displacement decreased as the number of interconnected abutment increased, especially in the models including the tooth #3 as an abutment. The 3-4-5 model interconnected model demonstrated a decrease by 35% compared with the 4-5 model.

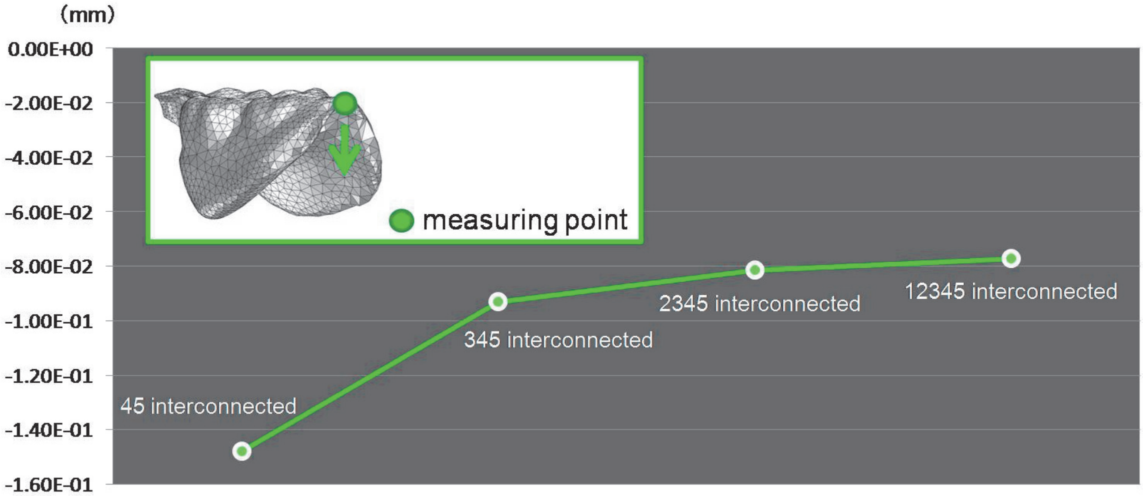


Fig . 14 Displacement of Denture

Discussion

1. Modeling

We have been investigating the influence of the number of interconnected abutment on the stress distribution in the tissue around the denture in order to provide theoretical evidence for the decision-making of the number of interconnected abutment. In previous studies, we performed the analysis using a simple designed model due to the difficulty in constructing a complex designed model. However, the analysis results could not be used as clinical evidence due to the simplicity of the model although analysis results were consistent. The model construction method that we used in the present study was non-invasive, and allowed to construct finite element models with accurate size and structure by fabricating simulated restorations. Each patient has a different oral cavity construction. We believe that Finite Element Method has a great potential for providing theoretical evidence for the optimal denture design in the clinical settings by using this method to easily fabricate the patient’s model.

2. Analysis results

The distal displacement of the most posterior abutment and vertical displacement of a denture significantly decreased by interconnecting three abutments between the second premolar and canine. No significant decrease was observed by increasing the number of interconnected abutment more than three. These results are presumably due to an increase of the number of interconnected abutment, and long canine root.

Conclusion

In the present study, more accurate analysis model was constructed by using actual patient’s data and a study model.

In the unilateral application of extracoronal attachment, the stress on abutments was mitigated and the vertical displacement of a denture decreased by increasing the number of interconnected abutment.

A significant stress relaxation was observed by including the canine as an abutment. No significant change was observed by increasing the number of interconnected abutment more than three.

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12. The effect of Bracing Arm with Extracoronal Attachment use evaluated by Three Dimensional Finite Element Method

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Introduction

In unilateral extension partial denture treatment situations, magnetic attachments are often used as a hidden retaining retentive elements to provide a superior esthetic result and improved patient comfort. When an extracoronal magnetic attachment is used for retention, the mechanics of a functional cantilever effect of denture behavior should be well understood[1-3].

Solutions to account for cantilever increased stress transfer concerns include the use of splinting abutments, use of lingual bracing arms and extracoronal interlocking attachments. There are few reports or evidence-based evaluations regarding the relative use and merits of these different design elements for improved treatment decision making purposes.

Objective

The aim of the present study was to investigate the effect of bracing arms and interlock designs employed with extracoronal attachments as applied to unilateral partial denture designs using the three-dimensional finite element method (FEM), and to seek alternative designs and comparisons.

Materials and Methods

Fig. 1 shows the overview of the three-dimensional FEM model. The three-dimensional FEM model was constructed from the CT data of patients according to the method developed by Ando. (Ando A, 2009, Aichi Gakuin)

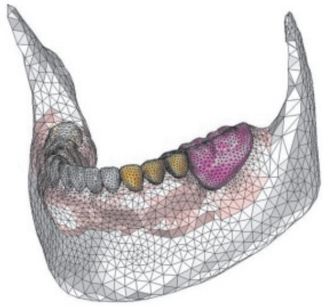


Fig 1 : F.E.M model

Dentures, crowns and retainers were fabricated on the study model using Scanning Resin (Yamahachi Dental Mfg., Co.), and were built into the Ando analysis model. (Ando A, 2009,Aichi Gakuin)

Table 1 : Material Properties

	Young's modulus (MPa)	Poisson's ratio
Periodontal ligament	1.00	0.45
GUM	0.10	0.45
Compact bone	11,760	0.25
Cancellous bone	1,470	0.30
Tooth	11,760	0.35
Metal	94,080	0.30
Denture	2,450	0.30

Table 1 shows components and material constants of the model. The same property value was set for crowns, attachments, metal frames and retainers. A preliminary experiment was performed before setting material constants so that the vertical displacement of teeth against the applied load is close to the known value. As for the constraining conditions, the bilateral coronoid processes was a complete restraint. A total of 10 N vertical loads were applied on the occlusal surface (Fig. 2).

The analysis model included connective crowns of #3, 4 and 5 based on Ando's results. Slits were prepared on the distal parts of extracoronal attachments in all models (Fig. 3).

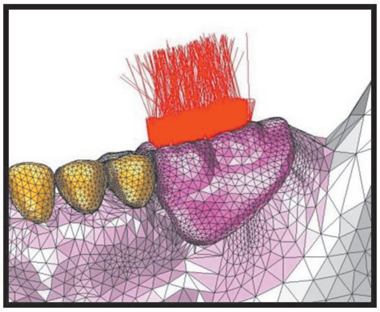


Fig 2 : Load condition (10N)

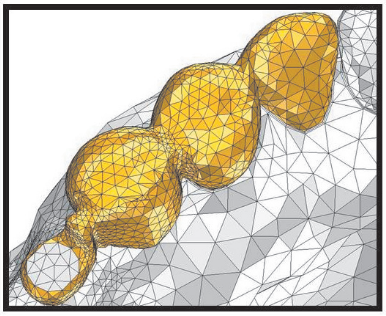
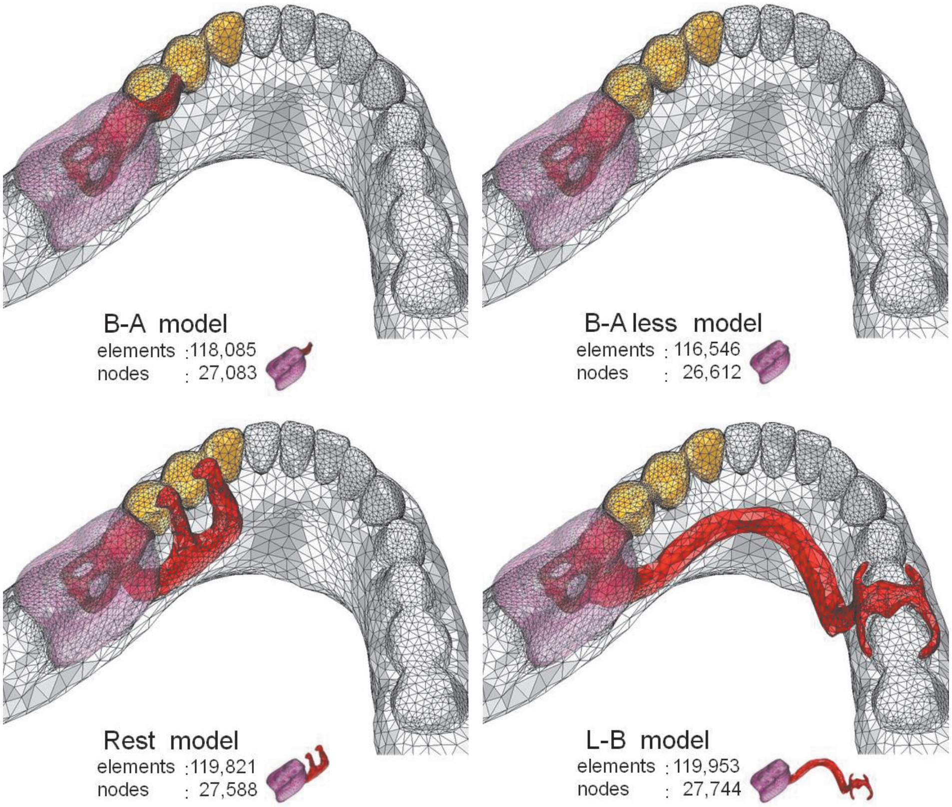


Fig 3 : Connective Crown

The following are four analysis models fabricated in the present study (Fig. 4).

