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Analysis of Abutment Tooth Movement utilizing Mandibular Kinesiograph (MKG)
Part 2. Effects of Clasp Design in Unilateral Free-end Denture

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The three-dimensional dymanic movement of the abutment tooth was successfully analyzed on a simulation model utilizing the mandibular kinesiograph. When the unilateral free-end denture retained by the RPA, RPI or Aker's clasp was subjected to various directions of loads, the abutment tooth was inclined mainly by the sliding displacement of the denture over the alveolar ridge and the lever action around the denture. The Aker's clasp assembly induced the largest tooth movement. The RPA clasp generally exhibited similar tendencies to the Aker's clasp, showing a larger tooth inclination in the disto-buccal direction. The RPI clasp seemed to be preferable for protecting the periodontal tissues from damage associated with unfavorable tooth movements since it induced less distal tooth inclination.

Key words : Abutment tooth movement, Clasp, MKG

INTRODUCTION

In removable partial prostheses, especially in distal extention partial dentures, the abutment tooth is subjected to various forces from the displacement or depression of the denture during mastication or swallowing. They may cause a movement or inclination of the tooth resulting in the damage of its periodontal tissues. Thus, the concept of stress breaking has been introduced and some modifications have been made on the form and shape of the clasp assembly.

The mechanical behaviors of abutment teeth and partial prostheses have been investigated in various ways using strain gauge, photoelastic and finite element methods[1-10]. However, it is difficult with these methods to detect the three-dimensional dynamic movement of the abutment tooth. Therefore, the application of the mandibular kinesiograph (MKG) has been tried in these investigations.

The characteristic aspects of the MKG record were examined in the previous report[11], and it was found that the MKG method might be valid for estimating the abutment tooth movement by adequate geometrical correction of the record.

In the present study, the dynamic movement of the abutment tooth was three-dimensionally recorded using the MKG for the unilateral free-end denture on a simulation model. The behaviors of the tooth were then compared among the three types of clasps to evaluate the partial denture design.

MATERIALS AND METHODS

The unilateral free-end denture was constructed on a simulation model of Kennedy class II as shown in Fig. 1. It was retained by the RPA, RPI or Aker's clasp on the first premolar abutment tooth. A gap of 0.5 mm was given between the abutment tooth and the canine so as to detect the mesial movement of the tooth. Figure 2 shows the configurations of the clasp assemblies used. The gingival and alveolar ridge areas of the model were covered with 1.2 mm thick silicone material for simulating the resilient natural mucosa. A thin coating with the same material was also applied to the root of the abutment tooth to form a pseudo-periodontal membrane. The thickness of the coating was 0.4 mm for the side wall and 0.7 mm

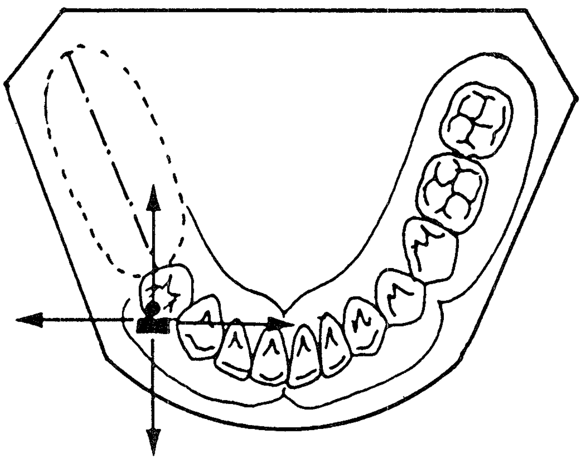

Fig. 1 Simulation model of Kennedy Class II.
The arrows denote the orientations of measurement with magnet in MKG assembly.

