Eur. J. Prosthodont. Rest. Dent., Vol.13, No. 4, pp 170–176
Printed in Great Britain

Mandibular Displacement Related to Simulated Loss of Posterior Occlusal Support

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Abstract - *Mandibular displacement related to simulated loss of posterior occlusal support was investigated. Twenty-four volunteers with natural dentitions were selected. To change the posterior occlusal support, occlusal splints fitted to maxillary dental arches were cut in sequence from the most posterior to anterior. The more the absence of posterior occlusal support increased, the more both condylar displacements were increased (R: 0.97mm, L: 0.94mm). Moreover, subjects could be divided into two groups depending upon their condylar mobility following with reduced occlusal support. These results suggest that individual adaptability to the imbalanced occlusal condition should be always considered.*

KEY WORDS: Occlusal support, Condylar position, Mandibular displacement, Shortened dental arch

INTRODUCTION

It was a common belief in prosthodontic treatment up to the 1970s that posterior teeth would support the mandible in the intercuspal position[1]. On the other hand, in the last two decades, Kayser[2,3] conducted a series of clinical studies to assert that partially dentate patients without posterior occlusal support would not suffer functional disturbances associated with temporomandibular disorders (TMD). Käyser[2,3] also showed the possibility of iatrogenic aspects of prosthodontic intervention for partially edentulous patients and introduced the concept of the shortened dental arch (SDA). He proposed that there is no need to restore the missing molar region with various prosthodontic appliances, if bilateral occlusion to the second premolars is stable. The SDA concept is potentially linked to the socio-medical strategy of governments in highly developed countries in Europe wishing to diminish the social insurance fee paid for restorative or prosthodontic dentistry.

Prosthodontists of other countries where the SDA concept was not widely accepted now faced the problem of whether or not to deliver prosthetic treatment for their patients with posterior deficiencies of the dentition. Clinical experience suggests various possibilities for functional disturbance starting from instability of the intercuspal position that may influence the condylar position. Epidemiologic studies have shown that the loss of posterior teeth and reduced number of contacting teeth in the intercuspal position are related to the development degenerative joint disease[4–6].

To cope with these SDA problems, it is necessary to understand the relationship between loss of posterior occlusal support and the mandibular position. Although some studies including our previous studies[7,8] have reported the relationship between posterior occlusal support and mandibular displacement, variation of this displacement depending upon the region of occlusal tooth contact has not been analyzed in detail using human volunteers. The purpose of this study was to investigate three-dimensional mandibular displacement related to loss of posterior occlusal support.

MATERIALS AND METHOD

Subject selection and their intraoral conditions

Twenty-four volunteers were selected for this study and informed consent was obtained. These subjects were five females and nineteen males and their age ranged from 24 to 31 years (average: 26.1). All subjects were clinical residents of Matsumoto Dental University. Criteria for subject selection were: (1) natural dentitions without removable prosthesis; (2) no symptom of the TMD; (3) no symptom of the periodontal disease; (4) no experience of the orthodontic treatment.

Procedures of changing occlusal support

Occlusal splints fitting for the maxillary dental arch were fabricated using self-curing acrylic resin (Unifast II). Mandibular position on the splint was determined using an interocclusal record which was registered with the anterior jig put on the palatal surface of upper incisors. As a procedure for making the anterior jig, the subject was asked to repeat tapping movement with the anterior jig until the mandibular closing position concentrated in a small area. The bite registration at this mandibular position was performed using a silicone-based bite registration material (Mushprint). The registered mandibular position was transferred to the mean value articulator (Gysi Articulator OU-2) and the splint was fabricated on the articulator. Occlusal tooth contacts on the splint were carefully adjusted and at least one occlusal contact was obtained against each antagonistic tooth. Mean values of the distance and the direction of altered mandibular position from the original intercuspal position were 2.12mm and 75.0 degrees (inferior-posterior direction from occlu-