1. The model with a bracing arm and an interlock incorporated into an extracoronal attachment (B-A model).
2. B-A model without a bracing arm (B-A less model).
3. B-A model with medial rests on the teeth # 4 and 5 (Rest model).
4. Lingual bar model with a twin clasp placed on the opposite side as an indirect retainer (L-B model).

Contact conditions were introduced between a denture and the mucosa, and an abutment and an attachment. The coulomb friction was applied, and friction coefficient was set at 0.01.



Results

1. Stress distribution

The Von Mises stress was used to analyze the stress distribution.

1) Connective crown

Fig. 5 shows the stress distribution in connective crowns where the load is directly transferred to the denture. For all four models, stress concentration was observed in attachments, #4-5, and #3-4 interconnected areas. In the B-A less model, the highest stress concentration was observed in #4-5 interconnected area. The highest stress relaxation was observed in the L-B model. The Rest model showed different results from other three models, and the stress concentration was also observed in #4-5 and #3-4 connective areas.

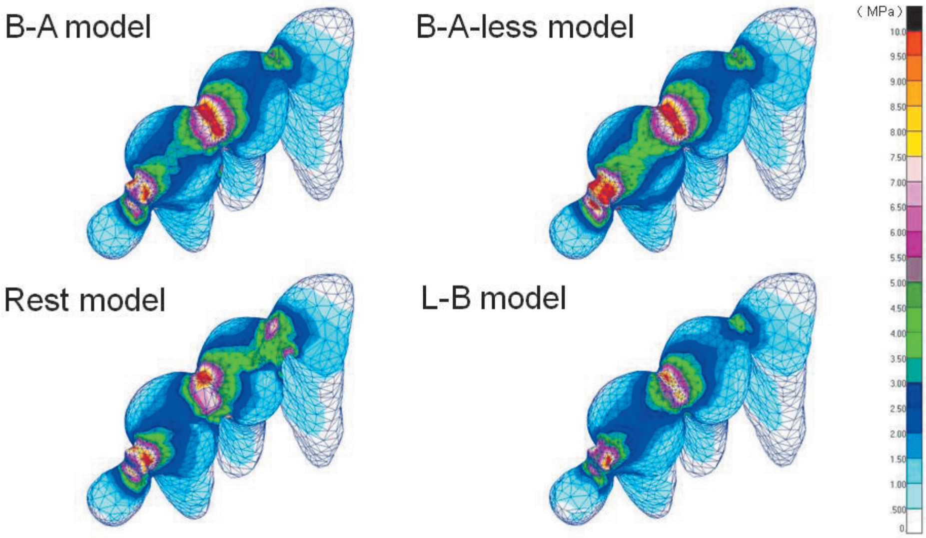


Fig 5 : Stresses distribution of Connective Crown

2) Attachment

Fig. 6 illustrates the stress distribution of attachments. Stress concentration was observed in the upper and neck parts of an attachment in all models. Stress distribution patterns were similar between the B-A and Rest models.

The stress value was calculated at the measuring point set in the neck part where the fracture is more likely to occur. The graph in Fig. 7 shows the stress at the neck part of extracoronal attachment. The B-A less model demonstrated the highest stress value, and the L-B model demonstrated the highest stress relaxation in the neck part. The comparison between the B-A and Rest models that have similar stress distributions revealed a higher stress value in the Rest model.

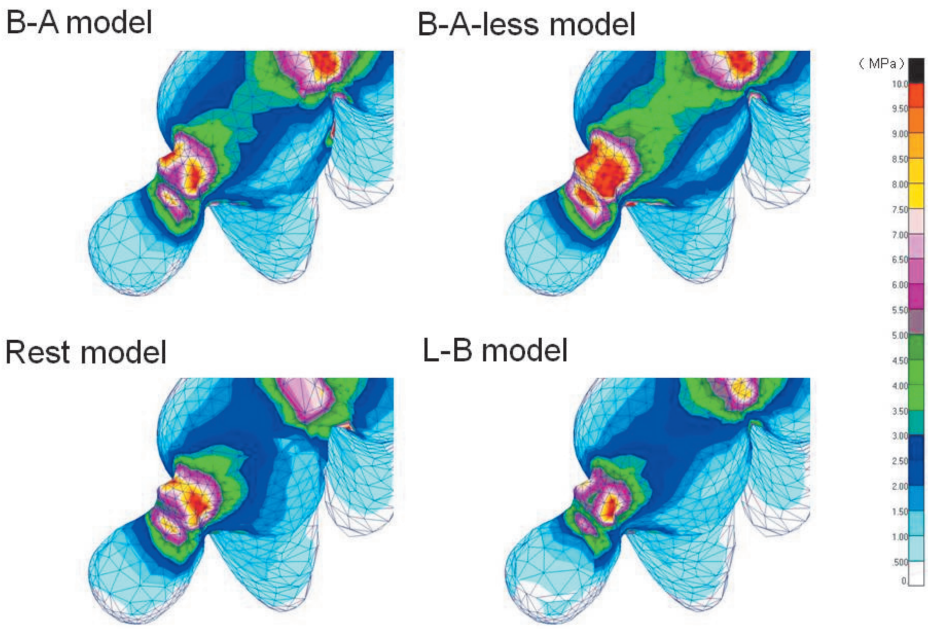


Fig 6： Stresses distribution of Extracoronal attachment

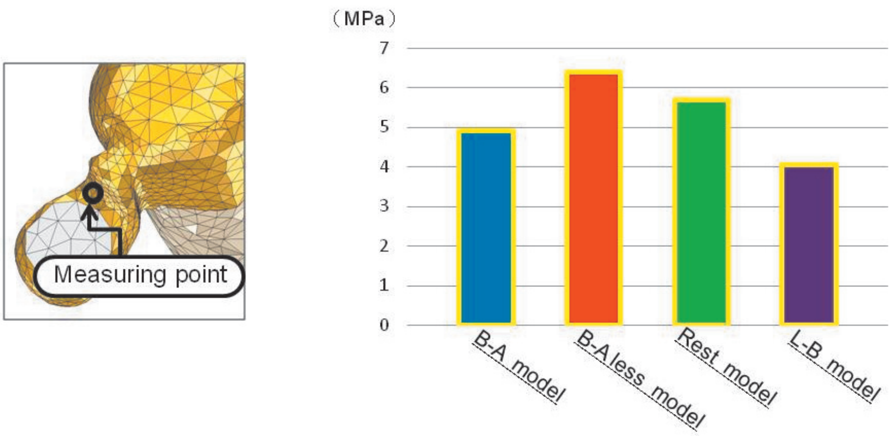


Fig 7： Stress at the neck part of extracoronal attachment.

3) Abutment

Fig. 8 shows the stress distribution of abutment teeth #3, 4 and 5. Stress concentrations were observed at the mesiodistal margin of the tooth #5, and the distal margin of the tooth #4 in all models. No stress concentration was observed around the margin of the tooth #3. For the stress distribution of the root, the L-B model showed the highest stress relaxation. There was no significant difference in stress distribution in other three models with unilateral design. The stress value was calculated at the measuring point set in the cervical area of the most-posterior tooth which is most affected by any denture cantilever effect.

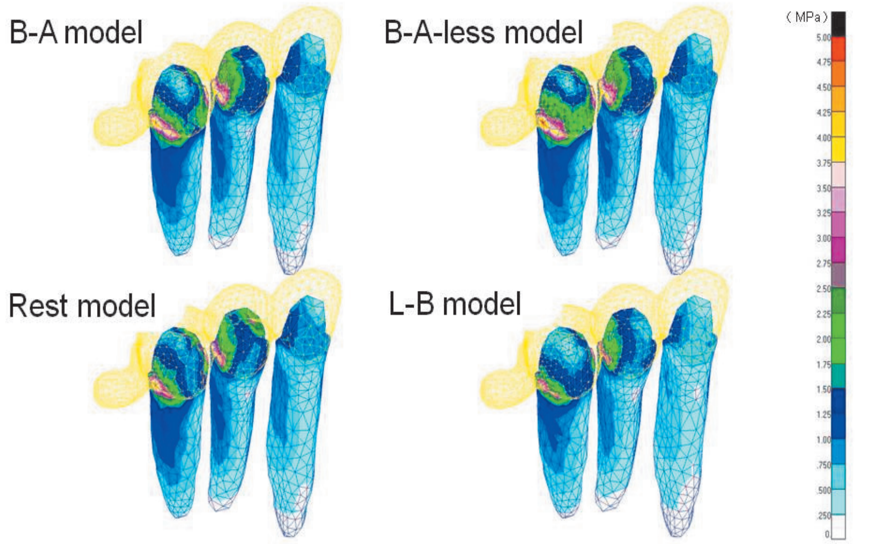


Fig 8 : Stresses of cuspid , first premolar and second premolar

The graph in Fig. 9 shows stress at the distal cervical margin of the tooth #5. The B-A less model demonstrated the highest stress value, and the L-B model demonstrated the highest stress relaxation. The comparison between the B-A and Rest models revealed a slightly higher stress value in the Rest model.

