ORIGINAL ARTICLE

Occlusal Factors associated with Temporomandibular Disorder based on a Prospective Cohort Study of Young Adults

Masatoshi Kawano, DDS, and Masanori Fujisawa, DDS, PhD

Department of Fixed Prosthodontics, School of Dentistry, Iwate Medical University, Morioka, Japan

Clinical significance

In this prospective cohort study, mandibular movement analysis was conducted together with clinical examinations to determine the intrinsic occlusal factors that might contribute to the development of TMD. Since mandibular movement analysis has never been conducted previously in this type of cohort study, our results highlight the important implications of occlusal factors potentially associated with TMD.

Abstract

Purpose: To determine the relationship between temporomandibular disorders (TMD) and the occlusal contact pattern, we conducted occlusal analysis in a prospective cohort study.

Methods: One hundred forty-six volunteers consisting of 98 males and 48 females with a mean age of 20.0 ± 1.9 years selected from the dental students of Iwate Medical University were enrolled for the study. All the subjects were asked to fill out a self-administered questionnaire to screen their general and oral health conditions, and then clinical examination, including evaluation of the occlusal contact pattern, was conducted during the first year. A second clinical examination was repeated 2.5 years later to ascertain the incidence of symptoms of TMD. The natural course of TMD symptoms in the 128 subjects were as follows: 66 were classified in the symptom-free group, 18 in the symptom incidence group, 14 in the symptom remission group, and 30 in the symptom continuation group. Then, the occlusal contact patterns during lateral mandibular excursion were classified into five types: ① canine protected occlusion and group function (CG; $n=192$), ② bilateral occlusal guidance (BG; $n=10$), ③ working side molar guided occlusion (WM; $n=45$), ④ non-working side molar guided occlusion (NM; $n=4$), and ⑤ incisal guided occlusion (IG; $n=5$).

Results: In the second examination, 18 out of the 84 subjects (21.4%) who showed no symptoms at the time of enrolment into the study reported TMJ click and/or pain. Of the total, 23, 11, 1, and 1 subjects with symptoms of temporomandibular joint origin were classified as having the CG, WM, NM, and BG pattern of occlusal contact, respectively. With CG as the standard, the relative risk of TMD in subjects shown the WM pattern was 2.79 (95%CI: 1.16 – 6.70).

Conclusion: Since the group showing the working side molar guided occlusion pattern showed a high risk of future development of TMJ click and/or pain, lateral excursion guidance may be a contributing factor for the development of TMD.

Key words: cohort study, TMD, occlusal contact pattern, mandibular movement, natural course of symptoms

Introduction

Several possible causes of temporomandibular disorders (TMD) exist, including parafunctional oral habits, psychological stress, structural abnormalities, and extrinsic trauma. Although the dental occlusal status plays an important role in the maintenance of proper mandibular function, the association between occlusal factors and TMD still remains controversial. In regard to the influence of the absence of molar teeth, several studies have compared the incidence of TMD in subjects with and without molar teeth. More than five missing teeth in the molar region significantly raised the odds ratio of TMD to as high as 1.18.¹ Recently, Tallents et al² reported a positive association between missing mandibular posterior teeth and the presence of disc displacement. Although occlusion cannot be considered as a unique or dominant factor in the development of TMD, there are no data to confirm or deny the existence of a relationship between occlusal factors and TMD. The aim of this study was to prospectively determine the relationship

Corresponding to: Masanori Fujisawa
Department of Fixed Prosthodontics,
School of Dentistry, Iwate Medical University,
1-3-27 Chuodori, Morioka 020-8505, Japan
Tel: +81-19-651-5111, FAX: +81-19-654-3281
E-mail: fujisawa@iwate-med.ac.jp

Received on September 2, 2005/Accepted on December 27, 2005

between occlusal factors and the risk of TMD, by focusing, in particular, on symptoms of TMJ origin and occlusal factors, including occlusal contact at the intercuspal position and during lateral excursion, together with analysis of the mandibular movements in a young adult cohort.

Materials and methods

Subjects

One hundred forty-six dental students from Iwate Medical University were enrolled for this study. The inclusion criteria for the subjects were: ① between the ages of 18 and 25 years in the first year of the survey, and ② eligible for enrollment as a subject for a 2.5 year-follow up. The exclusion criteria were: ① serious underlying systemic disease, ② missing incisors which make it impossible to record mandibular movements, and ③ subjective complaint of limited mouth opening, which can be not only of TMJ origin, but also be caused by muscle problems.

