DEVIATION OF THE MANDIBULAR LABIAL FRENUM AS RELATED TO SIGNS AND SYMPTOMS OF TEMPOROMANDIBULAR DISORDERS (TMDS)

Naif A. Bindayel, Moshabab A. Asiry, and Georgios Kanavakis

ABSTRACT

Aim: To investigate the association between mid-line deviation of the mandible, as determined by upper to lower labial frena, and signs and symptoms of Temporomandibular Disorders (TMDs).

Materials and Methods: The current study was original research conducted on a sample of 439 medical records of TMD patients treated at Tufts University. All patients underwent a clinical examination revealed ~~a~~ detailed information regarding temporomandibular joints, history of pain, and comprehensive intra-oral findings. Subjects were divided into three groups: 1. No frenal deviation, 2. Deviation to the right, and 3. Deviation to the left. **Results:** Signs and symptoms of TMD tend to occur more likely on the side of the frenum deviation. The signs and symptoms that were significantly associated to frenum position were TMJ crepitation sounds and locking, right muscles pain on palpation (medial pterygoid and sternocleidomastoid), and "reported locking on the left TMJ". Subjects with aligned frena showed a statistically significant increase in the range of motion to the right side. The results also revealed a highly significant association between maxillary plane canting and mandibular frenum position. Left posterior cross bite was significantly more prevalent in the left frenum deviation group. **Conclusion:** Expression of TMD signs and symptoms was more prevalent on the side of frenum deviation. TMD population showed a higher prevalence of left mandibular frenum deviation. Several signs and symptoms were significantly associated to frenum position.

Key Words: *TMD, Labial frenum, Frenum deviation*

INTRODUCTION

The definition of temporomandibular disorders (TMDs), as a group of orofacial signs and symptoms including pain, deviations from normal range of motion and temporomandibular joint sounds (American Dental Association, 1983), describes the large variability in the clinical presentation of patients with these conditions. Large population studies in adults have revealed frequency distributions of TMD signs and symptoms in various age groups. In a group of 739 young adults(Solberg, Woo, & Houston, 1979), 76% exhibited clinical signs of dysfunction, however, only 26% reported associated symptoms, indicating that the occurrence of TMJ symptomatology is multifaceted. Gesch, Bernhardt, Alte, Schwahn, Kocher, John, and Hensel (2004) studied the prevalence of TMDs in a homogenous population of 7008 adults older than 20 years, and reported that half of the subjects had at least one clinical sign with women presenting a higher frequency for all signs and symptoms. The study also reported that the most common sign of TMDs in this population were TMJ sounds with 25% prevalence. In a group of 433 TMD patients, the clinical examination (Manfredini, Chiappe, & Bosco, 2006), based on the RDC/TMD, 38% of patients diagnosed with group I disorders (muscle disorders), 52.3% with group II disorders (disc displacement), and 52.6% with group III disorders (arthralgia, osteoarthritis, osteoarthrosis). Bernal and Tsamtsouris (1986) studied a group of 136 children 3-5 years old. According to the parent's reports, 17% of the children ground their teeth and 7 % suffered from occasional headaches. Clinical examination revealed that 5% had TMJ clicking, and that 11% exhibited deviation of the mandible during opening. This deviation presented more frequently towards the left. This unexplained observation has also been reported in other studies (Nilner, 1981; Solberg et al., 1979). In addition, posterior crossbites, which commonly result in mid-line deviations as the teeth settle into centric occlusion, have also been found to be more prevalent in individuals with TMDs (Miyazaki, Motegi, Isoyama, Konishi, & Sebata, 1994; Thilander, Rubio, Pena, & de Mayorga, 2002), and mandibular skeletal transverse asymmetry has been described as a risk factor for the development of TMDs (Fukazawa, Endo, Kurita, & Mitani, 1990).

Fu, Mehta, Forgione, Al-Badawi, & Zawawi (2003) evaluated maxillomandibular relationship in TMD patients using the labial frena as a reference to evaluate mandibular shift. They found that after flat plane bite plate therapy, the mandibular position of all subjects shifted toward the labial frenum midline position. Pradham, White, Mehta, and Forgione (2001) reported that mandibular deviation, as

evaluated by labial frena, occurred in greater frequency in subjects with TMD than control. TMJ sounds were also reported to be correlated with midline deviation. Creagh and Smith (1989) found that TMJ sounds were directly related to minor deviation in the path of movement of the mandible on opening and closing. The interaction between midline deviation and occlusion was also reported. Using postero-anterior cephalographs and dental models, Ali, Yamada, Alkhamrah, Vergara, and Hanada (2003) showed that occlusal curvature might compensate for mandibular deviation in patients with TMD. It was also shown that the condyle on the deviated side was smaller and presented with more internal derangement. However, the reported clinical symptoms were not coincident with that pattern (Goto, Nishida, Nakayama, Nakamura, Sakai, Yabuuchi, & Yoshiura, 2005).