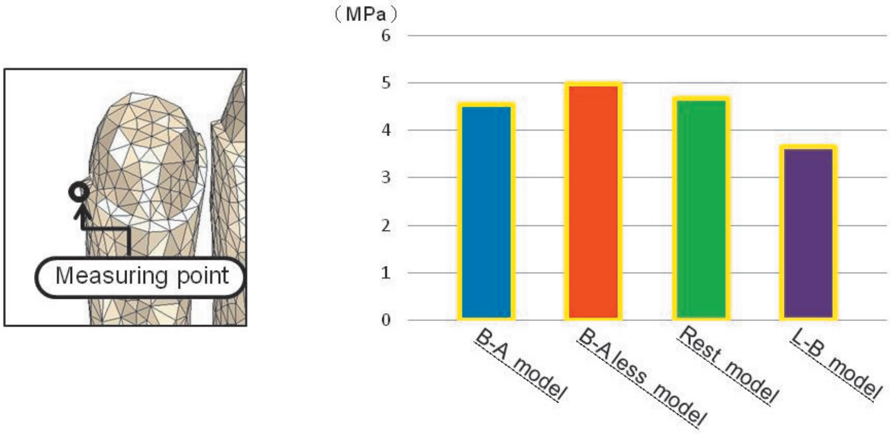


Fig 9 : Stress at the distal cervical margin of of second

2. Displacement

The coordinate axes were established in the abutment and the posterior margin of the denture, and the displacement amount was measured. Fig. 10 and 11 showed the distal displacement of the abutment, and the vertical displacement of the posterior margin of the denture, respectively.

1) Abutment

The L-B model showed the smallest distal displacement of the abutment. Other three models with unilateral design demonstrated large distal displacement, notably the B-A less model. No significant difference was found between the B-A and the Rest models.

2) Denture

The L-B model showed the smallest vertical displacement of the denture. Other three models with unilateral design demonstrated large vertical displacement, notably the B-A less model.

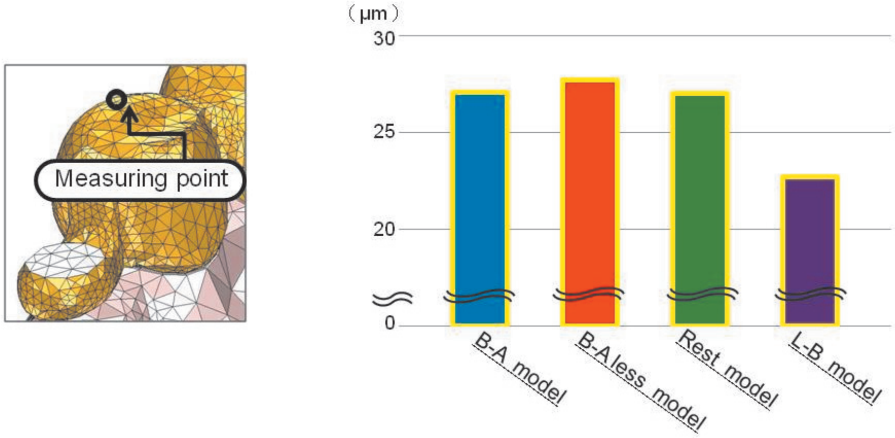


Fig 10 : Distal displacement of second premolar.

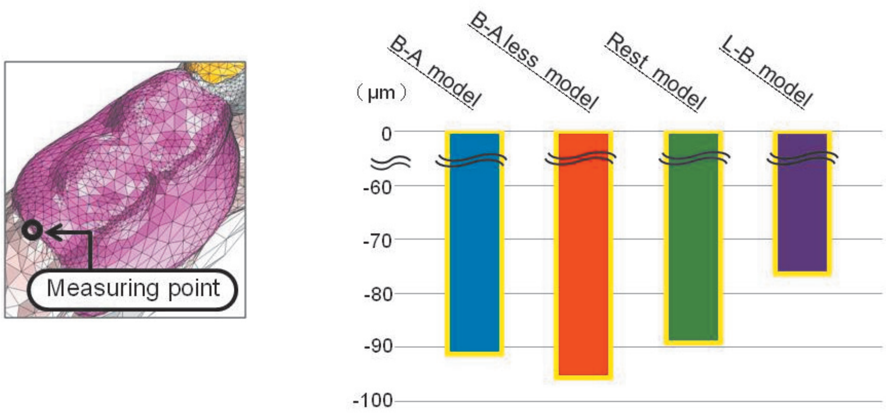


Fig 11 : Verticl displacement of denture

Discussions

1. Analysis model

Simple analysis models have been used in the previous studies due to the complexity of model construction. Although there was a consistency in the analysis results obtained from these models, these results were not reliable enough to use as the clinical evidence due to their simple design. The model construction method developed by Ando enables to construct the finite element model with a realistic size and structure in a non-invasive manner by simulating different restorations. In the present study, the effect and availability of a bracing arm and interlock employed with an extracoronal attachment in unilateral partial dentures were examined, and a new model with the same effect and requires less laboratory work was constructed. The finite element model was used as a fundamental model.

2. Analysis results

The analysis of stress distributions and vertical displacement of a denture demonstrated the following results. Although the vertical displacement of a denture with the attachment and the distal margin of the second premolar were larger in the B-A model than the Rest model, the stress value was smaller in the B-A model. This observation is due to the differential displacement of a denture when the load is applied. The Rest model revolved buccal direction around the upper area of the extracoronal attachment in the denture. On the other hand, the B-A model revolved around the interlock area at the tip of a bracing arm. The difference between these two models is considered to contribute to stress mitigation findings. The stress distribution figure (Fig. 5) shows the stress concentration in the connective area between the first and second premolars both in the B-A and B-A less models. The result suggested the stress concentration is centered around an interlock when the load is applied.

These results showed that a bracing arm mitigates and distributes the stress on an extracoronal attachment, and distal margin of the posterior abutment tooth.

Conclusions

The effect and availability of a bracing arm and interlock used with extracoronal attachments was examined in this study. The following conclusions were drawn:

1. In unilateral free-end edentulous case, the L-B model is considered to be an optimal design based upon the analysis results of the stress distribution and displacement findings.
2. Bracing arms proved to be effective in an unilateral denture design.
3. The analysis result of the Rest model was similar to the B-A model, suggesting that mesial rests can replace a bracing arm.

13. A case report of an RPD with magnetic attachments applied to a partially edentulous patient without occlusal contact

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Introduction

It is well known that partially edentulous cases with few or no occlusal contacts are severe because the remaining dentition, supporting tissue and residual ridges are apt to be damaged and prosthodontic devices are easily fractured. Miyachi proposed calling these conditions with such defects “collapsed areas” and recommended applying affirmative prosthodontic intervention.

The authors applied magnetic attachments in the preparatory treatment in order to decrease overloading on the abutment teeth and increase the retention and stability of the denture.

Case Report

A 74-year-old male patient presented partial edentia of maxillary Kennedy class Ⅳand mandibular Kennedy class I (Fig.1) in contact with the upper right lateral incisor(#12), canine(#13) and lower right canine(# 43) at the habitual occlusal position(Figs.2 and 3). The existing maxillary denture was recurrently fractured(Fig.4) and the right lower canine which was only contacting at the occlusal position, had marked mobility.

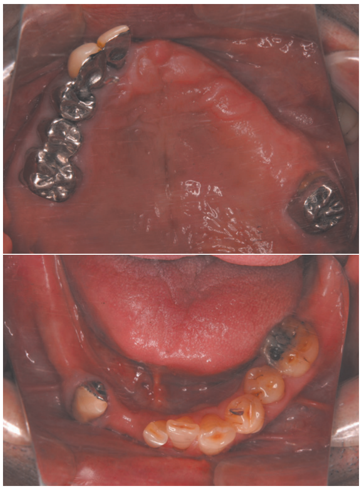

Fig.1 Occlusal view of the remaining dentition at the initial visit.

Fig.2 Intraoral view with and without the existing denture at the initial visit.

Fig.3 Occlusal view with the existing mandibular denture.

Fig.4 Top and bottom view of the existing maxillary denture.

