European Journal of Orthodontics 28 (2006) 83–88
doi:10.1093/ejo/cji073
Advance Access publication 28 October 2005

Temporomandibular joint internal derangement in mandibular asymmetry. What is the relationship?

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SUMMARY The purpose of this study was to clarify the contributing factors and their influences on temporomandibular joint internal derangement (TMJ ID) symptoms in subjects with mandibular asymmetry.

Postero-anterior (PA) cephalograms of 187 pre-orthodontic treatment subjects (aged 18–45 years, mean 23.9 years) were used to investigate the inclination of the frontal occlusal (FOP) and frontal mandibular (FMP) planes to determine vertical asymmetry. Mandibular dental midline shift (DMS) and mandibular midline shift (MMS) were studied to determine transverse asymmetry. The degree of asymmetry was analysed in conjunction with the results from self-administered TMJ ID history forms.

A prevalence of TMJ ID was most related to the inclination of the FMP ($P < 0.01$), with the symptoms being notably higher when the cant was greater than 3 degrees. The symptomatic side was related only to the inclination of the FOP and FMP. Symptoms confined to the ipsilateral side were primarily found in subjects with mild asymmetry, whereas symptoms on both sides and those on the contralateral side were greater in those with moderate and severe asymmetry, respectively. No significant correlation was found for DMS and MMS.

The results suggest that the degree of asymmetry in the vertical dimension is significantly correlated with TMJ ID symptoms.

Introduction

A mild degree of asymmetry in the craniofacial region is common in humans (Shah and Joshi, 1978; Leslie and Gwynne, 1981), including in individuals with a normal facial appearance (Farkas and Cheung, 1981; Peck *et al*., 1991). Clinically, various degrees of mandibular asymmetry are observed in many patients (Mulick, 1965). The problem of facial appearance and occlusal malfunction are important complaints of these patients. Temporomandibular joint internal derangement (TMJ ID) is also widely reported to be associated with mandibular asymmetry (Nickerson and Moystad, 1982; Katzberg *et al*., 1985; Fushima *et al*., 1989; Kurihara *et al.*, 1996). Nevertheless, how occlusal and skeletal discrepancies in mandibular asymmetry relate to TMJ ID is still debatable.

Some authors have reported TMJ ID itself as a primary cause of growth disturbance, including mandibular asymmetry (Ricketts, 1966; Hans *et al.*, 1992; Schellhas *et al.*, 1993). *In vivo* experiments of disc displacement in rabbits have also verified that permanent articular-disc displacement is one causal factor in the development of mandibular midline asymmetry (Legrell and Isberg, 1999).

On the other hand, various studies have investigated occlusal problems as a predisposing factor of TMJ ID. Occlusal instability, midline discrepancy, right–left differences in molar relationship, and inclination of the frontal occlusal plane (FOP) have also been considered to be important occlusal characteristics in patients with TMJ disorders (Solberg *et al.*, 1986; Fushima *et al.*, 1999). Differences in the heights of the right and left rami, have also been suggested as important skeletal problems associated with TMJ pathology (Inui *et al*., 1999; Trpkova *et al*., 2000). Not only are the factors contributing to TMJ ID still controversial, but the relationship between the amount and direction of asymmetry and the symptomatic side has also not been clearly defined.

The purpose of this cross-sectional study was to clarify the contributing factor and its influence on TMJ ID symptoms in mandibular asymmetry. An understanding of this would assist in improving diagnosis and treatment planning for dentofacial asymmetry patients in need of orthodontic and/or orthognathic and TMJ treatment.

Subjects and method

Subjects

The subjects were recruited from 392 Japanese patients with mandibular asymmetry, routinely referred to the Orthodontic Clinic, Tokyo Medical and Dental Hospital, for treatment from 1998 to 2001. The inclusion criteria were (1) Mandibular asymmetry in the transverse and/or vertical dimension that could be measured on a postero-anterior (PA) cephalogram, and (2) over 18 years of age. Subjects were excluded if they had a history of infection, tumours,

rheumatoid disease, injuries to the TMJ, or other clinically significant pathology affecting the craniofacial region, or a congenital syndrome. A total of 187 adults (112 female and 75 male) aged 18 to 45 years of age (mean 23.9 years) were included in this study.