This research was approved by the Human Research Ethics Committee of the Iwate Medical University Dental School, and each participant signed a consent form prior to enrolment in the study.

Methods

Data collection

All the subjects were requested to fill out a questionnaire^{3,4} containing eight major categories of general health conditions (12 items), TMD symptoms (6 items), history of dental treatment (2 items), daily habits (9 items), eating routines (8 items), sleeping condition (4 items), and histories of extrinsic trauma (1 item), and mental health (1 item). A clinical examination was then performed for each subject by several examiners on separate days after their completion of the questionnaire, usually a week later. The subjects sat on a dental chair in an upright position with the Frankfort horizontal plane set parallel to the floor. The number of teeth in contact at the intercuspal position (IP) was counted by a pulling-out test for each pair of upper and lower teeth using a piece of foil 0.012 mm in thickness (occlusal registration strips; ARTUS, Englewood). Guided teeth at a point 3 mm away from the IP during lateral movements were also examined by a pulling-out test, followed by visual examination. Both sides of the mid point of the masseter,⁵ sternocleidomastoid muscle, the anterior portion of the temporal muscle, and the lateral side of the TMJ were examined by palpation. For pressure pain examination, a bilateral index finger tip test under a pressure intensity of less than 2.0kgf, calibrated beforehand,⁶ was performed to ascertain whether the subjects felt pain rather than pressure. The range of jaw opening was measured between the upper and lower left central incisor edges using a millimeter ruler while the subject opened his/her mouth as widely as possible. In this measurement, vertical overlap along the incisors was excluded.

All the results of the clinical examinations were described in a protocol prepared for this study. All the patients were requested to fill out a questionnaire describe their TMD symptoms such as TMJ sound, TMJ and/or masticatory muscle pain on mouth opening and/or mastication, and mouth opening limitation at baseline and at the 2.5-year follow-up. The signs and symptoms described were then confirmed by clinical examination. Final evaluation of the incidence of TMD symptoms was based on the results of the clinical examination.

Furthermore, the mandibular movements of the subjects were recorded using a six-degree-of-freedom jaw-tracking device (MM-JI-E; SHOFU, Kyoto), to evaluate the transition and rotation parameters under lateral excursion, habitual opening closing movements, and boarder mandibular movements. The kinematic condylar points on both sides and the incisal point were selected for the reference points^{7,8} to be measured and occlusal plane coordinates defined by the natural dentition⁹ were used as a reference plane for this study. All the mandibular movement data were digitized at a sampling rate of 100 Hz.

Then, the occlusal parameters and mandibular movement parameters were compared among the different natural course groups according to the incidence of TMD symptoms.

Data analysis

For theoretically ideal occlusion during lateral movements, the teeth on the nonworking side are disclosed, and there is occlusal contact between the opposing canines on the working side alone and together with one or more pairs of adjacent posterior teeth.¹⁰ The occlusal contact pattern was divided into two groups, as follows; having or not having canine contact on the working side

Table 1 Symptoms observed at the time of enrolment into the study.

Symptom-free	87
Joint noise	45
Joint pain	2
Muscle pain	4
Joint noise + joint pain	3
Joint noise + muscle pain	3
Joint pain + muscle pain	1
Joint noise + joint pain + muscle pain	1
Total	146

during lateral excursion. Furthermore, the group without canine contact guidance was divided into subgroups based on the presence of working and/or non-working side molar tooth guidance. From the mandibular movement data, the guided angles defined by anatomical structures of the TMJ and teeth in the anterior region were investigated. An analyzing target line was drawn from the IP to a point 3 mm away from the IP at the incisal and kinematical condylar points. Then, the angle between the analyzing target line and reference axis was calculated in sagittal, horizontal and frontal projections.^{11, 12} Since occlusal contact during chewing has been suggested to be generated within 3 mm from the centric occlusion position,¹³⁻¹⁷ 3 mm movement was chosen for guiding teeth detection and mandibular movement point analysis.

Then, the mandibular movement parameters were compared between the groups divided based on the TMD symptom status on the non-working side TMJ at the 2.5-year follow up.