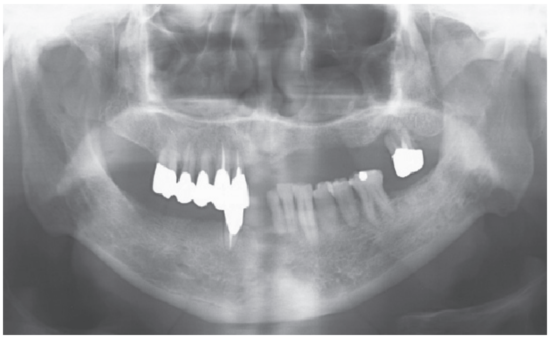

Fig.5 Panoramic radiograph taken at the initial visit.

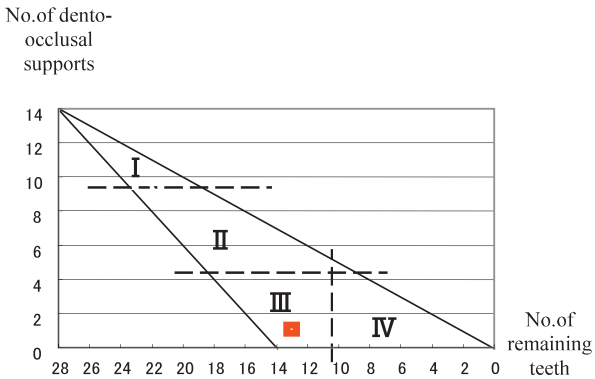

Fig.6 Dento-occlusal triangular relationship corresponding to Miyachi's classification.

A panoramic radiograph showed remarkable distorted resorption of the left maxillary residual alveolar ridge and localized bone resorption around the bucco-mesial root of the extruding left upper second molar(#27, Fig.5). Plotting along the dento-occlusal triangular relationship, according to Miyachi's classification, was located in area Ⅲ, which is called the "collapsed area" (Fig.6), and represented an unfavorable prognosis with fewer occlusal supports despite of the multiple number of remaining teeth.

Treatment Planning and Procedures

A clinical examination revealed the need to fabricate maxillary and mandibular denture separately in order to maintain the existing occlusal height. Due to the patient's economic situation, resin-based dentures were selected within the design limitations of the social health insurance system. The treatment plan was as follows;

- Remove the cast crown of the left upper second molar(#27)
  - → Tri-section and remove bucco-mesial root
  - → Perform a root canal treatment of the remaining roots
  - → Deliver a cast base with a keeper of the magnetic attachment
- Fabricate a maxillary denture first with the existing occlusal height
- Remove the resin-faced crown of the lower right canine(# 43)
  - → Perform a root canal treatment of # 43
  - → Deliver a cast base with a keeper of the magnetic attachment
- Fabricate a mandibular denture with the occlusal height with a newly delivered maxillary denture
- Design the upper and lower partial dentures on the basis of "The Rigid Connecting Concept".

First, to clear the working area and lessen the possibility of a recurrent fracture, the deformed occlusal plane was modified. In addition, the full-cast crown of the isolated extruding #27 was removed, and the bucco-mesial root, which was in poor condition, was extracted following a tri-sectional operation (Fig.7). A magnetic attachment was applied to #27 and, temporarily, to the corresponding upper existing denture (Fig.8).

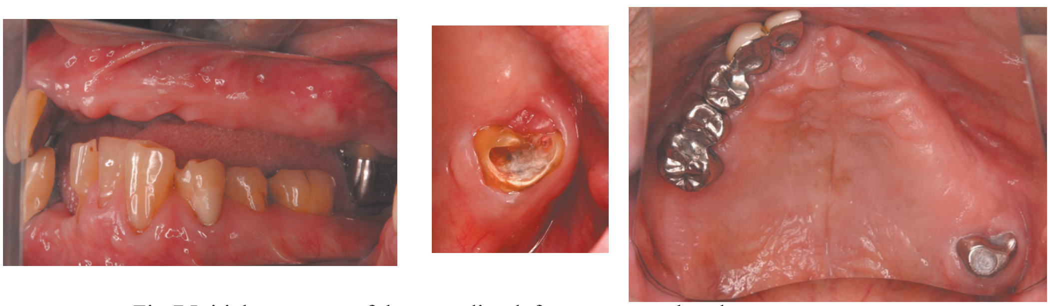

Fig.7 Initial treatment of the extruding left upper second molar.

Fig.8 Repaired existing upper denture with the magnetic assembly

Secondly, a new resin-based upper denture which was designed with a magnetic attachment as the direct retainer and with wrought wire clasps as the indirect retainer was fabricated. With the exception of the retainers, the components of the denture; namely, the occlusal rests, embrasure hooks, and reinforcing framework, were cast with a cobalt-chrome alloy in one piece to increase the rigidity of the denture and effectively distribute the functional loads to each abutment(Fig.9). The reinforcing metal framework was delivered with a T-shape in a cross section(Fig.10) that resists bendingn and squamous processes were added in order to prevent fractures of the buccal portion of the resin base(Fig.10).

Each buccal wrought wire clasp was reinforced with cast embrasure hooks; therefore, the stability of the denture was ensured(Fig.11).

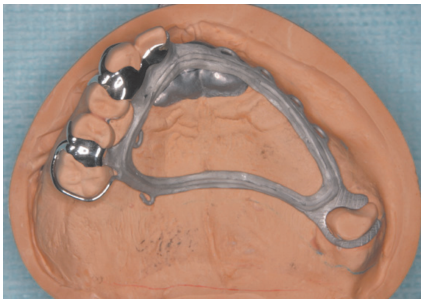

Fig.9 Maxillary framework design on the master cast

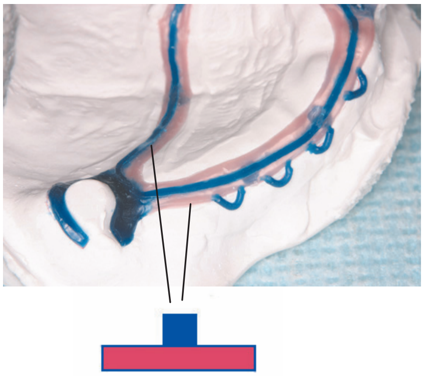

Fig.10 Wax-up of the framework on the refractory cast and the cross-sectional view of the reinforcing bar.

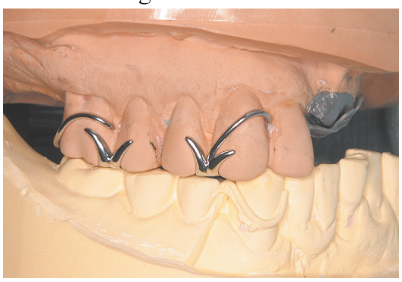

Fig.11 Buccal wrought wire clasps and reinforcing cast embrasure hook

Fig12 Intraoral view and top/ bottom view of the fabricated upper denture with the magnetic assembly.

Thirdly, the resin-faced crown of #43 with marked mobility was removed. Thus the mobility was attributed to occlusal trauma because less periodontal attachment loss was found. To improve crown-root ratio, the canine crown was reduced and a cast base with a keeper of the magnetic attachment was delivered(Fig.13).

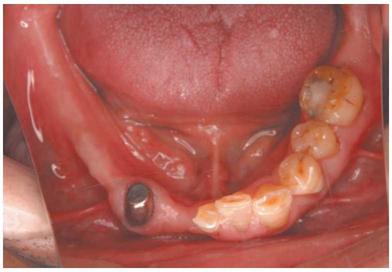

Fig.13 Intraoral view of the delivered cast base with the magnetic keeper on #43.

Fig.14 Occlusal recording for the lower denture with the delivered upper denture.

Finally, the mandibular denture was fabricated with the occlusal height of the new maxillary denture(Fig.14). The magnetic attachment as a direct retainer and wrought wire and cast clasps as indirect retainers were designed with one-piece cast reinforcing framework, as was the maxillary denture(Fig.15).

Occlusal contact was not attained and over closure was presented without upper/lower dentures, whereas a favorable occlusal height at the initial visit was attained with upper/lower dentures (Fig.16). The mobility of the right lower canine was reduced.

Fig15. Lower denture and magnet assembly embedded in the denture.

Fig.16 Intraoral view with and without the fabricated upper/ lower dentures.

In the 3 years since the upper/ lower dentures setting, fracture of the resin base has not occurred, but the wrought wire clasp of the upper denture has become loose and fractured after continuous adjustment. The occlusal height of the upper/ lower dentures has shown a slight decrease(Fig.17).

Continuous follow-up is necessary with bite-up or relining of the denture base to prevent any reduction of the occlusal height. In addition, periodontal management and force control of the remaining dentition are required.

This case suggested that magnetic attachments are useful for distributing overload on abutments and for efficiently obtaining retentive force of dentures.

Fig.17 Three years after setting the upper/ lower dentures.

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14. Development of a Measurement System for Jaw Movement

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Introduction

The number of people who are suffering from temporomandibular arthrosis is increasing. It is fundamental to understand jaw movement to diagnose it. However, it is difficult to measure the jaw movement because it has six degrees of freedom. In addition, measured points are invisible because they are hidden by the skin. Therefore, few of such systems are satisfactory at this point.