Cephalometric radiography and analysis

A PA cephalogram, lateral cephalogram, and panoramic radiographs obtained routinely prior to orthodontic treatment were used for quantifying the asymmetry of each patient. During exposure the mandible was in the maximum intercuspal position.

All PA cephalograms were traced and the landmarks identified and investigated for asymmetry by one author (BB). The landmarks selected were based on previously published PA reproducibility studies (Major *et al*., 1994). The vertical reference plane (the facial midline) was constructed as a line passing through crista galli and anterior nasal spine (ANS) perpendicular to the line between the intersections of the greater wing of the sphenoid bone and the orbital margin. The angle measured between the perpendicular line of the facial midline and a line passing through the occlusal surface of the bilateral lower first molar was defined as the FOP, and the angle between the perpendicular line of the facial midline and a line connecting the right and left antegonial notches as the frontal mandibular plane (FMP). The FOP and FMP were used to represent asymmetry in the vertical dimension: positive values for FOP and FMP indicated that these planes were inclined superiorly towards the short side. The angle between the facial midline and a line passing through ANS and menton was defined as the degree of mandibular midline shift (MMS). The distance (mm) between the facial midline and the midline of the mandibular incisors was described as the dental midline shift (DMS). A DMS on the left and right side was considered as the absolute value for diagnostic criteria for transverse asymmetry (Figure 1).

The lateral cephalogram and panoramic radiographs were used with PA cephalograms to identify valid landmarks. The error of the method was determined by retracing each cephalogram on separate occasions, two weeks after the first tracing. The following formula was used for measurement error (ME) calculation:

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

where d is the difference between two measurements of a pair and n is the number of subjects. The mean double-determination errors for the linear and angular measurement (Baumrind and Frantz, 1971; Ahlqvist *et al*., 1986, 1988) were 0.5 mm and 0.5 degrees, respectively.

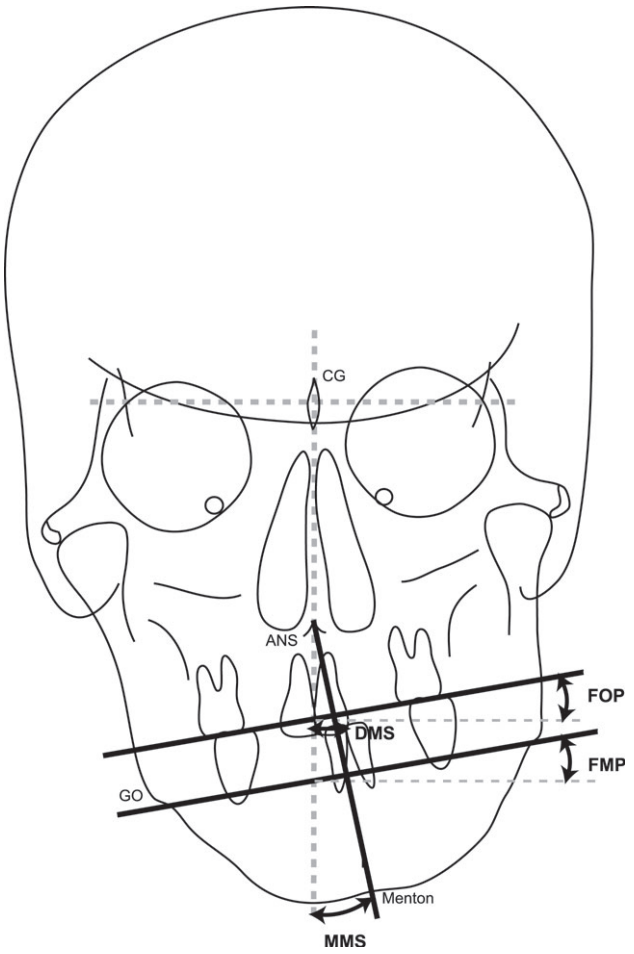


Figure 1 The cephalometric landmarks, reference planes, and measurements of the frontal occlusal plane (FOP), frontal mandibular plane (FMP), dental midline shift (DMS), and mandibular midline shift (MMS).