Statistical analysis

For multiple-group comparisons, Kruskal-Wallis nonparametric ANOVA test following Dunnett's multiple comparisons were used as the post-hoc test. For two-group comparisons, Mann-Whitney's U test was used. Statistical significance was assumed at a level of lower than $\alpha = 0.05$. The relative risk (RR) of each parameter for the development of TMD was also calculated, and the significance level was ascertained by the 95% confidential interval (CI). Fisher's exact test was also performed to evaluate the relationship between the lateral guidance and the incidence of TMD symptoms. The SPSS statistical package (ver. 13.0J for Windows, SPSS Japan, Tokyo, Japan) was used for the statistical calculations.

Fig. 1 The natural course of TMD symptoms. Seven subjects were excluded from the analysis, because they had muscle pain. Eleven subjects were eliminated from the follow-up survey because of dropout.

SF: Symptom free group

SI: Symptom incidence group

SR: Symptom remission group

SC: Symptom continuation group

Results

Natural course of symptoms

In the initial year, 59 subjects had at least one symptom of TMD; 45 had TMJ noise, two had TMJ pain, four had masseter muscle pain, and eight had complex symptoms as described in Table 1. However, none of the subjects had subjective restriction of mouth opening.

In the determination of the association among the occlusion pattern, mandibular movements and TMD, nine subjects with muscle pain, including five in the complex symptom group, were excluded from the analysis, since mandibular movements might be affected not only by occlusal factors, but also by muscle pain. For the follow-up survey, 11 subjects dropped out due to withdrawal from the school or not being eligible for reexamination due to illness. Since two subjects with muscle pain were also included in the dropout group, 128 subjects were finally included for the analysis, consisting of 86 males and 42 females, with a mean age of 20.0 ± 2.0 years, who completed all the data collection procedures for the 2.5-year period.

According to the natural course of the patients during the 2.5-year period, the subjects were divided into four groups; symptom-free group throughout the study period (SF group), development of TMD symptom incidence group during the study period despite being symptom free at the time of enrolment (SI group), symptom re-

Table 2 Relative risk (RR) of TMD symptoms in relation to the occlusal contact pattern.

	SI	SF	RR	95%CI
CG	23	105	1	
WM	11	18	2.79	1.163– 6.695
NM	1	2	2.28	0.198–26.255
BG	1	4	1.14	0.122–10.692
IG	0	3	–	–

CG: Canine protected occlusion and group function occlusion

WM: Working side molar guided occlusion

NM: Non-working side molar guided occlusion

BG: Bilateral occlusal guidance

IG: Incisal guidance

mission of TMD during the study period (SR group), and symptom-continuation group (SC group).

Among the 128 subjects enrolled in the final analysis, 66 were classified in the SF group, 18 in the SI group, 14 in the SR group, and 30 in the SC group (Fig. 1).

All the subjects in the SI group reported TMJ noise during habitual opening-closing movements of the mouth. Of the 18 subjects in SI, four complained of unilateral TMJ pain.

Occlusal contact

There were no statistically significant differences in regard to the number of occluding teeth at IP among the four groups described above (21.2 ± 4.95 in SF, 20.3 ± 5.27 in SI, 20.9 ± 5.4 in SR, and 19.7 ± 5.5 in SC).

The occlusal contact pattern during lateral excursion was classified into the following 5 patterns; ① canine protected occlusion and group function (CG; $n=192$), ② bilateral occlusal guidance (BG; $n=10$), ③ working side molar guided occlusion (WM; $n=45$), ④ non-working side molar guided occlusion (NM; $n=4$), and ⑤ incisor guided occlusion (IG; $n=5$).

To determine the prospective factors influencing the guiding teeth during lateral excursion, the occlusal guidance patterns were compared between the SF and SI groups. Although the CG pattern was dominant in the SF and SI groups, the proportion with the WM pattern was higher in the SI than the SF group. Finally, the relative risk of TMD in the subjects with the WM pattern was 2.79, which was significant (Table 2).

Fig. 2 Range of movement during lateral excursion in each natural course group.

The number in each column represents the subject number in the natural course category.

SF: Symptom free group

SI: Symptom incidence group

SR: Symptom remission group

SC: Symptom continuation group

Mandibular movement analysis

The incidence of symptoms was ascertained on a joint-by-joint basis, and the range of motion and inclination angle at the incisal point were analyzed with regard to the incidence of TMJ symptoms on the non-working side. Condylar movement analysis was also performed in relation to the TMJ symptom status.