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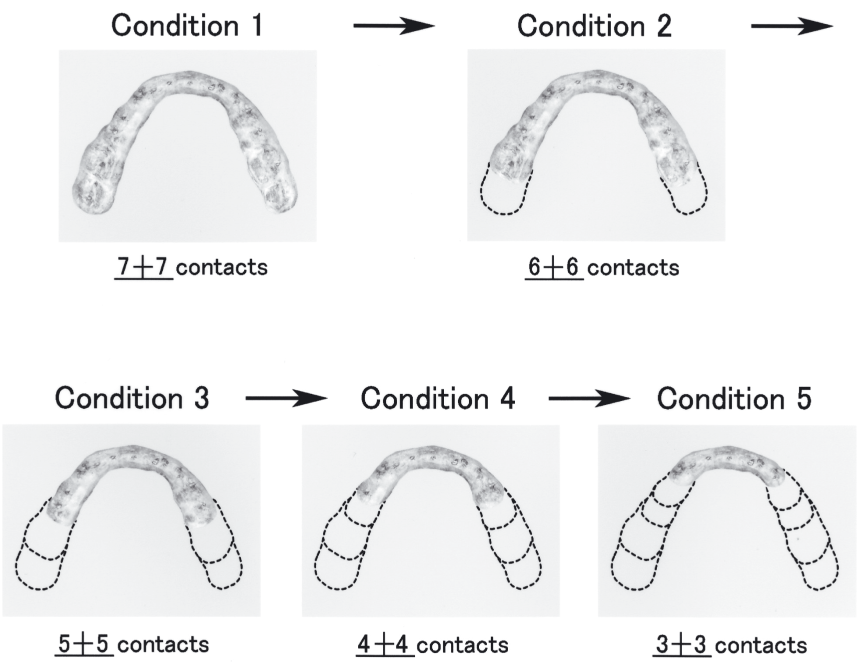

Figure 1. *The occlusal support could be changed by cutting the splint in sequence from posterior to anterior and five occlusal conditions (condition 1 to 5) were set up.*

sal plane), respectively. (These values were measured by a mandibular movement analyzing system with six-degree of freedom.

The occlusal support could be changed by cutting the splint in sequence from posterior to anterior and five occlusal conditions (condition 1 to 5) were set up as shown on *Figure 1*.

Mandibular displacement

Mandibular displacement was measured using a mandibular movement analyzing system with six-degree of freedom (3SPACE FASTRAK) (*Figure 2*). This system consists of a transmitter, two micro electromagnetic sensors, a system electronics unit, and a personal computer. A pair of resin clutches were attached to the labial surfaces of upper and lower incisor teeth to position the sensors. Rapid cure adhesive agent was used to fix the clutches.

Software was developed to analyze mandibular displacement. Five reference points were selected for measuring mandibular displacement, i.e. central lower incisor (point I), left lower first molar (point L6), right lower first molar (point R6), left condyle (point LC) and right condyle (point RC). In this study, the kinematic axis[9] was used to represent the condylar point. The distance and the direction of displacement at five reference points were measured during three seconds of maximum voluntary clenching in the habitual closing position. Mandibular displacement was assessed under natural occlusal condition (control) and each experimental occlusal condition including with the splint present and following systematic removal of each occlusal support from posterior to anterior on the splint (condition 1 to 5). The measurements were repeated three times with rest periods long enough to decrease the possibility of error. For the analysis of displacement angle, the occlusal plane was used as a standard plane,