Self-administered TMJ history form

The following subjective symptoms were assessed: joint pain in the previous month, defined as pain in the face, jaw, temple, in front of or in the ear according to the Research Diagnostic Criteria for Temporomandibular Disorders (Dworkin and LeResche, 1992), joint sound ('Have you ever had joint noises? If yes, which side?' Answer options: left, right, or both sides), and limitation of mouth opening ('Have you ever had difficulties in opening the mouth wide or jaw locking?'). The appearance of at least one symptom in each TMJ was considered as indicative of TMJ ID of that joint.

Statistical analysis

Statistically significant relationships between vertical and transverse asymmetry variables and the prevalence of TMJ ID were investigated by logistic regression models. This allowed the computation of odds ratios for TMJ ID outcome separately for each variable. To investigate the relationship between asymmetry variables and the symptomatic side, the

differences in the mean values of the asymmetry variables on each side were tested by ANOVA and then adjusted for multiple comparisons using Scheffe's analysis. The significance level of Scheffe's analysis is designed to allow all possible linear combinations of group means to be tested, not just pairwise comparisons. Therefore, this analysis is often more conservative than other tests, which means that a larger difference between means is required for significance.

A probability value of less than 0.01 was considered to indicate statistical significance. All data were analysed on a personal computer with the statistical package SPSS for Windows (Version 10.0, SPSS, Chicago, Illinois, USA).

Results

FOP and FMP were distributed from −5.0 to 10.0 degrees (4.2 ± 2.3 and 4.0 ± 2.1 degrees, respectively; mean ± SD). Most subjects had positive FOP and FMP values: only three of the 187 subjects (1.6 per cent) exhibited negative values, indicating that in these patients the planes inclined toward the contralateral side. Pearson's correlation analysis showed that FOP and FMP were positively correlated ($r = 0.91$, $P < 0.01$). DMS varied from 1.0 to 10.0 mm (4.3 ± 2.1 mm; mean ± SD) whereas MMS varied widely, from 1.0 to 15.0 degrees (6.1 ± 2.9 degrees; mean ± SD). DMS and MMS were positively correlated ($r = 0.73$). FOP–DMS and FMP–MMS were also positively correlated, with r values of 0.42 and 0.51, respectively.

Prevalence of TMJ ID

Symptoms of TMJ ID were found in 142 subjects (75.9 per cent) while 45 (24.1 per cent) did not demonstrate symptoms of TMJ ID. The presence of TMJ ID was directly proportional to the values of FOP and FMP, with the symptoms being notably higher when the asymmetry was greater than 3 degrees, i.e. the higher values associated with a higher prevalence of symptoms. A similar tendency of a higher prevalence of symptoms with a higher value of DMS and MMS was observed. Logistic regression analysis revealed a significant relationship between all variables and TMJ ID outcome, with the higher odds ratios for vertical asymmetry (Figure 2).