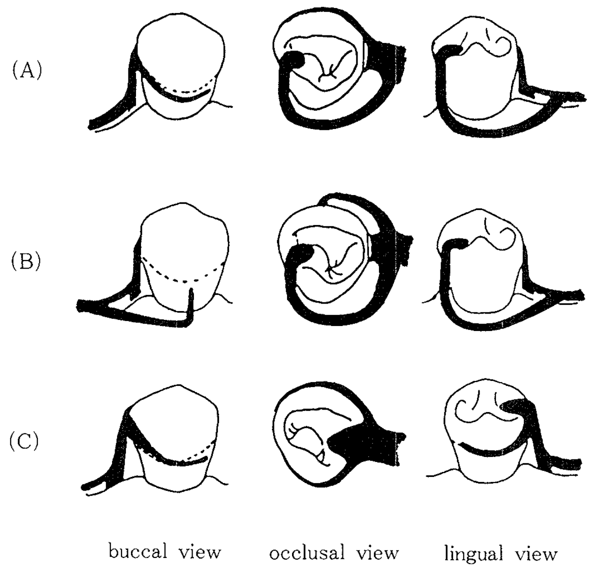

Fig. 2 Designs of the retainers.
(A) : RPA clasp (B) : RPI clasp by Krol (C) : Aker's clasp

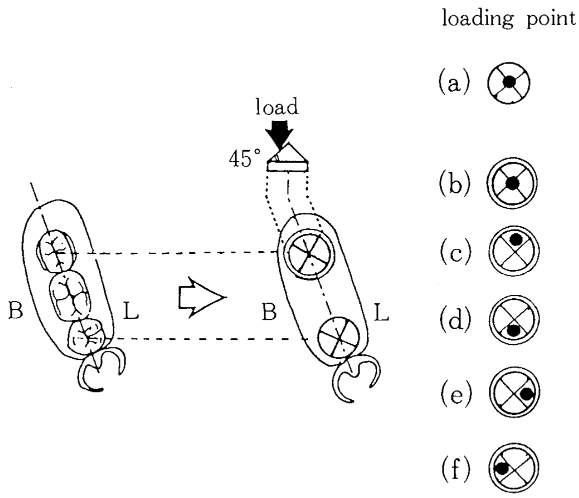

Fig. 3 Experimental unilateral free-end denture and loading points on the pyramids substituting for the second molar and premolar.
The load was vertically applied on the following points.
(a) : top of the second premolar pyramid
(b) : top of the second molar pyramid
(c) : distal oblique plane of the second molar pyramid
(d) : mesial oblique plane of the second molar pyramid
(e) : lingual oblique plane of the second molar pyramid
(f) : buccal oblique plane of the second molar pyramid

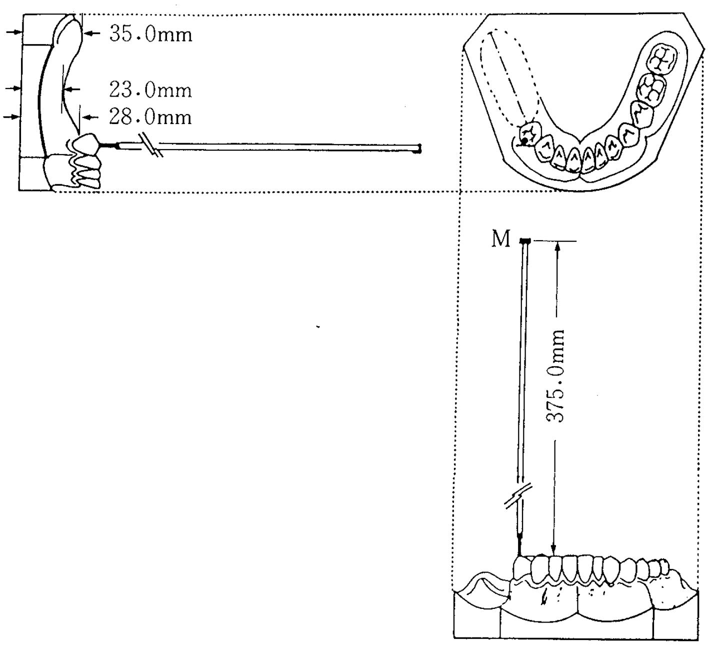

Fig. 4 Wooden rod extension arm for magnifying the tooth movement.
The magnet (M) for MKG was installed on the top of the arm.

for the apex.

The denture had two pyramid cones substituting for the second molar and premolar so that a simple vertical load and a load having a laterally dissolved component could be imposed at the top of the pyramid and each oblique plane, respectively. The experimental denture and the loading points are schematically drawn in Fig. 3.