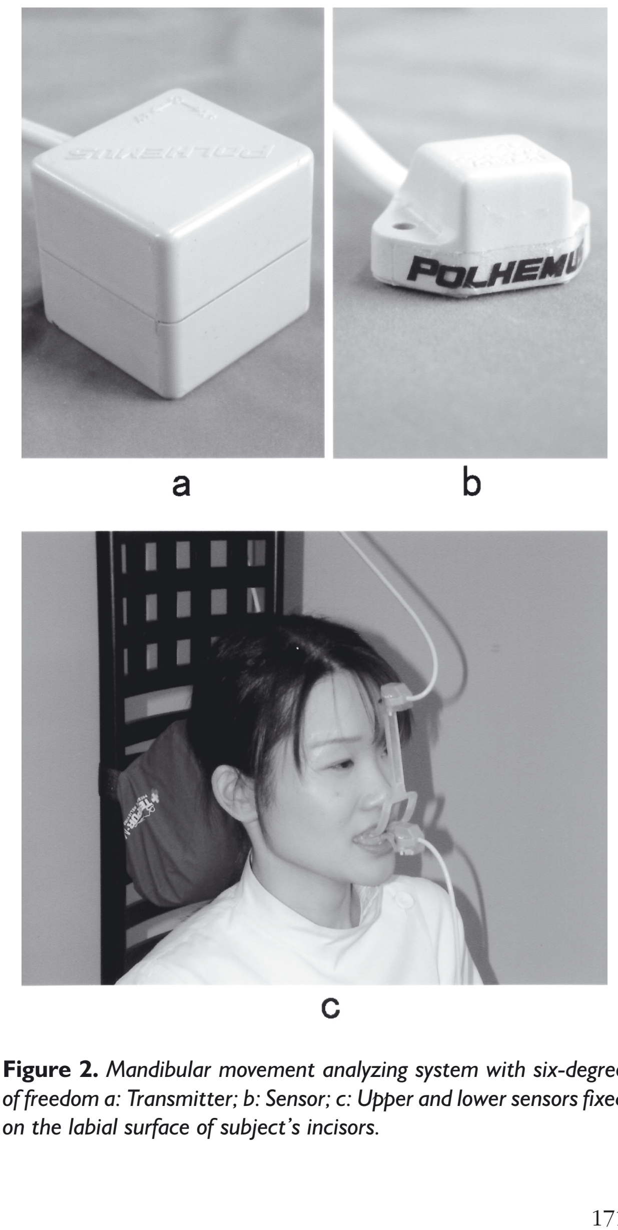

Figure 2. *Mandibular movement analyzing system with six-degree of freedom a: Transmitter; b: Sensor; c: Upper and lower sensors fixed on the labial surface of subject's incisors.*

