Analysis of Abutment Tooth Movement utilizing Mandibular Kinesiograph (MKG)

Part 1. Characteristic Aspects and Correction of MKG Records

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For the purpose of applying the mandibular kinesiograph (MKG) to the analysis of the abutment tooth movement to evaluate the partial denture design, the characteristic aspects of the MKG record were examined. The rectangular lattices resulting from shifting the magnet in the mesio-distal, right-left, and up-down directions were considerably distorted on the display. However, it was assumed that the three dimensional movement of the tooth could be approximately estimated by a simple correction of the record utilizing those distorted lattices in the sagittal, frontal and horizontal views. If only the record is appropriately interpreted on the basis of the characteristic aspects of the MKG, the MKG method may be valid for estimating the abutment tooth movement in evaluating the design of partial prostheses.

Key words : Abutment tooth movement, MKG, Correction of record

INTRODUCTION

One of the primary concerns in partial prosthodontics may be the behavior of the abutment tooth depending on the form and shape of the retainer as well as those of the other components of the prostheses. The mechanical behaviors of abutment teeth and partial prostheses have been investigated in various ways such as by strain gauge, photoelastic and finite element methods¹⁻¹⁰⁾. Although they are individually valid for particular purposes, the three dimensional dynamic movements involving the rotation or displacement of the abutment tooth cannot readily be analyzed with them.

The authors have attempted to apply the mandibular kinesiograph (MKG) to this area of study. It seems very convenient for observing the three dimensional movement. However, it is troublesome that the trace of the movement is apt to be distorted on the MKG record as demonstrated in some papers¹¹⁻¹⁴⁾. This study, therefore, was scheduled to examine the characteristic aspects of the MKG and find an appropriate correction for estimating the actual movement from the record.

APPARATUS AND METHODS

The schematic diagram of the apparatus using the MKG* employed in this study is

*Model K6, Myo-tronics Research Inc., Seattle, USA

Fig. 1 Schematic diagram of the apparatus.

- a : MKG sensor
- b : MKG magnet
- c : extension arm
- d : movable and rotatable stage
- e : CRT display
- f : recorder

shown in Fig. 1. In a series of future studies for detecting the small movement of abutment tooth, the magnet for the MKG assembly will be installed on the top of a wooden rod extension arm fixed on the cusp of the tooth to magnify the movement thirty times. Therefore, in this study, the arm with the magnet was fixed on a three dimensionally movable and rotatable stage instead of the simulation model of the abutment tooth to check the movement in various directions.

The principal axes of x , y and z are defined here as the mesio-distal, right-left, and up-down directions, respectively, in which $+x$ denotes the distal movement, $+y$ the right, and $+z$ the upward. The magnet was shifted successively by 1 mm parallel to the x -, y - and z -axes, and its traces were recorded with the MKG to obtain the two dimensional lattices in the sagittal, frontal and horizontal views. The resultant lattices were used for correcting the data thereafter.

In order to examine the characteristic aspects with the MKG system, the three dimensional movement of the magnet was recorded by inclining the arm downward along the representative directions of the $x-y$ plane until the magnet moved by 3 mm from the origin in horizontal projection. The effects of the assembly condition of the sensor and magnet were also checked.

RESULTS AND DISCUSSION

Figure 2 shows the traces of the magnet movements along the x-axis (mesial and distal direction parallel to the midium line), y-axis (right and left direction), and z-axis (up and down direction) for the conditions in which the sensor was parallel to the magnet. The traces of the movements were recorded in the same way when the sensor framework was set tilted 10 degrees toward the magnet (Fig. 3). They were not always displayed in straight lines on the CRT display. Each segment exhibits 1 mm of movement. The resultant lattices were considerably distorted, depending on the tilt of the sensor. It is difficult in practice to estimate the actual movement from the traces on the display themselves under these circumstances. Some corrections have been tried for the distorted lattices. In this study, however, the correction of the data was attempted using those prerecorded, distorted lattices.