A wooden rod extension arm 375 mm in length was fixed on the cusp of the abutment tooth (Fig. 4). The magnet for the MKG assembly† was installed on the top of the arm. A load up to 5 kg was vertically applied on the pyramid with the use of a portable type digital tension-compression tester††. The resulting movement of the abutment tooth cusp was recorded through the MKG, and the record was geometrically corrected onto the rectangular coordinates in the manner described in the previous report[11].

RESULTS

Figures 5-1 and 5-2 show the corrected MKG records of the trace of the abutment tooth crown movement when a load up to 5 kg was applied onto the molar or premolar of the free-end denture. The interspace between the dotted lines was 1 mm for the magnet movement on the MKG display but the real interspace for the tooth movement was 1/47 mm since the movement was magnified by the extension arm. The x-, y-, and z-axes were defined as the median line, transverse line perpendicular to the median line, and the vertical line, respectively, according to the previous report[11]. The alveolar ridge line in the molar and premolar region formed an angle of about 10 degrees with the median line, and it was drawn together with the perpendicularly intersecting bucco-lingual line by the chain lines on the horizontal view record.

Figure 5-1 (a) shows the tooth movement when a simple vertical load was applied onto the second premolar of the denture. Referring to the MKG record patterns of the movement in the representative directions in the previous report[11], it was found that the RPA clasp assembly produced the mesio-linguo-downward movement, *i. e.* inclination in the mesio-lingual direction of the abutment tooth. In the RPI clasp, the tooth was once slightly inclined toward the disto-lingual direction and then toward the mesial direction along the alveolar ridge line. In the Aker's clasp, on the other hand, the tooth was apt to incline toward the mesial side slightly meandering laterally. The path was the longest in the RPI clasp.

When the vertical load was applied on the second molar, the RPA and Aker's clasp assemblies showed an inclination of the tooth toward the mesial side along the alveolar ridge line after once inclining the tooth toward the disto-buccal direction (Fig. 5-1 (b)). The tooth was inclined toward the mesial direction almost over the alveolar ridge in the case of the RPI.

For the vertical load on the distal oblique plane having the mesially dissolved force, the abutment tooth was inclined toward the mesio-buccal direction, showing a larger mesial component in the RPA and Aker's clasps (Fig. 5-1 (c)). The RPI clasp produced the straight inclination of the tooth to the mesial side over the alveolar ridge.

Figure 5-1 (d) shows the tooth movement for the vertically applied load on the the mesial oblique plane of the second molar. The RPA clasp caused a simple distal inclination of the tooth over the alveolar ridge. In the RPI clasp, the tooth was inclined toward the disto-buccal direction for a while and suddenly turned toward the opposite direction. In the Aker's clasp,

† Model K6, Myo-tronics Research Inc., Seatle, USA
†† ps-10, Showa Measuring Instruments Co., Tokyo, Japan