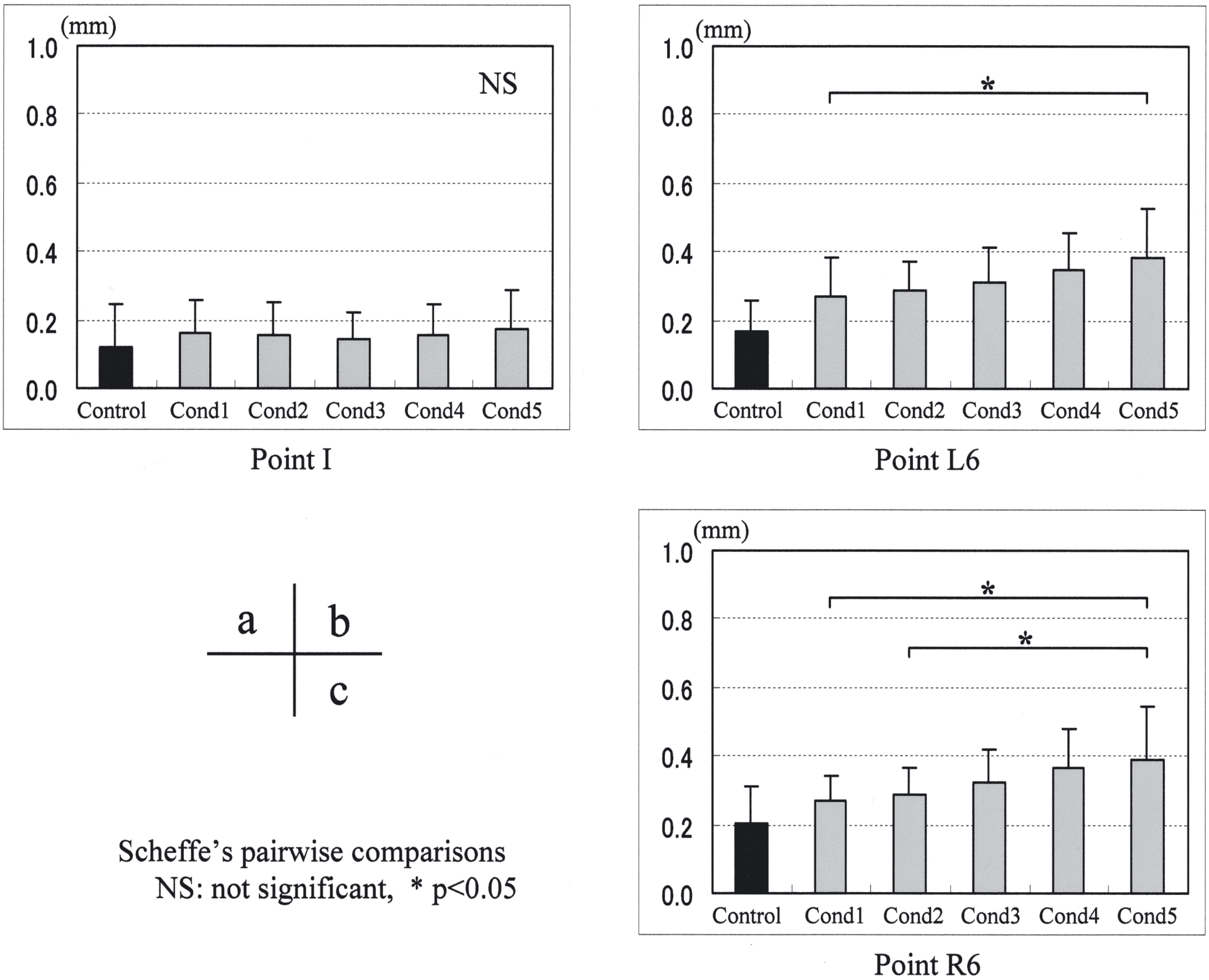

Figure 3. *Displacement distances at points I, L6 and R6 under each experimental occlusal condition (mean and standard deviation). By cutting the splint in sequence from posterior to anterior systematically, the displacement distances were increased at both first molars and significant differences were shown among measured distances under each experimental occlusal condition. a: point I, b: point L6, c: point R6.*

and 0 degree and 90 degree of displacement coincided with posterior and superior direction, respectively.

In addition to measuring mandibular displacement, to control the clenching force at maximum level, electromyography (EMG) was recorded simultaneously from both masseters and anterior temporal muscles using surface electrodes. Signals from these EMG activities were rectified and displayed on the screen as a visual feedback system which enabled the subjects to exert always maximum voluntary clenching.

Statistical analysis

Associations of the mandibular displacement with experimental occlusal conditions were analyzed using one-way analysis of variance (one-way ANOVA).

RESULTS

Displacement distance at points I, L6 and R6 (*Figure 3*)

With all occlusal supports on the splint present (condition 1), the mean values of displacement distance at points I, L6 and R6 during maximum voluntary clenching were 0.16mm, 0.27mm and 0.27mm, respectively. These values were a little larger than those without splint (control). By cutting the splint in sequence from posterior to anterior systematically, the displacement distances were increased at both first molars and significant differences were shown among measured distances under each experimental occlusal condition (ANOVA; L6: $p<0.01$, R6: $p<0.01$). When all occlusal supports were removed, mean values at points L6 and R6 were 0.39mm and 0.39mm, respectively.