1. Range of motion

For habitual opening-closing movements, there were no significant differences in the range of motion at the incisal (49.36 ± 8.4 mm in the SF group, 48.16 ± 8.59 mm in the SI group, 49.78 ± 5.78 mm in the SR group, and 48.55 ± 6.87 mm in the SC group) or at the bilateral condylar points (16.59 ± 3.78 mm in the SF group, 18.45 ± 2.73 mm in the SI group, 18.08 ± 3.28 mm in the SR group, and 17.44 ± 3.23 mm in the SC group) among the groups.

For lateral excursion movements, the range of movement in the SF group (9.76 ± 2.43 mm) was significantly greater than that in the SI group (8.30 ± 2.81 mm) at the incisal point ($P=0.002$), and also at the condylar point on the non-working side (SF group; 9.44 ± 2.21 mm, SI group; 7.96 ± 2.81 mm, $P=0.001$) (Fig. 2).

In relation to the lateral guidance pattern, CG (9.82 ± 2.51 mm) was significantly greater than WM (8.42 ± 2.50 mm) at the incisal point ($P=0.003$) (Fig. 3).

Fig. 3 Range of movement during lateral excursion in each lateral guidance pattern group.

The number in each column represents the subject number in the guidance category.

CG: Canine protected occlusion and group function occlusion

WM: Working side molar guided occlusion

NM: Non-working side molar guided occlusion

BG: Bilateral occlusal guidance

IG: Incisal guidance

2. Guided angle at the 3 mm lateral excursion position

There were no statistically significant differences among the four natural course groups in terms of the angles of the incisal or condylar path in the frontal, horizontal or sagittal projections. Next, further analysis was conducted for comparison among the lateral guidance patterns in relation to working side guidance. The angle of the incisal path for CG ($35.06 \pm 12.72^\circ$) was significantly steeper than that for WM ($27.82 \pm 12.96^\circ$) during lateral movement in the frontal projection ($P=0.001$). On the other hand, the angles at the condylar point on the non-working side were almost the same among the groups (Fig. 4).

3. Relationship between guidance pattern and symptoms

The numbers of TMJ showing each occlusal guidance pattern in the SF and SI groups are listed in Table 3. Since numbers showing the NM, BG and IG occlusal contact patterns were small, frequency analysis was performed using Fisher's exact test between CG and WM. There was a trend towards a higher frequency of WM in the SI group (37.9 %) as compared to CG (18.0 %) ($P=0.0251$).

Fig. 4 Angle of the incisal and condylar path during 3 mm lateral excursion in the frontal projection.

The number in each column represents the subject number in the guidance category.

CG: Canine protected occlusion and group function occlusion

WM: Working side molar guided occlusion

NM: Non-working side molar guided occlusion

BG: Bilateral occlusal guidance

IG: Incisal guidance

Discussion

Numerous studies have been undertaken to examine the intrinsic factors associated with the fluctuating nature of TMD by using questionnaires and/or clinical examination. Several studies with prospective cohort designs which are recommended as a suitable way to address the issue of prevalence of diseases have been conducted. Carlsson et al. found in a survey with over 20 years' follow-up that oral parafunction is associated with the future development of TMD.¹⁸ Wänman evaluated the influence of gender, and found in a 10-year follow up study that it affects the natural course of TMD symptoms.¹⁹ Both studies also concluded that the longitudinal course varies with regard to symptomatic fluctuations, which suggests that the incidence of TMD symptoms may be influenced by various factors. Also, the demand for treatment may not be directly related to the presence of objective TMD signs or symptoms. Kamisaka et al.²⁰ stated the associated factors of age and extrinsic trauma in addition to gender, from a 4-year longitudinal survey which covered a wider age range than in the studies of Carlsson et al.¹⁸ and Wänman.¹⁹ Since TMD is a multifactorial disease, any prospective cohort study aiming to determine the exposure factors should be carefully designed to

Table 3 Number of cases in the SF and SI groups classified according to the occlusal guidance pattern

	CG	WM	NM	BG	IG	total
SF	105	18	2	4	3	132
SI	23	11	1	1	0	36
total	128	29	3	5	3	168