Prevalence of the symptomatic side

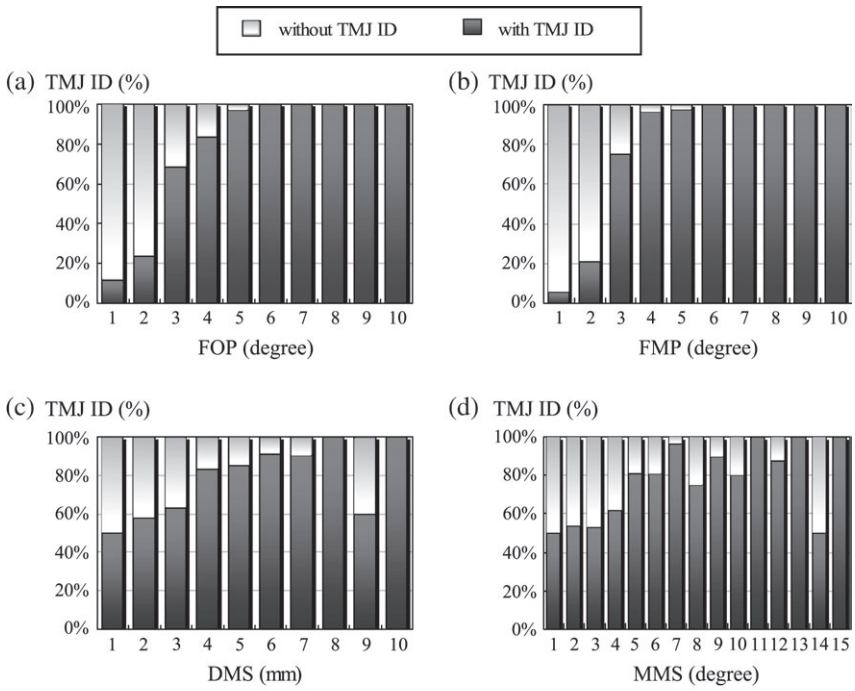
Symptoms were present on the ipsilateral side, on both sides, and on the contralateral side in 37.3, 32.4, and 30.3 per cent of subjects, respectively. The side with TMJ ID symptoms was significantly correlated with the values for FOP and FMP: higher values were associated with fewer symptoms on the ipsilateral side and correspondingly more symptoms on the contralateral side. In other words, the symptoms were found primarily on the ipsilateral side than on both sides and finally on the contralateral side with increasing values of FOP and FMP (Figure 3a,b). Significant differences in the mean values for FOP and FMP were found by ANOVA; moreover, Bonferroni and Scheffe's analyses revealed a significant difference in the mean values for FOP and FMP with each side with symptoms. No significant correlations were found with DMS and MMS (Figure 3c,d). With Scheffe's analysis, the mean values of FOP for symptoms on the ipsilateral side, bilaterally, and on the contralateral side were 4.0, 5.3, and 6.7 degrees, respectively; the corresponding mean values for the FMP were 3.7, 5.0, and 6.2 degrees, respectively (Figure 3e).

Discussion

The components in the craniomandibular region are closely interrelated, and hence disturbances in one part to some extent affects other parts. Asymmetry of the mandible influences normal TMJ structure and function, and *vice versa*. The results of the present study indicate that there is a relationship between vertical asymmetry and TMJ ID. It can be hypothesized that dental and skeletal discrepancies disrupt the normal symmetrical load to the TMJ. Such asymmetrical loads may influence intra-articular pressure and act as a trauma to the TMJ structures, inducing the development of TMJ ID and subsequent TMJ disorders. On the other hand, TMJ ID itself may cause growth disturbances which may result in mandibular asymmetry. Since the present study was cross-sectional, the cause-relationship of the vertical asymmetry and TMJ ID could not be completely clarified.

The prevalence of a symptomatic side has been a matter of controversy. From an investigation of orthodontic patients, Fushima *et al*. (1989) and Tallents *et al.* (1991) reported that TMJ ID was more prevalent on the short side of the mandible, but these studies involved small samples. In contrast, Kurihara *et al.* (1996), in a study of 433 orthodontic patients, found that the symptoms were more frequently bilateral. However, there was no clear evidence of how symptoms were observed on each side of the TMJ.

Interestingly, the main finding of the present study was the high tendency for the symptomatic side to be related to the degree of FOP and FMP. Based on the results of the significant differences between the mean values of vertical asymmetry on each side, TMJ problems in mandibular asymmetry patients may be classified into three grades: (1) mild (FOP and FMP less than 4 degrees), with a tendency for ipsilateral TMJ ID; (2) moderate (FOP and FMP of 4–7 degrees), with a tendency for bilateral TMJ ID; and (3) severe (FOP and FMP greater than 7 degrees), with a tendency for contralateral TMJ ID. The prevalence of a symptomatic side is not an unexpected phenomenon but is causally related to the degree of vertical asymmetry. It is hypothesized that these observations are attributable to a different pattern of load on the ipsilateral and contralateral sides of the TMJ. Moreover, differences in bilateral TMJ