Displacement distance at points LC and RC (*Figures 4 and 5*)

With all occlusal supports on the splint present (condition 1), the mean values of displacement distance at points LC and RC during maximum voluntary clenching were 0.62mm and 0.59mm, respectively. These values were a little larger than those without splint (control). By cutting the splint in sequence from posterior to anterior systematically, the displacement distances were increased at both condyles, however, these values varied with the subject. To analyze the displacement patterns in detail, twenty-four subjects were divided into two groups depending upon the displacement distance as a boundary of 1mm of displacement in the experimental condi-

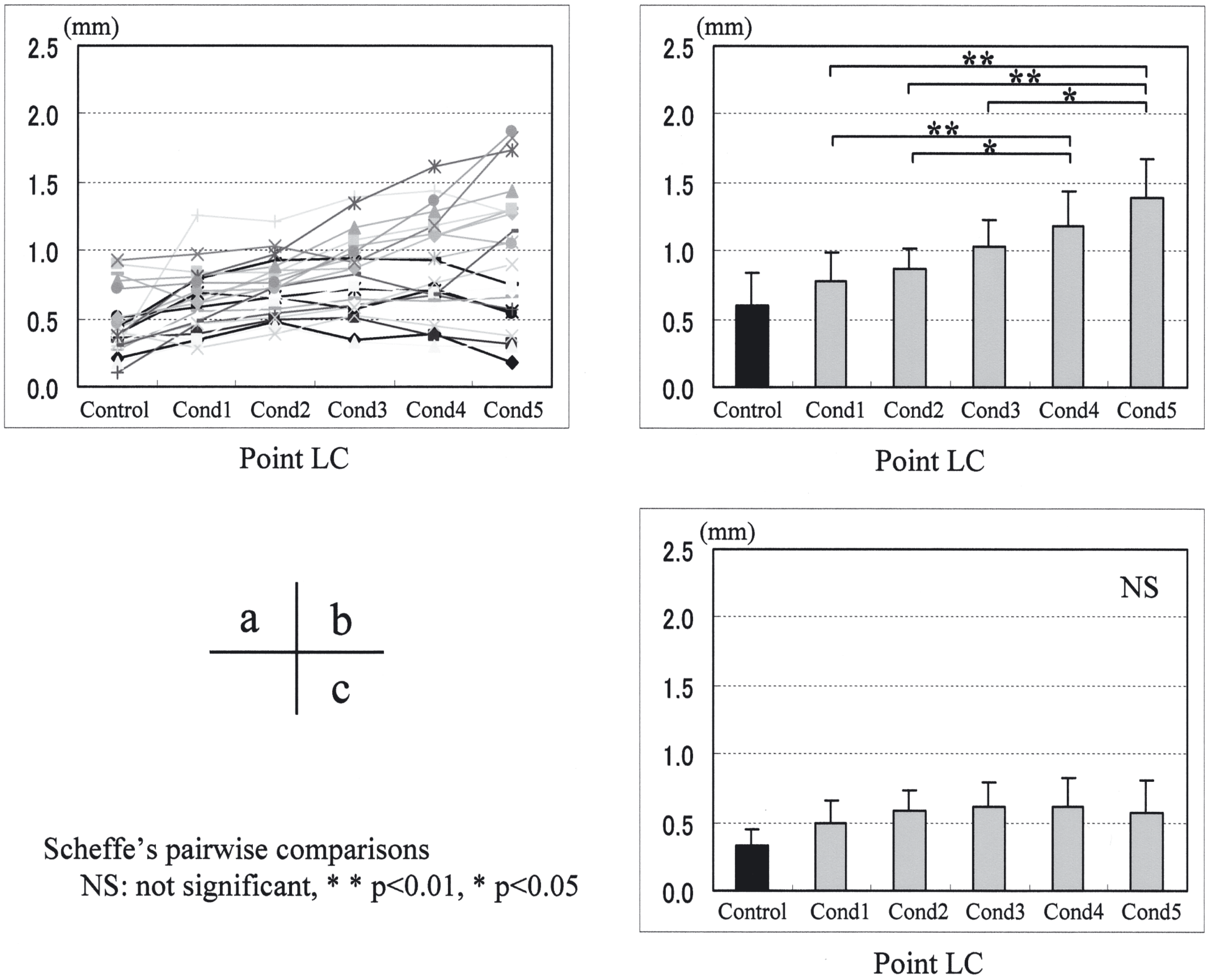

Figure 4. *Displacement distances at points LC under each experimental occlusal condition*

a: raw data of 24 subjects: By cutting the splint in sequence from posterior to anterior systematically, the displacement distances were increased, however, these values varied with the subject.