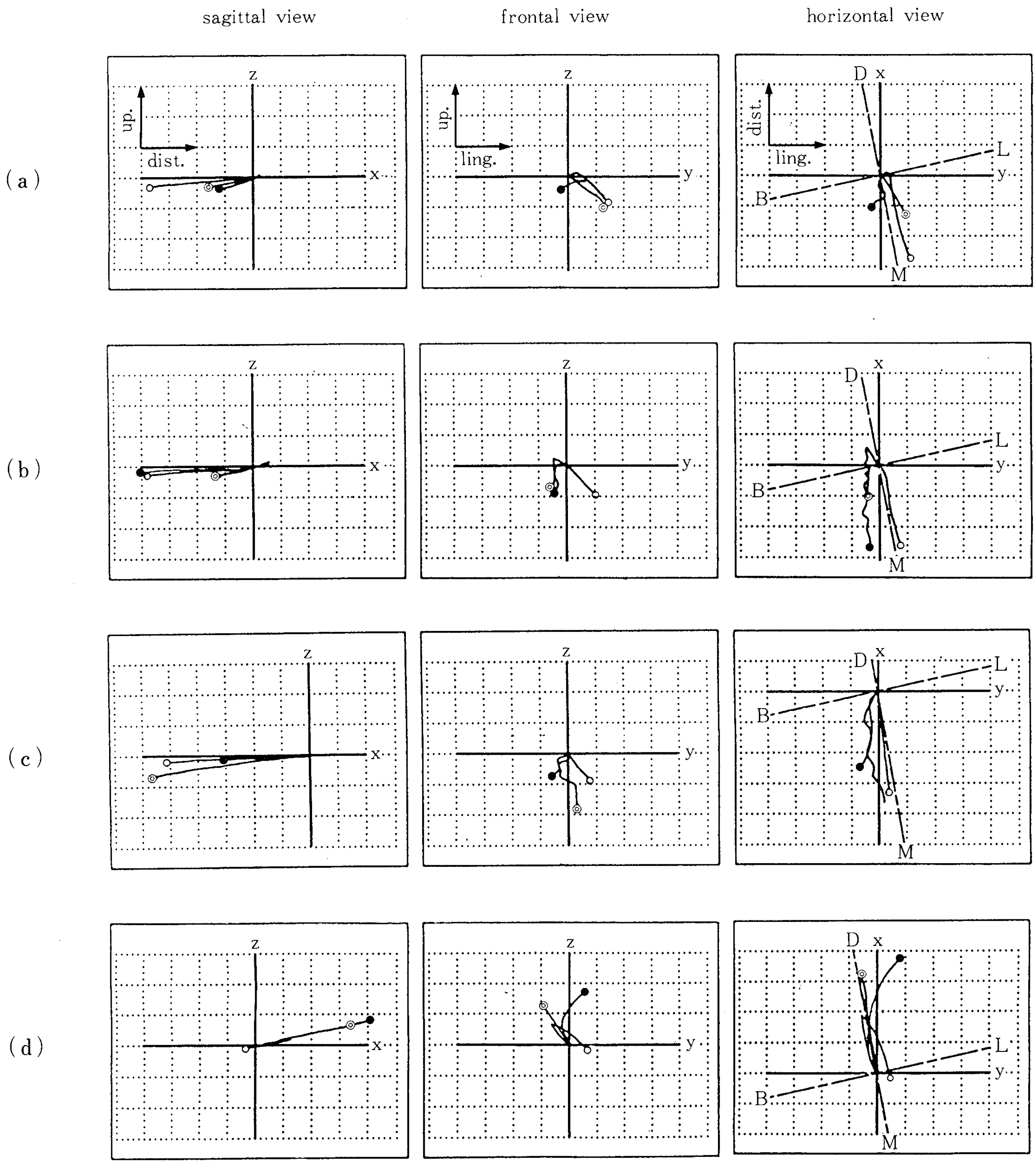

Fig. 5-1 MKG records of abutment tooth movements when a load was applied on the points shown in Fig. 3.
D, M, B and L in the horizontal view denote the distal, mesial, buccal and lingual directions, respectively, on the molar alveolar ridge of the model.
◎: RPA clasp ○: RPI clasp ●: Aker's clasp

the tooth was inclined first toward the disto-buccal direction and then changed its movement toward the disto-lingual direction. The path was the largest in the three clasps.