CG: Canine protected occlusion and group function occlusion

WM: Working side molar guided occlusion

NM: Non-working side molar guided occlusion

BG: Bilateral occlusal guidance

IG: Incisal guidance

exclude confounding factors. In this study, attention was focused on TMD symptoms of TMJ origin, including TMJ pain and noise. Masticatory muscle pain, which is thought to be associated with bruxism and/or psychological stress, was excluded for the reasons mentioned above. Also, the age distribution was limited and the observation period was set at 2.5 years, which was shorter compared to that in the previous studies.¹⁸⁻²⁰

Probably related to the limited age distribution, few differences were found among the natural course groups in regard to the number of occluded teeth at IP. Based on the results described above, lateral movement guidance was compared among the four natural course groups. While the relationship between lateral guidance and TMD has been discussed previously,^{2, 21, 22} none of the studies have used a prospective cohort design. In the results of this study, 30.6% of subjects in the SI group showed WM, while the incidence of WM in the SF group was as low as 17.1%. Also, the relative risk of developing TMD in subjects showing WM was 2.79 times that in subjects showing CG, which was statistically significant. These results imply that there might be an association between lateral guidance and the incidence of TMD. In a previous study that focused on the relationship between anterior and posterior guidance, the angle of the condylar path was larger than that of the incisal path in the TMJ disc displacement group, while the condylar angle was smaller than the incisal angle in the non-displacement group.¹² This result implies that disharmonious anterior-posterior relationship could induce reversal rotation to push the disc in an improper forward position. A possible explanation for our result is the difference in the inclination angle during lateral guidance, which generates various directions of joint loading during

mandibular function. To clarify this, analysis of the lateral guidance patterns was performed, and we found steeper guidance in cases showing CG than in those showing WM. Furthermore, the rate of WM in the SI group was higher than that of CG. Although measurement of temporomandibular joint loading has been conducted using various ways, including invasive and non-invasive approaches, the effect of occlusal guidance on TMD still remains unknown. Ito et al²³ investigated joint loading by measuring the condylar movements under various occlusal patterns at the IP using splints. Okano et al²⁴ showed muscle EMG activity variations in simulated occlusal guidance during lateral excursion suggesting an influence of condylar movement performance in TMJ. Furthermore, Otake et al²⁵ reported there was little change on the non-working side condylar path angle when the incisor path angle was altered with artificial tooth guidance. However, the working side molar guided pattern, which was the dominant guidance pattern in terms of the risk of TMD in our study was not included in previous studies. There exist case reports of habitual TMJ condylar dislocation suspected to have been caused by a lack of canine guidance.^{22, 26} In both cases above, the dislocation disappeared after changing the working molar guidance into canine guidance. Since not all people with anterior open bite occlusion at the IP always have such discomfort, canine guidance is not necessarily a dominant factor related to the risk of TMD. However, anterior guidance harmonized with TMJ as posterior guidance would be desirable, based on reports from asymptomatic²⁷ and symptomatic¹² subjects. These previous results support the idea of tooth guidance being associated with harmonized functioning of the TMJ. In this study, the anterior guidance inclination in WM was gentler than that in CG in the frontal projection during lateral excursion, which might affect TMJ loading and increase the risk of TMD. Moreover, psychological factors and life events/changes should be considered together with focusing on the occlusal status as a contributing factor. Since multifactorial evaluation would be ideal for clarifying this point, we propose to conduct a study with a prospective cohort design taking various parameters into consideration in the future.

Conclusion

Since the working side molar guided occlusion group showed a high risk of future TMJ click and/or pain, lateral excursion guidance may be one of the contributing factors for TMD.

Acknowledgments: The authors wish to thank Professor Kanji Ishibashi, Director of the Department of Fixed Prosthodontics, School of Dentistry, Iwate Medical University, for his helpful advice.

This research was supported by a Grant-in-Aid for Scientific Research (No.12470422) from the Japan Society for the Promotion of Science.