Figure 4 shows the method for converting the MKG record onto the rectangular coordinates by correcting the direction and amount of the trace utilizing the distorted lattices in Fig. 3. When the extension arm was inclined downward to the right (y) direction until the magnet moved by 3 mm from the origin in horizontal projection, for example, its traces in the sagittal, frontal and horizontal views were recorded on the CRT display and recorder chart as shown in the top of Fig. 4. As the records were taken under the condition where the sensor was set at an angle of 10 degrees against the magnet, the coordinates of the records were not for the dotted rectangular screen lines on the display but the distorted ones in Fig. 3. Therefore, the distorted lattices in Fig. 3 were superpositioned over the respective records

Fig. 2 Distorted MKG records of the magnet movements along the x-, y- and z-axes when the sensor framework was set parallel to the magnet.

Fig. 3 Distorted MKG records of the magnet movements along the x-, y- and z-axes when the sensor framework was set tilting 10 degrees to the magnet.

(Fig. 4-middle). Regarding the curved lines in the lattice intersecting the origin as the standardized coordinate axes, the record was read for the curved axes. The axes were then converted into the rectangular ones and the readings of the record were plotted on the new coordinates. Thus, the actual traces were obtained on the rectangular coordinates (Fig. 4-bottom). In this manner, the corrected traces of the downward inclination of the arm in the representative directions, x , y , $-x$, and $-y$, were drawn in Fig. 5-1, and those in xy , $(-x)y$, $(-x)(-y)$, and $x(-y)$ directions were drawn in Fig. 5-2. It should be noted from these figures that any downward ($-z$) component of the movement resulting from the inclination of the arm to the distal ($+x$) direction was displayed as the upward movement showing the $+z$ component on the display while the other movements were recorded as they were. It may be attributed to the modified arrangement of the assembly in which the sensor was set tilted

Fig. 4 Correction and conversion of the MKG record onto the rectangular coordinates for an example of a right-downward inclination of the arm.
top : raw record
middle : superposition of the standardized, distorted lattice
bottom : corrected record

Fig. 5-1 Corrected traces of the downward inclination of the arm in the following representative directions.

- (a) x (distal) direction
- (b) y (right) direction
- (c) -x (mesial) direction
- (d) -y (left) direction

Fig. 5-2 Corrected traces of the downward inclination of the arm in the following representative directions.

- (e) xy (distal-right) direction
- (f) (-x) y (mesial-right) direction
- (g) (-x) (-y) (mesial-left) direction
- (h) x (-y) (distal-left) direction

Fig. 6 Loops obtained by linking the plots of the trace terminals in Figs. 5-1 and -2. The broken lines were drawn by symmetrically shifting the plots in the $+z$ region to the $-z$ region with respect to the abscissa.

Fig. 7 Changes in the loops when the magnet was set tilting 5 degrees up- and downward.

- (a) upward tilting
(b) downward tilting

10 degrees toward the magnet.

Figure 6 shows the loops obtained by linking the plots of the trace terminals in Figs. 5-1 and -2. This means that the downward inclination of the arm around the origin up to 3 mm of displacement in horizontal projection will drop within these loops. It is a significant feature that the downward movements having the distal ($+x$) component were exceptionally displayed as the upward movement as mentioned above and the loops appeared only in the first and third quadrants in the sagittal view. Therefore, the plots in the $+z$ region should be actually presented in the $-z$ region. The broken lines may exhibit the true movement associated with the inclination in the distal ($+x$) direction.

Fig. 8 Changes in the loops when the magnet was set tilting 5 degrees to the right and left.