To measure jaw movement, a small magnet with 18 three-dimensional magnetic sensors (MI sensors) and Neural Networks (NN) is used. The magnet is attached at the jaw in the measurement area, and 18 MI sensors arranged around the magnet measure the magnetic flux density. Outputs obtained from MI sensors are presented to the NN, and the position and direction of the magnet are estimated. This experiment has been conducted by a computer simulation. According to the results of the computer simulation, estimation errors are up to 10 μm and 0.002 degrees.

For this study, a measurement system that adapts to the computer simulation was developed. The magnet was placed in the measurement area, and the outputs of the MI sensors were obtained. They were presented to the NN, and the position and direction of the magnet were estimated.

Objective

The purpose of this study is to develop an experimental measurement system for jaw movement and confirm its applicability.

Materials and Methods

We developed a device to estimate the position and direction of the small magnet. Figure 1 shows the MI sensor, and Figure 2 shows the device developed in the course of this study. In this study, 18 MI sensors are used as shown in Figure 3 (a), (b), and (c). The direction of the magnet is restricted within 60 degrees, as shown in Figure 3 (c).

As shown in Figure 4 (a), the small magnet is placed in the measurement area (100mm x 100mm x 100mm) with the direction of the magnetic axis turned to the z-axis. The magnet is on the grid point. On the plane, each grid point is away by 10mm on the x-axis, by 30mm on the y-axis, and by 30mm on the z-axis. The output value of 18 MI sensors of 33 points is acquired in each plane. These data are input to the NN, and the coordinates (p_x, p_y, p_z) and the direction (i_x, i_y, i_z) of the magnet are output.

Next, as shown in Figure 4(b), the small magnet is placed in the measurement area with the direction of the magnetic axis inclined 15 degrees (the direction of arrows). Each grid point is away by 10mm on the x-axis, by 30mm on the y-axis, and by 30mm on the z-axis.

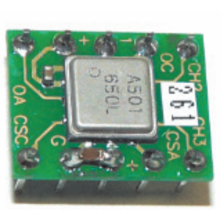


Fig. 1: Three-dimensional magnetic sensor AMI501
Aichi Micro Intelligent Corporation

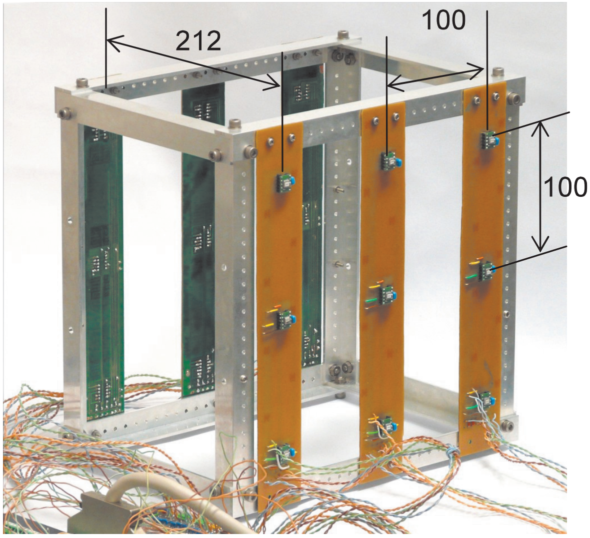


Fig. 2: The experimental device

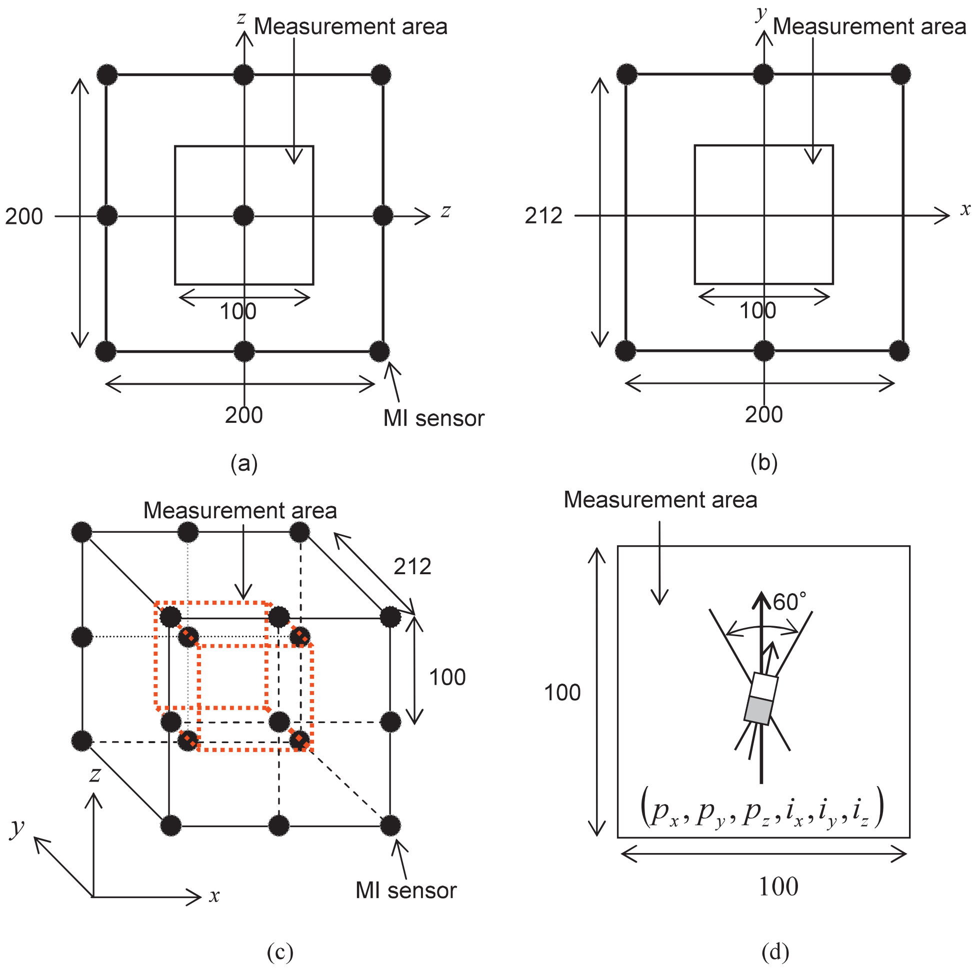
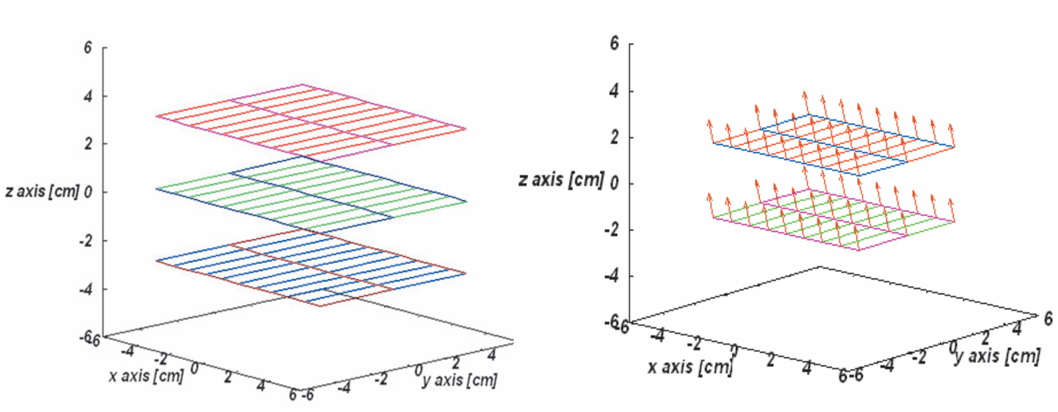


Fig. 3: Measurement area and position of sensors



(a) (b)

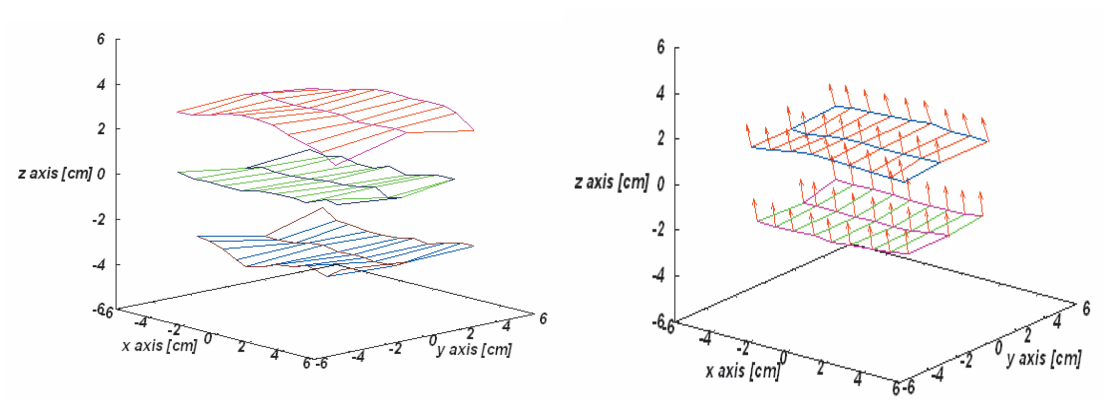
Fig. 4: Position and direction of the magnet

Results

Figure 5(a) shows the output of the NN when the magnet is placed as shown in Figure 4(a), and Figure 5(b) shows the output of the NN when the magnet is placed as shown in Figure 4(b). The results of the error are shown in Table 1.