b: 11 subjects whose condyles displaced more than 1mm in condition 5: Significant differences were shown among measured distances under each experimental occlusal condition.

c: 13 subjects whose condyles displaced under 1mm in condition 5: No significant difference was observed among measured distances under each experimental occlusal condition.

tion 5. Namely, the first group whose condyles displaced more than 1mm in condition 5 consisted of eleven subjects and the second group under 1mm consisted of thirteen subjects. In the former group, by cutting the splint in sequence from posterior to anterior systematically, the displacement distances were increased and significant differences were shown among measured distances under each experimental occlusal condition (ANOVA; LC: $p<0.01$, RC: $p<0.01$). By contrast, in the latter group, no significant difference was observed among measured distances under each experimental occlusal condition (ANOVA; LC: $p>0.05$, RC: $p>0.05$).

Displacement direction at points LC and RC

The directions of condylar displacements varied from superior-posteriorly to superior-anteriorly, unrelated to the numbers of occlusal support. Significant difference was not shown among measured angles under each experimental occlusal condition (ANOVA; LC: $p>0.05$, RC: $p>0.05$).

DISCUSSION

In the present study, newly developed mandibular movement analyzing system with six-degree of freedom, which was based on low-frequency magnetic transducing technology, was used to measure the mandibular displacement. Our previous study[10] showed that, when the distance between the transmitter and the sensor was set within 300mm, total measurement errors were less than 100 μm and 0.2 degree for distance and for angle, respectively. Moreover, this system was based on the assumption of mandibular rigidity, which did not allow the physiological deformation under maximum voluntary clenching. Comparing the system with other jaw tracking systems on the market, the advantages of the system are: (1) since the sensor is small and lightweight (16.3g), this apparatus causes minimum interference to the subject during measurement; (2) the mandibular movement is reproducible as a movie on the screen just after completing the measurement; (3) the