(a) right tilting

(b) left tilting

Figures 7 and 8 show the loops obtained in the same manner as Fig. 6 when the magnet was tilted 5 degrees upward and downward in the z -axis, and right and left in the y -axis, respectively, from the normal arrangement. It was found that the loops were somewhat expanded in the z direction as compared with those of Fig. 6 under the normal condition although the effects of the tilting direction were not clear. These findings indicate that unexpected errors are likely to occur unless the sensor and magnet are normally arranged. Such a tilting of the magnet may inevitably be included in the inclination of the object during its moving process. It seems imprudent, in a strict sense, to correct the whole data with the initial distorted coordinates and lattices obtained under normal conditions. It may be necessary to correct the data using momentary correcting coordinates and lattices associated with the tilt angle of the magnet if the movement is as large as 5 degrees. In the application of MKG to the analysis of abutment tooth movement, however, the movement will probably be so small that the inclination of the detecting arm may be less than 1 degree at most. Such a small movement can be approximately estimated by correcting the record with the standardized initial lattices of Fig. 3.

CONCLUSION

It is well known that the data obtained with the MKG are distorted. In applying the MKG to the analysis of abutment tooth movement, the distortion of the record may be one of the biggest problems. When the magnet was shifted along the x -, y - and z -axes, the resultant rectangular lattices were considerably distorted on the display. However, it was

assumed that the three dimensional movement of the tooth would be approximately estimated by a simple correction utilizing those distorted lattices. The correcting procedure consists of superpositioning the lattice over the movement record in each view, reading the record for the standardized curved axes, converting the axes into the rectangular ones and plotting the record on the new rectangular coordinates. The MKG may be convenient and useful for estimating the small movement of abutment teeth so long as the data are dealt with in due regard to the characteristic aspects of the MKG record.

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の物性との関係を検討した。ビスフェノールAやフルオロビスフェノールA骨格を有するジメタクリレートの重合体は、総体的に良好な機械的性質を示し、各重合体の物性が、モノマーの分子構造の剛直性および疎水性によって影響を受けることが明らかとなった。また、運動

性に乏しい分子構造のモノマーでは、立体障害によるものと考えられる物性の低下が認められた。フルオロ基を有するビスフェノール骨格のジメタクリレートは比較的優れた物性ならびに耐水性を示し、修復用レジンベースモノマーとしての有用性が示唆された。

人歯牙象牙質のねじりにおける動的ずり弾性率

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人歯牙の種々の物性についての報告は比較的少なく、未解明の部分が多い。なかでも歯牙の粘弾性的性質は口腔内における修復材料の挙動に大きく影響するものとみられることから重要である。本研究ではねじれ自由減衰型粘弾性測定装置をもちいて人歯牙象牙質の動的ずり弾性率の測定を試みた。

試料は履歴の判明した新鮮抜去歯をマイクロカッターにて短冊状に切断し測定に供した。測定は雰囲気温度を1°C/minの速度で昇温し、23°Cから150°Cの温度範囲に

わたっておこなった。

弾性率(G)は温度の上昇に伴ってわずかに大きくなる傾向がみられたが、温度による弾性率の変化は小さかった。損失率($\tan \delta$)は75°C付近にピークがみられた。37°Cにおける20個の試料の弾性率の値は小さいもので 5.77×10^{10} dyne/cm², 大きいもので 1.06×10^{11} dyne/cm²であった。各試料の弾性率と試料を作成した歯牙の履歴との間に明確な相関はみられなかった。

MKGによる鉤歯の挙動の分析

第1報, MKG記録の特性ならびにその修正

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補綴物を製作する上で最も重大な関心事は、その補綴物に最適なデザインを決定することであろう。とくにパーシャル・デンチャーにおいては、このことは不可欠な問題である。この問題を解決するために従来から、パーシャル・デンチャーの鉤歯の機械的な挙動を分析することによって判定しようとする試みがストレイン・ゲージ法、光弾性法、有限要素法、その他の方法を用いてなされ数多くの報告がある。しかし、いずれも三次元的な観

察が困難であったり、物性値に問題があるなどの難点がある。

著者らは、鉤歯の三次元的な挙動を分析するためにMKGを応用することを試み、今回、そのMKGの特性について検討した。その結果、MKGのディスプレイ上に表示される運動記録にはかなりのひずみが生じるが、近似的な補正が可能であり、鉤歯の挙動の定性的な観察には有効な方法であることが判明した。