Table 1: Estimated error of the position and direction

Case	Position error [mm]		Direction error [deg.]	
	Average	Maximum	Average	Maximum
(a)	3.82	13.43	3.20	7.71
(b)	4.67	11.47	4.08	6.36



(a) (b)

Fig. 5: Output of the NN

In our measurement system, the position and the direction of the magnet were estimated with an error margin of about 4.5mm and 4.0 degrees.

Conclusions

We confirmed that the proposed measurement system is available to measure the movement of a magnet. However, in this stage, the accuracy of the measurement is insufficient for use in practical diagnoses.

References

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15. Analysis of Characteristics of Attractive Force of a Magnetic Attachment Using Finite Element Method

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Introduction

A magnetic attachment is a new retainer for a removable denture using an attractive force of a permanent magnet. This device attained widespread clinical use since the first commercially available product was introduced in 1992. Two magnetic circuits of clinically used magnetic attachment assembly are cup and sandwich types (Fig 1). It is widely known that attractive force of a magnetic attachment is markedly affected by air gap between a magnetic assembly and a keeper. However, the functional behavior of a denture using a magnetic attachment still remains to be elucidated since the mechanism of a magnetic attachment is different from that of a conventional mechanical retainer. Although Nakamura[2),3)] from our department has already reported an analysis of a sandwich-type magnetic attachment, the mechanism of a cup type magnetic attachment remains largely unknown.

Fig 1: Magnetic circuit

Objective

We performed an analysis of the mechanical properties of a cup type magnetic attachment as a denture retainer using the Finite Element Method, and compared with that of a sandwich type magnetic attachment to elucidate the mechanical behavior of a denture with magnetic attachments.

Analysis Method

1. Analysis model

GIGAUSS D 600 (GC) was used as a cup type analysis sample (Fig.2). This is the most frequently used magnetic attachment in clinical settings. The measurement of a sample was performed before modeling. The measurement provided by the maker and the actual measurement were checked to know the external shape of an attachment. As for the detailed internal shape, an attachment was embedded, sliced, and measured since the maker does not provide any information. Figure. 3 shows the measured size of a sample. The MENTAT (MSC. Software) was used to construct analysis model. Figure. 4 shows the analaysis model where a magnetic assembly and a keeper are in contact in maximum area. The element type was quadrilateral element. Element count was 10302, and nodal point was 10506. Element breakdown of the analysis area 10 mm in height and width was performed, and the result was set as an analysis object range.

Fig 2: GIGAUSS D600 （ GC ）

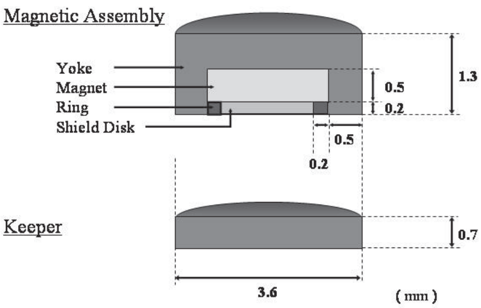

Fig 3: Size of the magnetic attachment

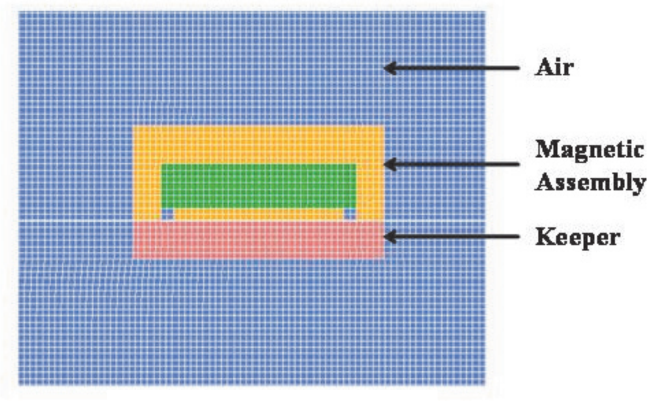

Fig 4: Analysis Model

2. Analysis condition

The magnet used in the present study was neodymium iron boron (Nd-Fe-B), and the magnetic stainless steel for the yoke and keeper were SUS447J1. The magnetic characteristic value was determined based on the thermal characteristic of GIGAUSS D600 obtained by Miyata[4] in our department and maker's catalog. The original material of a yoke and keeper was SUSXM27. However, the value for SUS447J1 which is considered to have the similar magnetic characteristics as SUSXM27 was assigned since detailed information regarding its magnetic characteristics was not provided. The B-H curve was approximated from these values, and regarded as magnetic characteristics (Table 1). The GiD (CIMNE) was used for the input of the analysis condition. The MAGNA/FIM (CTC Solution) and GiD (CIMNE) were used for the analysis and the analysis result display, respectively. Nastran format was used for the file exchange between MENTAT and GiD.

Table1: Analysis conditions

- **Component**
  - Magnetic assembly magnet : Nd-Fe-B
    Yoke : SUS447J1
  - Keeper : SUS447J1

- **Magnetic Characteristic**
  - Magnet (BH) max = 46 MGOe
    Residual magnetic induction = 1.22 T
  - Yoke Saturation magnetic induction = 1.35 T

    B-H curve $B = Bs\{1 - \exp(-\mu_r \cdot \mu_0 \cdot H / Bs)\}$

3. Analysis items

There were 8 analysis items including 4 items of vertical displacement and 4 items of horizontal displacement (Fig. 5). The amount of displacement was set based on the Nakamura's [2),3)]report regarding the analysis of a sandwich-type magnetic attachment. The analyses were performed on the magnetic flux density distribution and attractive force when the vertical and horizontal displacements were applied between a magnetic assembly and a keeper.

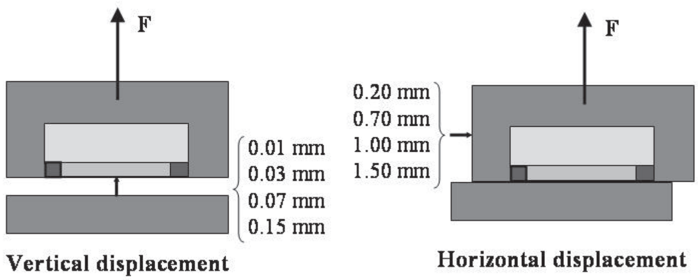

Fig 5: Analysis items

Results

1. Magnetic flux distribution

For the vertical displacement (Fig. 6), magnetic flux distribution density in a yoke decreased with an increase of displacement amount both in the sandwich and cup types. In the cup type, an increase in the leak magnetic field around the attraction face was confirmed with an increase of the displacement amount, but no leak magnetic field was found around the upper part of a magnetic assembly as was seen in the sandwich type. For the horizontal displacement (Fig. 7), the leak magnetic field was the smallest in 0.2 mm, followed by 0.70, 1.00, and 1.50 mm. This is because the right edge of a keeper has a contact with the lateral side of a yoke in the displacement amount of 0.2 mm, but not in the other displacement amount. An increase in the magnetic flux distribution density was observed in the left side of a yoke with an increase of horizontal displacement amount. A significant change was noted in the magnetic flux density in the horizontal displacement when unilateral yoke loses contact with a keeper.

2. Attractive force

For the vertical displacement (Fig. 8), the attractive force significantly decreased with an increase of the displacement amount. The attractive force in displacement amount of 0.03 mm was 370 g in the cup type, and 500 g in the sandwich type. The reduction rate in the attractive force was 30% in the cup type, and 20% in the sandwich type. In displacement amount of 0.15 mm, the attractive force decreased by 80% in the cup type, and 63% in the sandwich type. For the horizontal displacement (Fig. 9), a decrease in the attractive force was milder compared to the vertical displacement. In displacement amount of 0.2 mm, the attractive force decreased by 10% in the cup type, and by 5% in the sandwich type. The attractive force in the displacement amount of 1.0 mm was 190 g in the cup type, and 290 g in the sandwich type. The reduction rate in the attractive force was 64% in the cup type, and 53% in the sandwich type. The decreasing trend in the attractive force during the vertical and horizontal displacements of a magnetic attachment was similar between the cup and sandwich types.