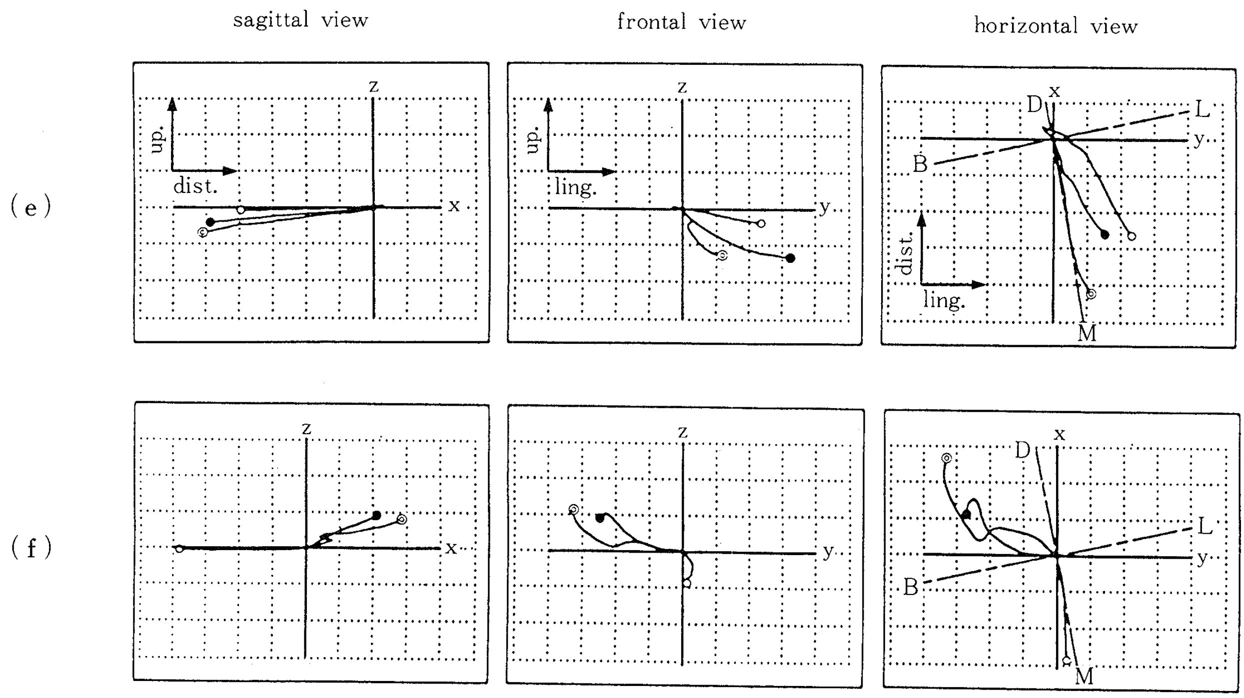

Fig. 5-2 MKG records of abutment tooth movements when a load was applied on the points shown in Fig. 3.
D, M, B and L in the horizontal view denote the same directions as those in Fig. 5−1.
◎: RPA clasp ○: RPI clasp ●: Aker's clasp

When a vertical load was applied on the lingual oblique plane, the RPA clasp showed a mesial inclination of the tooth over the alveolar ridge as seen in Fig. 5-2 (e). In the RPI clasp, the tooth was slightly inclined toward the disto-buccal direction and then moved toward the mesio-lingual direction. The Aker's clasp caused a simple inclination of the tooth in the mesio-lingual direction.

When the vertical load was applied on the buccal oblique plane, only the RPI clasp showed the mesial inclination of the tooth with a slight buccal component (Fig. 5-2 (f)). On the contrary, the tooth was largely inclined disto-buccally in the RPA and Aker's clasps although there were significant differences in the process between them.

Figure 6 shows the resultant areas of mobility of the abutment tooth when the 5 kg load was applied to the free-end denture in various directions at the molar or premolar. A larger distal domain was observed in the Aker's and RPA clasps, in which the disto-buccal inclination was marked. In the RPI clasp, on the other hand, most of the tooth movement included the mesial component.

DISCUSSION

The MKG has a disadvantage that it does not show good linearity in its records over wide ranges. However, it was useful for three-dimensionally analyzing the dynamic movement of the abutment tooth with the unilateral free-end denture on a simulation model, in which the record of the tooth movement could be geometrically corrected in the same way as shown in the previous report[11].

When a simple vertical load was applied onto the second molar or premolar of the denture, the abutment tooth was inclined downward in the mesial direction with some buccal or lingual deviations from the alveolar eidge line in all types of clasp assemblies. It indicates that the denture might slide over the sloping alveolar ridge toward the abutment tooth to push the tooth crown. In the RPI clasp assembly only, a slight inclination of the tooth in the disto-buccal direction was observed at the early stage of loading probably due to the lever action. However, it seems that the vertical loading would preferably induce the sliding displacement of the denture along the downward slope of the alveoalr ridge rather than the lever action around the denture.

It is reasonable that the tendency of the tooth to be inclined toward the mesial direction was accelerated by the application of the load having a mesially dissolved component (Fig. 5-1 (c)).

When the load having a distally dissolved component was applied onto the second molar of the denture, on the other hand, the abutment tooth movement was distinctive among the clasp assemblies used (Fig. 5-1 (d)). The tooth with the RPA clasp was largely inclined toward the distal direction over the alveolar ridge line, while the Aker's clasp inclined the tooth disto-lingually showing the largest movement of the three. In the case of the RPI clasp, the tooth was once lnclined distally and suddenly went back toward the original position. It is commonly accepted that this type of clasp is inferior to the other two in bracing the abutment tooth. This may allow the clasp to easily move out of place as the displacement of the denture increases, resulting in such a singular behavior of the tooth.