(e) **Test statistic**

Variable	99% confidence interval for odds ratio TMJ ID	Lower	Upper
FOP	2.5	2.0	3.0
FMP	3.0	2.1	4.1
DMS	1.4	1.1	1.7
MMS	1.3	1.1	1.5

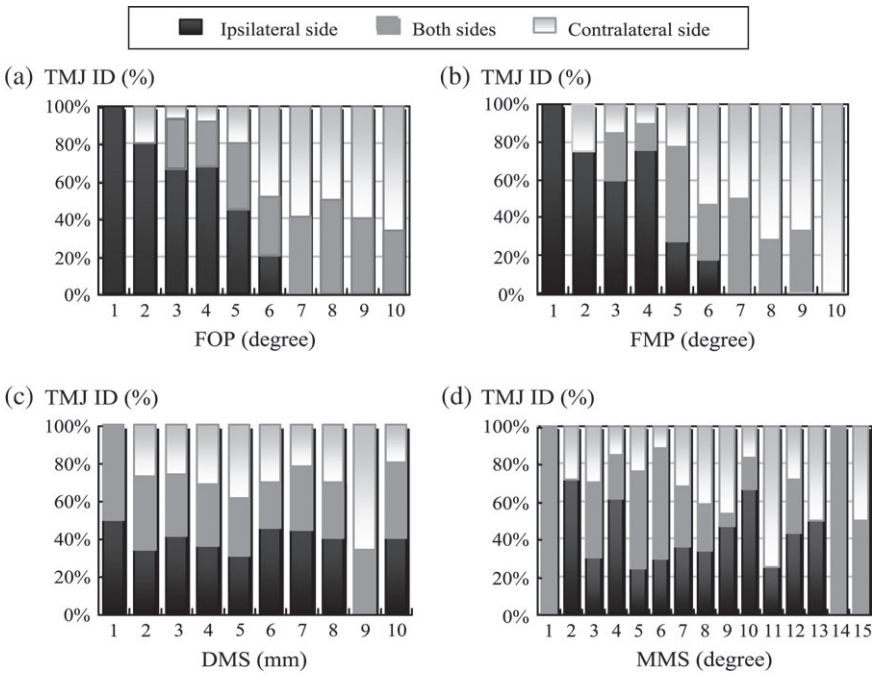
Figure 2 Prevalence of temporomandibular internal derangement (TMJ ID) (%) as detected by various asymmetry variables: (a) frontal occlusal plane (FOP), (b) frontal mandibular plane (FMP), (c) dental midline shift (DMS), and (d) mandibular midline shift (MMS). The prevalence of TMJ ID was directly proportional to the amount of all asymmetry variables. FOP and FMP values higher than 3 degrees were significantly associated with a higher prevalence of TMJ ID. (e) FOP and FMP were more likely related to the TMJ ID symptom than DMS and MMS (logistic regression analysis).

morphology (Tallents *et al.*, 1991; Akahane *et al.*, 2001) in patients with mandibular asymmetry may represent anatomic disorders that predispose these patients to TMJ problems on each side in different ways.

The amount of asymmetry and the time difference in the duration of TMJ ID may explain the development of symptoms from one side to the other. It was found that the duration of TMJ ID symptoms was significantly longer for bilateral (8.2 ± 3.1 years) and contralateral (8.0 ± 2.9 years) than for ipsilateral (4.8 ± 3.8 years) symptoms, even though there were no significant differences in the mean ages in each group (Table 1). However, it is puzzling as to why, in some subjects with severe asymmetry, the symptoms on the ipsilateral side were absent. It is not known if the symptoms in these severe asymmetry subjects were always absent from the ipsilateral side or had disappeared at some stage. Further studies using magnetic resonance imaging (MRI) are required to detect the disc–condyle relationship as well as to assess the disc configuration in these patients.