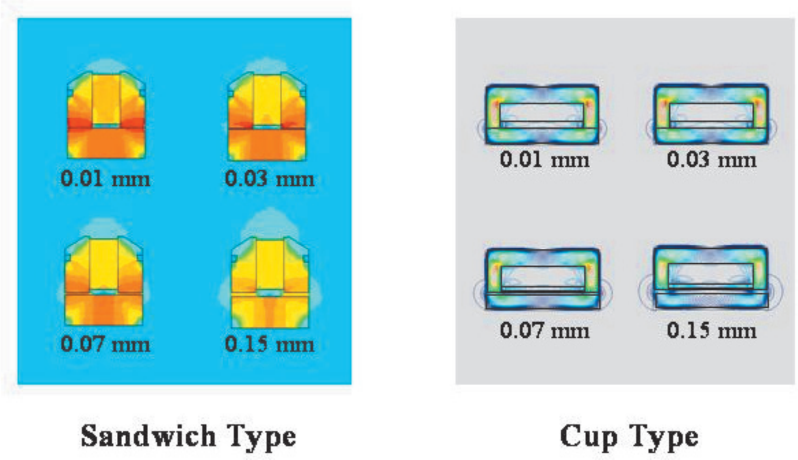

Fig 6: Magnetic flux distribution for the vertical displacement

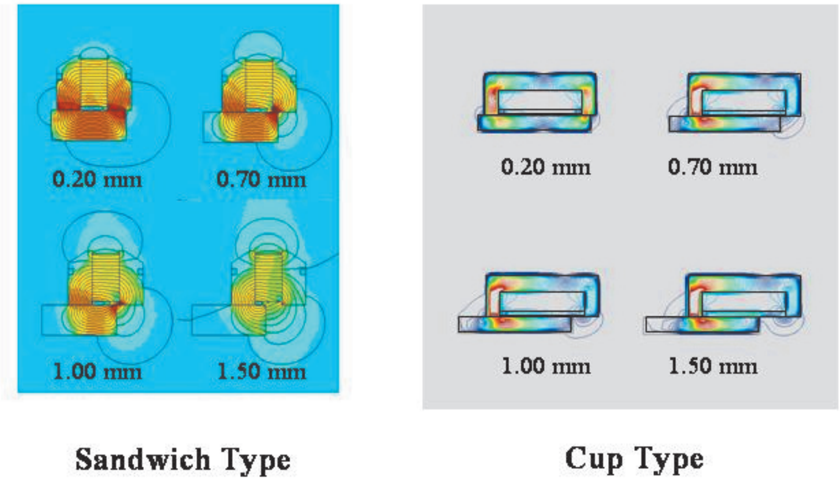

Fig 7: Magnetic flux distribution for the horizontal displacement

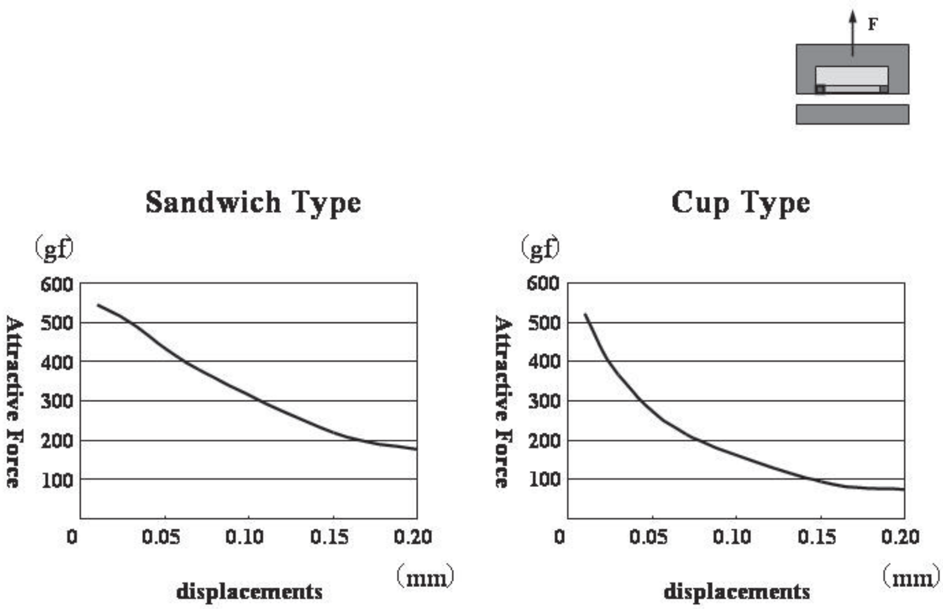

Fig 8: Attractive force for the vertical displacement

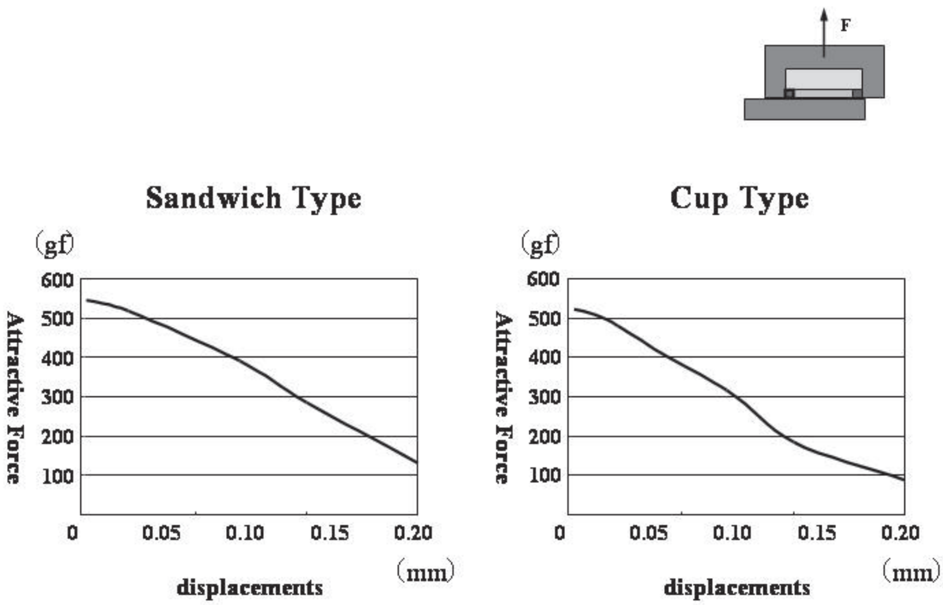

Fig 9: Attractive force for the holizontal displacement

Discussions

Little is known about the detail in the dynamics of the attractive and repulsion forces created by a magnet. Although magnetic force and magnetic field can be calculated using a device, it is difficult to design a magnet with maximum magnetic force based on the results, and to verify the optimization of the minimal leak magnetic field. Finite Element Method is the most effective and only way to visualize the dynamics and run a simulation by changing conditions. The two dimensional analysis in the present study reproduced the internal shape precisely, and simulate a change in the magnetic force and magnetic field by a subtle displacement. In the cup type magnetic attachment that we focused in the present study, an increase in the leak magnetic field was more evident compared with a sandwich type when a magnetic assembly displaced horizontally against a keeper, and the contact area between a yoke and keeper of a magnetic assembly decreased. A magnetic attachment protects an abutment by reducing the lateral force. However, the structure that minimizes the leak magnetic field needs to be validated. The value for SUS447J1 which is considered to have the similar magnetic characteristics as SUSXM27 was assigned since detailed information regarding SUS447J1 was not provided.

The B-H curve was approximated, and regarded as magnetic characteristics of a magnetic attachment. The challenges for the future include the accurate measurement of values, and finding a material with better magnetic characteristics.

Nakamura in our department reported that the difference in the magnetic reduction trend was found between the two and three dimensional models with an increase of air gap. Further study is needed to verify the maximum degree of air gap when valid two dimensional analysis results can be obtained considering the complexity of three dimensional model construction, time efficiency, and performance of a computer.

Conclusions

We performed an analysis of the mechanical properties of a cup type magnetic attachment as a denture retainer using the Finite Element Method, and compared with that of a sandwich type magnetic attachment to elucidate the mechanical behavior of a denture with magnetic attachments. The following results were drawn:

1. In the cup type magnetic attachment, the attractive force decreased significantly when a magnetic assembly and a keeper separate vertically and horizontally, and create a magnetic space.
2. The results reaffirmed the difference in the magnetic flux density distribution around a magnetic assembly and a keeper in different magnetic circuit.

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16. An Application of a Magnetic Attachment to Cast Clasp - Development of a Magnetic Rest Clasp -

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Introduction

The increased emphasis on physical appearance in contemporary society has increased the demand for esthetic dental treatment.

The metallic color of the buccal clasps on premolars or canines is one of the common causes of patient rejection. The appearance would be vastly improved if metal buccal clasps were eliminated. However, the retentive function of clasps eliminated buccal arms is extremely poor. We developed a new retainer of no buccal clasp arm with the magnetic attachment in the occlusal rest of clasps (Magnetic Rest Clasp).