References

1. Pullinger AG, Seligman DA, Gornbein JA. A multiple logistic regression analysis of the risk and relative odds of temporomandibular disorders as a function of common occlusal features. *J Dent Res* 72: 968-979, 1993.
2. Tallents RH, Macher DJ, Kyrkanides S, et al. Prevalence of missing posterior teeth and intra-articular temporomandibular disorders. *J Prosthet Dent* 87: 45-50, 2002.
3. Fujisawa M, Asano A, Terui Y, et al. Prospective study of psychological properties as contributory factors to temporomandibular disorders. *Jpn J Psychosomat Dent* 16 : 25-30, 2001.
4. Tanabe N, Fujisawa M. Prospective cohort study of pressure pain threshold and electromyograms associated with masticatory muscle pain incidence. *Prosthodont Res Pract* 4 : 48-57, 2005.
5. Shoji S. An evaluation of the pressure pain threshold in the temporal and masseter muscle regions. *J Jpn Prosthodont Soc* 36: 1331-1338, 1992.
6. Sasaki S, Fujisawa M, Kanda T, et al. Application of palpation pressure measuring system in pressure pain examination. *J Jpn Soc TMJ* 12: 21-26, 2000.
7. Fukagawa M. The movement of articular disc and condyle of the temporomandibular joint with reciprocal clicking. *J Jpn Prosthodont Soc* 39: 296-302, 1995.
8. Suzuki T. Analysis of mandibular movement during opening and closing jaw movement in patients having anterior disc displacement. *J Jpn Prosthodont Soc* 40: 1102-1110, 1996.
9. Suzuki A. A study on mandibular movement in six degree of freedom with a newly developed Jaw movement analyzer. *J Jpn Prosthodont Soc* 31 : 712-725, 1989.
10. Mohl ND, Diagnostic Rationale: A Textbook of Occlusion. 179-184, Chicago : Quintessence, 1988.
11. Kanemura K. Effect of condylar guidance inclination on anterior disk displacement TMJ. *J Jpn Prosthodont Soc* 43: 293-298, 1999.
12. Nagao A. The relationship between the angles of condylar and incisal paths in temporomandibular disorder patients with anterior disk displacement. *J Jpn Prosthodont Soc* 45: 710-718-2001.
13. Beyron HL. Occlusal relations and mastication in australian aborigines. *Acta Odontol Scand* 22: 597-678, 1964.
14. Suit SR, Gibbs CH, Benz ST. Study of gliding tooth contacts during mastication. *J Periodontol* 47: 331-334, 1976.
15. Ingervall B, Mohlin B, Thilander B. Prevalence of symptoms of functional disturbances of the masticatory system in Swedish men. *J Oral Rehabil* 7: 185-197, 1980.
16. Takai A, Nakano M, Bando E et al. Evaluation of three occlusal examination methods used to record tooth contacts in lateral excursive movements. *J Prosthet Dent* 70: 500-505, 1993.
17. Ogawa T, Koyano K, Suetsugu T. The relationship between inclination of the occlusal plane and jaw closing path. *J Prosthet Dent* 76: 576-580, 1996.
18. Carlsson GE, Molin C, Friling B et al. Frequency of symptoms of mandibular dysfunction in young Swedish men. *J Oral Rehabil* 3: 9-18, 1976.
19. Wänman A. Longitudinal course of symptoms of craniomandibular disorders in men and women. A 10-year follow-up study of an epidemiologic sample. *Acta Odontol Scand* 54: 337-342, 1996.
20. Kamisaka M, Yatani H, Kuboki T. Four-year longitudinal course of TMD symptoms in an adult population and the estimation of risk factors in relation to symptoms. *J Orofac Pain* 14: 224-232, 2000.
21. Coffey JP, Mahan PE, Gibbs CH et al. A preliminary study of the effects of tooth guidance on working-side condylar movement. *J Prosthet Dent* 62: 157-162, 1989.
22. Nishigawa K, Nakano M, Bando E et al. Effect of altered occlusal guidance on lateral border movement of the mandible. *J Prosthet Dent* 68:965-969, 1992.
23. Ito T, Gibbs CH, Bonnet RM et al. Loading on the temporomandibular joint with five occlusal conditions. *J Prosthet Dent* 56: 478-484, 1986.
24. Okano N, Baba K, Akishige S et al. The influence of altered occlusal guidance on condylar displacement.

- ment. *J Oral Rehabil* 29: 1091-1098, 2002.
25. Otake T, Mayanagi A, Tsuruta J et al. The role of posterior guidances under the altered anterior guidance. *J Oral Rehabil* 29: 1196-1205, 2002.
26. Sawada K, Arai Y, Medina R et al. Guidance of mandibular movements by molar teeth as a trigger of chronic condylar dislocation observed in one patient. *J Jpn Prosthodont Soc* 41: 763-768, 1997.
27. Kohno S, Nakano M. The measurement and development of anterior guidance. *J Prosthet Dent* 57: 620-625, 1987.