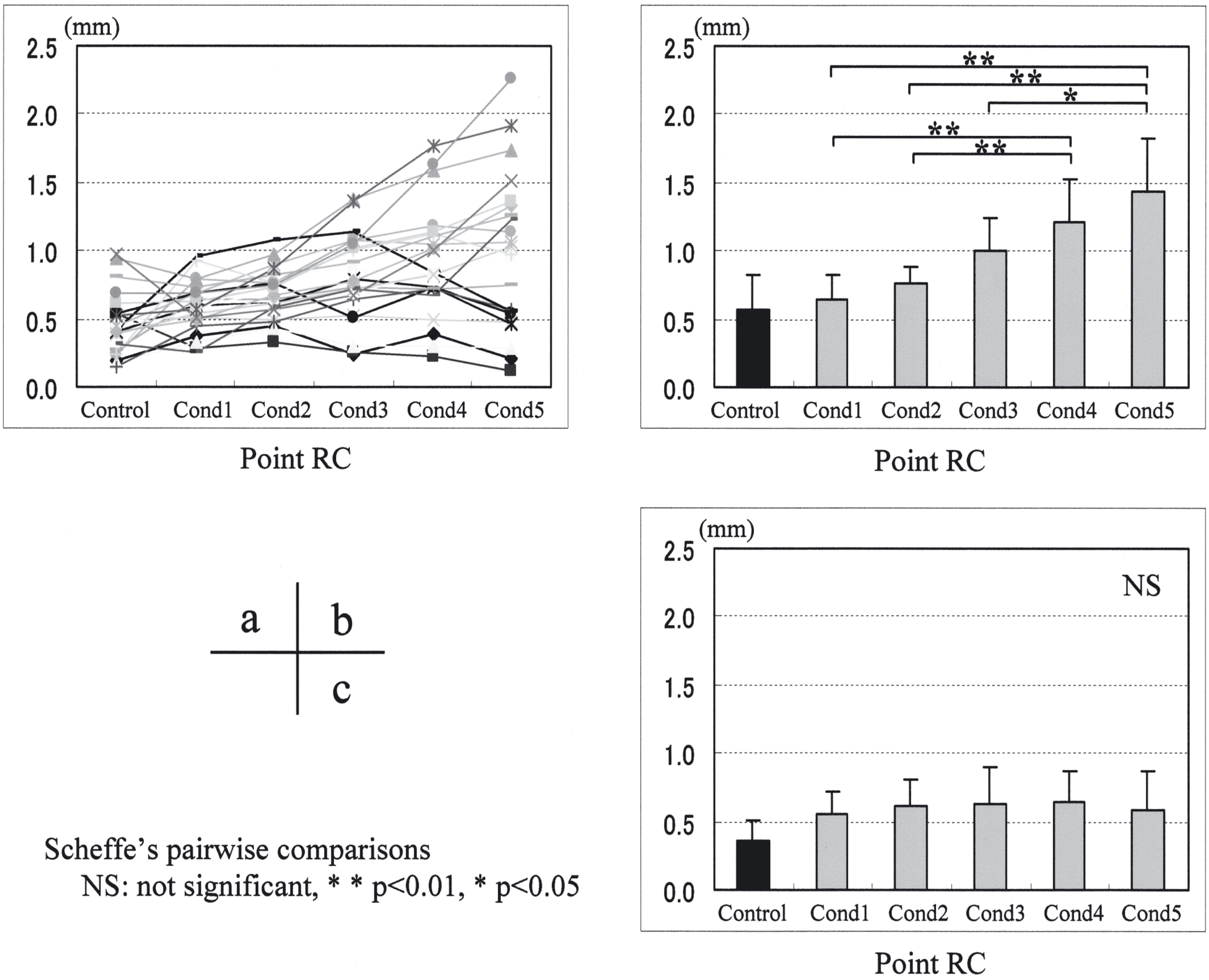

Figure 5. *Displacement distances at points RC under each experimental occlusal condition*
a: raw data of 24 subjects: By cutting the splint in sequence from posterior to anterior systematically, the displacement distances were increased, however, these values varied with the subject.
b: 11 subjects whose condyles displaced more than 1mm in condition 5: Significant differences were shown among measured distances under each experimental occlusal condition.
c: 13 subjects whose condyles displaced under 1mm in condition 5: No significant difference was observed among measured distances under each experimental occlusal condition.

kinematic axis can be automatically searched by using bespoke software.

Subject gender distribution was not equal in this study. Although Yamashita *et al.*[11] reported that maximum bite force of male subject was stronger than that of female subject, the present study did not show any statistical difference between males and females, in terms of mandibular displacement during maximum voluntary clenching under natural occlusal condition (Two-factor factorial ANOVA; $p>0.05$). Therefore, both male and female subjects were treated as one category.

Mandibular position on the splint was determined precisely using an interocclusal record which was registered with the anterior jig. With all occlusal supports on the splint present, the subjects would be able to exert stable maximum voluntary clenching at this mandibular position. On the other hand, by cutting the splint in sequence from posterior to anterior, mandibular position during clenching would be unstable and it would be difficult for the subjects to exert constant biting force. Therefore, the visual feedback system using EMG activities was helpful to keep mandible always at same position and to improve the reproducibility of recording data. The coefficient of variation (CV) values of displacement distance at both condylar points under each experimental condition were shown on *Table 1*. These values showed high precision of experimental procedure uniformly, and it was suggested that influences of both inserting the splint and reducing occlusal supports upon the reproducibility of recording data were negligible.