Objective

The purpose of this study is to introduce the fabrication of a new retainer, a “Magnetic Rest Clasp,” for lower premolars with a plastic jaw model having artificial teeth.

Materials and Methods

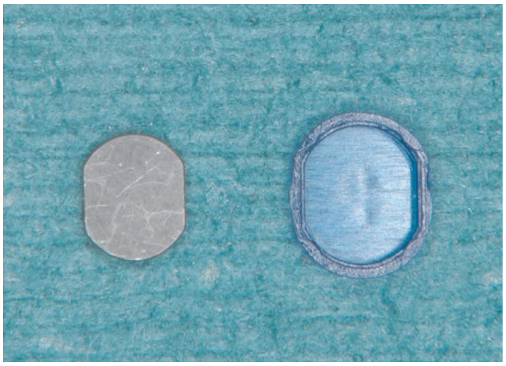

Fig.1 Keeper and its housing pattern
GIGAUSS C400 (GC) used in this study.

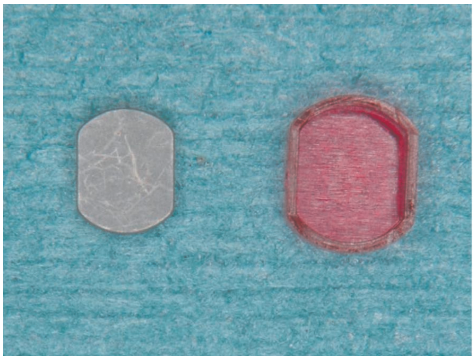

Fig.2 Magnetic assembly and its housing pattern

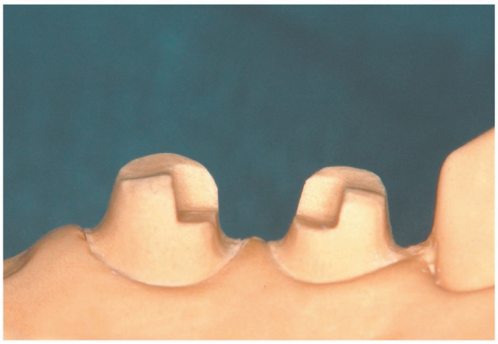

Fig.3 Working model (lingual view of the abutments)
The abutments have partially concave forms for the magnetic attachment.

Fig.4 Working model (occlusal view of the abutments)

Fig.5 Wax pattern of connected full-cast crown
The wax pattern has a guide plane on the lingual and distal sides.

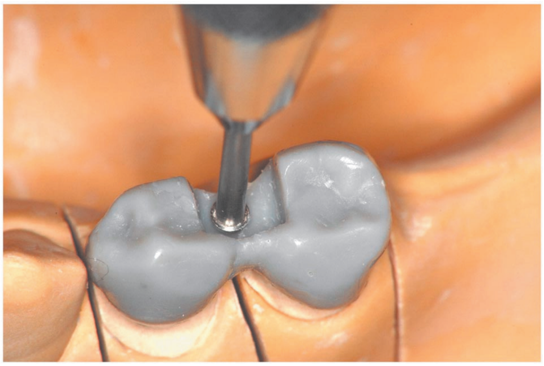

Fig.6 Space adjustment of the wax pattern for the keeper and magnetic assembly with a surveyor
A minimum 0.3mm thickness of wax between the keeper and abutment is required for proper casting.

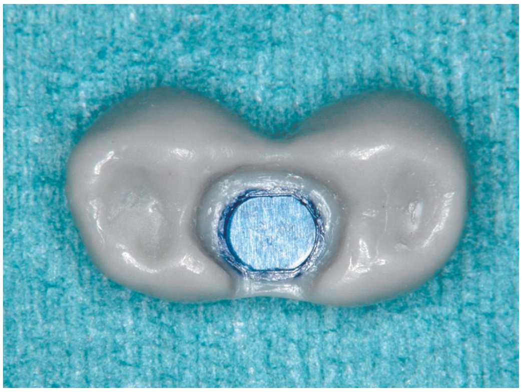

Fig.7 Wax pattern with a keeper housing pattern

Fig.8 Connected full cast crown without a keeper on the working model (lingual view)

Fig.9 Connected full cast crown without a keeper on the working model (occlusal view)
The connected full cast crown is cast with a 12% gold and silver palladium alloy (CASTWELL M.C., GC).

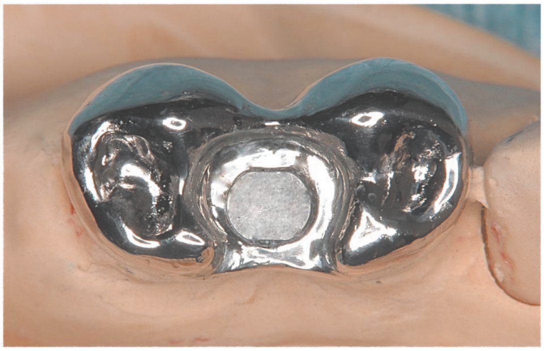

Fig.10 Connected full cast crown with a keeper on the working model
The keeper is fixed with a cementing material (Super-Bond C&B, SUN MEDICAL).

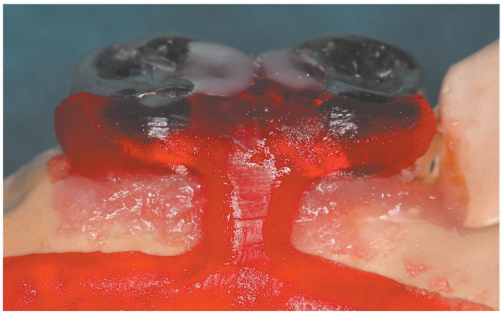

Fig.11 Resin pattern of the Magnetic Rest Clasp and minor connector incorporating the magnetic assembly housing pattern (lingual view)
This pattern has no buccal clasp arm.

Fig.12 Finished Magnetic Rest Clasp (lingual view)

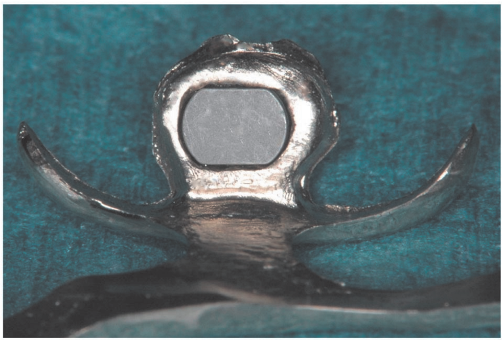

Fig.13 Inner surface of the Magnetic Rest Clasp
The magnetic assembly is fixed with a cementing material (Super-Bond C&B, SUN MEDICAL).

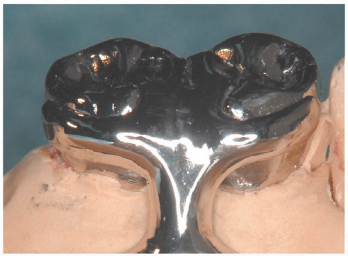

Fig.14a

Fig.14b

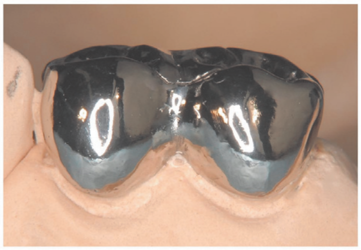

Fig.14c

Fig.14 Magnetic Rest Clasp seated in the connected full cast crown on the working model
a: lingual view b: occlusal view c: buccal view

Conclusions

In this study, we introduced the fabrication of a new retainer "Magnetic Rest Clasp" for lower premolars with a plastic jaw model with artificial teeth. For the future we will try to apply the Magnetic Rest Clasp to the porcelain fused to metal crown for patients.

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How to Write the proceedings

TiTle including No. : Times New Roman 14pt Bold

0.5 line

Name (Initial. Family name) : Times New Roman 11 pt, (indent of a 0.5 line above and under this line)
ex. Y. Takada, N. Takahashi[1] and O. Okuno[2]

0.5 line

Affiliation: Times New Roman 11 pt, ex. Division of Dental Biomaterials, Graduate School of dentistry, Tohoku University
[1]Depatrtment of Magnet Science, School of Dentistry, Inaka College
[2]Laboratry of Magnet, Institute of Sendai

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The components of a paper are (in order of appearance)

Introduction
Objective
Materials and Methods
Results or (Results and discussion)
Discussion
Conclusion
Acknowledgements
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One line

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0.5 line

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- be written by the standard format of MS Word 2003 (number of characters and lines in a page)

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References

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1. Journal article (example): Y. Takada, N. Takahashi and O. Okuno: Electrochemical behavior and released ions of the stainless steels used for dental magnetic attachments, J J Mag Dent, 16(2), 49-52, 2007.
2. Book (example): R. Kunin, On Exchanging Resins, pp 88, Robert E. Kreiger Publishing Company, New York, 1972.