For the load having a transverse component, the tooth showed larger movement which was partly associated with the lever action around the denture. An especially marked disto-buccal inclination of the tooth was found in the RPA and Aker's clasp assemblies when

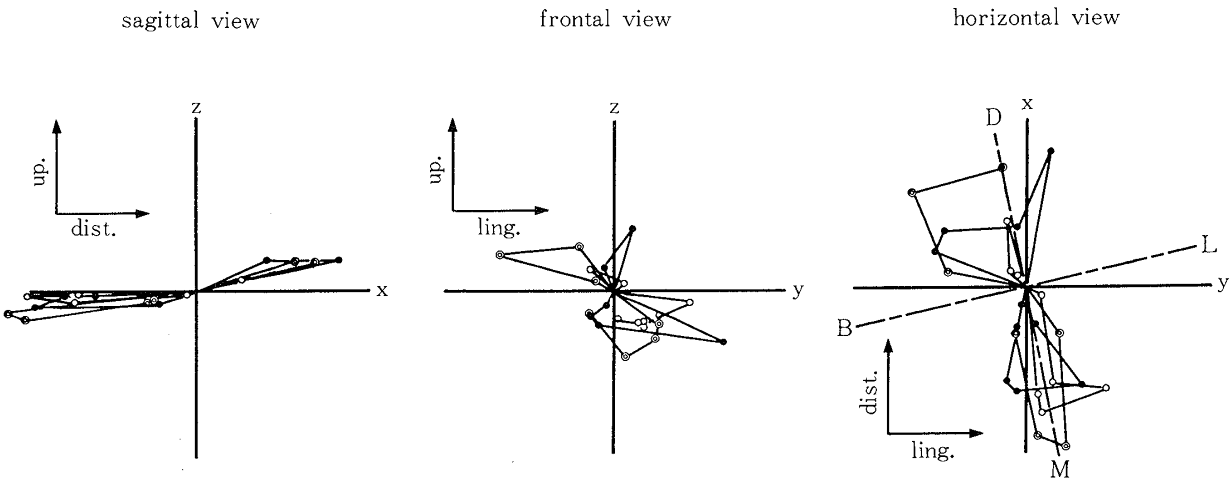

Fig. 6 Areas of mobility of the abutment tooth crown for various directions of loading up to 5 kg.
D, M, B and L in the horizontal view denote the distal, mesial, buccal and lingual directions, respectively, on the molar alveolar ridge of the model.
◎: RPA clasp ○: RPI clasp ●: Aker's clasp

the load involved lingually dissolved component.

It has been generally accepted that the Aker's clasp causes unfavorable abutment tooth movements[12-19]. The RPI clasp was devised to eliminate such disadvantages with the Aker's. The RPA clasp was designed by further modifying the form and shape of the RPI. Nevertheless, it was found in this study that the behaviors of the abutment tooth with the RPA clasp were more similar to those of the Aker's than to those of the RPI. As seen in Fig. 6, the Aker's and the RPA clasps showed a tendency to induce larger inclination of the abutment tooth in the distal and buccal directions.

A gap of 0.5 mm was given between the abutment tooth and the canine in this study to secure the allowance for the tooth to move mesially. In the practice, however, it is expected that the mesial tooth movement would be restrained by the presence of the adjacent canine and the following teeth. Therefore, the situation producing mesial direction of the tooth movement may not always be a serious problem. On the contrary, such a restraint cannot be expected against distal movement because of the absence of any barriers. The frequent and larger movement or inclination of the abutment tooth will cause damage to its periodontal tissues. From this point of view, the Aker's and the RPA clasp assemblies seem to be less favorable than the RPI because of their tendencies to induce a larger inclination of the tooth in the distal direction. The distal direction of tooth movement was minimized by the use of the RPI clasp. Even if the displacement of the denture occurs in the distal direction to pull the abutment tooth, the RPI clasp may easily slip over the tooth as the displacement of the denture increases as seen in Fig. 5-1 (d). The inferiority of the RPI clasp in bracing may be rather favorable in protecting the periodontal tissues from damage.