Although statistical analysis failed to demonstrate a relationship between transverse asymmetry and the symptomatic side in TMJ ID, vertical and transverse asymmetries are often coincidently observed in patients with mandibular asymmetry. Positive or negative masticatory influences of transverse asymmetry on TMJ ID therefore have to be considered, including the influence of asymmetry on masticatory muscle activity.

Assessments of asymmetry tend to be critically subjective (Chebib and Chamma, 1981), and treatment planning depends on attempting to quantify the facial appearance that is acceptable and the severity of functional problems. An occlusal plane inclination within the range of 0–3 degrees has been observed in normal, healthy patients (Lu, 1965;



(e) Test statistic

	Side of TMJ ID symptoms	N	Mean value of FOP	FMP	DMS	MMS
Scheffe[a,b]	Ipsilateral	53	4.0	3.7	4.5	6.1
	Bilateral	48	5.3 *	5.0 *	4.6	6.5
	Contralateral	41	* 6.7 *	6.2	4.9	7.3

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 46.808
b. The group sizes are unequal. The harmoic mean of the group sizes is used.
* The mean difference is significant at $P < 0.01$

Figure 3 Prevalence of temporomandibular internal derangement (TMJ ID) side with symptoms by (a) frontal occlusal plane (FOP), (b) frontal mandibular plane (FMP), (c) dental midline shift (DMS), and (d) mandibular midline shift (MMS). (a) and (b) show a significant correlation between the values of FOP and FMP and the prevalence of the TMJ ID side. The prevalence of TMJ ID on the ipsilateral side is inversely proportional to that on the contralateral side. Ipsilateral symptoms were primarily found in mild asymmetry subjects, whereas bilateral and contralateral symptoms were greater in those with moderate and severe asymmetry, respectively. This relationship was not found in either DMS or MMS. (e) There was a significant difference in the mean values of FOP and FMP according to the symptomatic side.

Table 1 Scheffe's analysis revealed a significantly longer duration of TMJ ID symptoms for bilateral and contralateral side TMJ ID than for ipsilateral TMJ ID, even though there was no significant difference in the mean ages of the groups.

	Side of TMJ ID symptoms	*n*	Mean range	Mean value of TMJ ID duration
Scheffe's[a,b]	Ipsilateral	53	22.5	4.8
	Bilateral	48	24.2	8.0 *
	Contralateral	41	24.5	8.2 *

Means for groups in homogeneous subsets are displayed.
[a]Uses harmonic mean sample size = 46.808.
[b]The group sizes are unequal. The harmonic mean of the group sizes is used.
*The mean difference is significant at $P < 0.01$.

Ferrario *et al*., 1993). Furthermore, 4 degrees of canting has been reported as the threshold for recognition of an occlusal plane inclination by 90 per cent of observers (Bonnie *et al.*, 1997). In the present study, the subjects possessing clinical symmetry and soft tissue balance were not concerned with aspects of subclinical asymmetry, whereas asymmetry greater than 3 degrees was frequently associated with orthodontic diagnosis and treatment planning. The consequence of this is that only subjects with severe asymmetries or asymmetries with an associated functional impairment tend to be treated (Arnaud *et al*., 2001).

The present study focused on adult subjects which is the main group presenting TMJ problems and in which the skeletal asymmetry had not progressed significantly.

Therefore the factors of growth and high adaptive capacity in the growing period that may obscure the exact relationship between asymmetry and TMJ problems could be excluded. However, as self-adaptation and tolerance ratios differ between individuals, these factors cannot be excluded in studies involving humans. Investigations into the biomechanics of stresses on the TMJ using finite element analysis would assist in a better understanding of the mechanical changes associated with TMJ ID.

Conclusion

In mandibular asymmetry patients, the degree of asymmetry in the vertical dimension is significantly correlated with TMJ ID symptoms. Therefore, even a mild degree of vertical asymmetry should be considered when formulating an orthodontic and/or orthognathic treatment plan to establish a normal TMJ and occlusal function.

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Acknowledgements

This study was financially supported by a Grant-in-Aid for Scientific Research (no. 14370688) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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