In our previous study using five subjects whose mandibular premolars and molars needed to be restored, three dimensional mandibular displacement related to loss of posterior occlusal support was investigated by removing their experimental prostheses in sequence from the most posterior to anterior[8]. The more the absence of posterior occlusal support increased, the more condylar displacements increased and the maximum bite forces decreased. These results suggest that condylar position would be

Table 1. *The coefficient of variation (CV = SD/Mean) values of displacement distance at both condylar points under each experimental condition These values showed high precision of experimental procedure uniformly.*

	Control	*Cond 1*	*Cond2*	*Cond3*	*Cond4*	*Cond5*
Point LC	15.1	14.2	10.9	10.7	9.4	15.1
Point RC	14.2	13.7	14.6	11.5	9.9	14.8

easily displaced with low level bite force following loss of posterior occlusal support.

Results derived from the present study showed similar tendencies. Apparent and gradual increase of displacement distances were shown at both first molars and condyles when the posterior occlusal supports were removed in sequence from posterior to anterior. However, because of the technical difference for setting occlusal support compared to the previous study, mandibular displacement could be produced not only by non-rigidity of the bone and periodontal ligament, but by distortion of occlusal splint fabricated with acrylic resin. This perhaps explains why the displacement distances of this study are larger than those of the previous one.

Subjects could be divided into two groups depending upon their condylar displacement following with reduced occlusal support. In the present study, threshold level for dividing subjects was arranged at 1mm of condylar displacement in experimental condition 5. From the result of our pilot study using same subjects, condylar displacements at LC and RC during maximum voluntary clenching in the intercuspal position without occlusal splint ranged from 0.10mm to 0.93mm and from 0.15mm to 0.98mm, respectively. Since all data were within 1mm, this value was thought to be appropriate for the threshold level. The first group whose condyles displaced more than 1mm in condition 5 may be defined as a group with low rigidity in their condylar structures and this phenomenon may depend upon subject-related condylar lability[12]. On the other hand, the second group showing a small amount of condylar displacements, even if all experimental occlusal supports were removed, and may possess high rigidity in their condylar structures.

From the clinical point of view, we can not agree to the hypothesis that all the individuals with distal extension loss of teeth will suffer from the degenerative changes of temporomandibular joints leading to TMD. This may be prevented by individual adaptability to the imbalanced occlusal condition. However, our findings may be important, if they have parafunctional activities such as clenching habit. One study suggested that sleep bruxism patients have approximately a 3 to 4 times higher number and duration of sleep bruxism episodes and tooth contacts compared to normal subjects[13]. Yamashita *et al.*[14] also reported a relationship between prolonged tooth contacts and TMD, and some other studies[15–18] of nocturnal bruxism described characteristic tooth contact patterns during sleep. In terms of muscle activities, some investigators reported that EMG activities of masticatory muscles during bruxism sometimes exceeded the 100% level of maximum voluntary clenching[19,20].

Within the limit of this study, it is hard to conclude whether we should restore posterior occlusal support with prosthetic treatment or leave the posterior tooth missing in a shortened dental arch (SDA). The SDA concept may be best restricted to individuals who demonstrate low risk factors.

CONCLUSIONS

The following conclusions are proposed regarding the mandibular displacement related to loss of the posterior occlusal support.

1) The distances of displacement at both first molar and condyle were increased by cutting splint in sequence from posterior to anterior.
2) Subjects could be divided into two groups depending upon their condylar mobility following with reduced occlusal support.
3) The directions of condylar displacements varied from superior-posteriorly to superior-anteriorly, unrelated to the numbers of occlusal support.

MANUFACTURERS' DETAILS

- Mandibular movement analyzing system with six-degree of freedom FASTRAK, Polhemus Inc, Vermont, USA
- Unifast II clear, GC Inc, Tokyo, Japan
- Mushprint, Dentsply Sankin Inc, Tokyo, Japan

ADDRESS FOR CORRESPONDENCE

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