The depression, displacement and lever action of the denture in use may be affected by intraoral conditions such as the configuration of the alveolar ridge, resilience and thickness of the mucous membrane, and fitness of the denture base. Since it was suggested that tooth movement would be more or less induced by any clasp assemblies, however, its characteristic aspects with an individual clasp should be taken into consideration in designing a unilateral free-end denture.

CONCLUSION

The dynamic movement of the abutment tooth was three dimensionally analyzed on a simulation model utilizing the mandibular kinesiograph when various directions of loads were applied on the unilateral free-end denture retained by the RPA, RPI or Aker's clasp.

The tooth was inclined mainly by the sliding displacement of the denture over the alveolar ridge and the lever action around the denture, although the distinctive aspects were observed among the clasps used. The Aker's clasp assembly induced the largest tooth movement. The behaviors of the RPA clasp were generally similar to those of the Aker's. They showed a larger disto-buccal inclination of the tooth. The RPI clasp seemed to be preferable for protecting the periodontal tissues from damage associated with larger tooth movement since it induced less inclination of the tooth in the distal direction.

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分子鎖の運動性に依存しており，鎖長の短い Bis-MEPP をベースモノマーとしたコンポジットレジンは Bis-MPPP や Bis-$ME_{2.6}$PP に比べ，脆性に富む傾向が認められた。

歯科用銀基合金の腐食と変色（第1報）電気化学的腐食試験

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3種の市販銀合金，Ag-Sn-Zn, Ag-In および Ag-Pd-Cu 合金の腐食挙動を 0.1%硫化ナトリウム溶液とリンゲル液中で，電気化学的手法を用いて調べた。

Ag-Sn-Zn 合金は，0.1%硫化ナトリウム溶液中よりもリンゲル液中において腐食するのに対し，Ag-Pd-Cu 合金は逆に，リンゲル液中ではほとんど腐食しないが，0.1%硫化ナトリウム溶液中において著しく腐食した。Ag-In 合金は 0.1%硫化ナトリウム溶液およびリンゲル液中で同程度に腐食した。

特に，Ag-Pd-Cu 合金は，0.1%硫化ナトリウム溶液中における腐食速度がリンゲル液中の約 500 倍にも達し，硫化物イオンあるいは硫化水素イオンを含む溶液中で，表面が単に変色するのみならず，腐食により著しく劣化することが明らかとなった。

歯科用銀基合金は，その成分・組成により腐食に影響するイオン種が異なる。したがって，腐食試験を行なう際には，個々の合金系において，口腔内で起こると考えられる重要な腐食反応を充分に検討した上で，最適な腐食液を選定する必要がある。

MKG による鉤歯の挙動の分析
第2報，片側遊離端義歯におけるクラスプ・デザインの影響

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片側遊離端義歯の維持装置として，RPA, RPI, および Aker の三種類のクラスプをシミュレーション・モデル上に設定し，鉤歯の三次元的動的挙動をマンディブラーキネジオグラフ (MKG) を用いて分析し，比較検討した。

義歯床の第二小臼歯および第二大臼歯相当部に種々の荷重を加えることによって，鉤歯はその歯根を回転中心とした傾斜的挙動を示したが，Aker デザインのものが最も著しく，遠心頬側への傾斜が認められた。RPA も概略的にみて Aker の場合と類似した傾向を示した。RPI においては，鉤歯を遠心に牽引する傾向が最も少なかった。歯牙は側方的な力に対して耐性が極めて小さいという構造的な特徴から考えて，RPI のこの性質は，鉤歯々周組織保護の観点から今回の三種類の維持装置のうちでは最良のクラスプであろうと考えられた。

歯科用アマルガムの曲げクリープとクリープ破壊

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6種の歯科用アマルガムの曲げクリープを異なる静荷重下で最長 30 日間連続的に測定した。その結果，試験した 6 種のアマルガムは 30 日以内のうちに 9 kgf の静荷重下ですべてクリープ破壊を起こした。また，これより低い荷重下でもいくつかのアマルガムはクリープ破壊を起こした。高銅アマルガムは，従来型の低銅アマルガム