The aforementioned studies investigated factors found to be associated with TMD. Those papers discussed different aspects of malocclusion and skeletal discrepancies (i.e. cross bite, asymmetry) that might usually have an impact on the position of the mandibular arch in reference to the facial midline. Although some of them addressed mandibular deviation, they were not designed specifically to test the relationship between mandibular midline deviation and the development of TMD. The literature lacks studies investigating the pattern and laterality of TMD signs and symptoms in patients presented with midline deviation. Therefore, the aim of this proposed study is to investigate the association between mid-line deviation of the mandible, as determined by upper to lower labial frena and signs and symptoms of TMD.

MATERIALS AND METHODS

To determine our study population, a sample size calculation (Fleiss, Tytun, & Ury, 1980) was performed using Chi-Square test, based on 50% of prevalence, under 80% of power, and with a 0.05 level of significance ($\alpha = 0.05$),(Pagano & Gauvreau, 2000) It was determined that 439 subjects were required in order to detect a significant difference of at least 7.7% of TMD signs/symptoms between groups. The power analysis was estimated based on an early published craniomandibular index (CMI) value for control subjects of 0.07 (Fricton & Schiffman, 1987). The CMI scoring method composed of combining all joint dysfunctions and head and neck muscle findings, similar to the presented study. As a result, our final sample consisted of 439 medical records of consecutively treated patients at the Craniofacial Pain, Headache and Sleep Center of Tufts University School of Dental Medicine (Tufts University, Boston, MA) over the period from the year 2000 to 2010. The study was reviewed and approved by the Tufts Institutional Review Board.

All patients were seeking treatment for orofacial pain, and underwent a clinical examination following a standardized protocol. This includes information regarding past medical and dental history, history of pain or dysfunction in the oro-facial-neck region, a detailed intra-oral examination, and a comprehensive assessment of the temporomandibular joints, the oro-facial-neck musculature and their surrounding structures. Signs of pain were evaluated with bilateral digital palpation (Kaplan & Assael, 1991) performed by residents at the Craniofacial Pain Center at Tufts University. Residents are trained to palpate in a standardized and reproducible way. In addition, the temporomandibular joint range of motion was recorded in millimeter. An important feature also recorded is the alignment of the maxillary and mandibular labial soft tissue frena.

Data collection was performed separately for each of the parameters of the examination protocol, as well as collectively providing a combined score for every subject including all measurements for signs and symptoms of temporomandibular disorders. Subjects were divided into three groups (no frenal deviation, deviation to the right, and deviation to the left) based on their lower labial frenum position in relation to the upper labial frenum. Differences between groups were explored with Pearson's chi-square test and and one-way ANOVA, at the 0.05 level of statistical significance. All statistical analyses were performed with SPSS version 16.0 (SPSS, IBM©, Armonk, NY, USA).

RESULTS

The mean age of subjects was 41 years (range: 10-88 years) with vast majority of sample were females (82%). There were no differences between genders in frenum alignment, and the lower frenum was deviated to the left in 50.3% of participants (Table 1). The results displayed a tendency of signs and symptoms of temporomandibular disorders to occur more likely on the side of the frenum deviation, however this was not statistically significant for any of the three groups (Table 2). Chi-Square test utilized to investigate the association of frenum position variable with each TMD sign and symptom (Appendix 1). After listing the prevalence (%) of each TMD sign and symptom, a 2∗3 contingency table analysis was conducted for the presence (or absence) of the signs and symptoms within the three frenum deviation groups. The only symptom that was significantly associated to frenum position was "reported locking on the left TMJ". However, there were several signs of TMDs significantly related to frenum position, including TMJ crepitation sounds, TMJ locking, and right medial pterygoid and right sternocleidomastoid (SCM) pain on palpation (Table 3).

Table 1. Frenum position and gender distribution of the studied sample.*

			Mandibular Frenum			
			aligned	to right	to left	Total
Sex	Male	Count	25	21	33	79
		% of Total	5.7%	4.8%	7.5%	18.0%
	Female	Count	109	63	188	360
		% of Total	24.8%	14.4%	42.8%	82.0%
Total		Count	134	84	221	439
		% of Total	30.5%	19.1%	50.3%	100.0%

*Pearson Chi-Square = 4.238 (p= 0.120)

Table 2. Combined positive signs and symptoms means among different frenum positions groups.

		N	Mean	Std. Deviation	F value	P value
Signs and symptoms combined	Aligned frenum	134	10.94	5.147	.327	.721
	To the right	84	11.12	4.668		
	To the left	221	11.42	4.760		
	Total	439	11.21	4.858		
Signs and symptoms on right	Aligned frenum	134	5.43	2.985	.419	.658
	To the right	84	5.46	2.955		
	To the left	221	5.21	3.078		
	Total	439	5.32	3.022		
Signs and symptoms on left	Aligned frenum	134	5.51	3.150	2.599	.075
	To the right	84	5.65	2.818		
	To the left	221	6.21	2.914		
	Total	439	5.89	2.981		

Table 3. The prevalence (%) of TMDs signs and symptoms of the studied populations. Chi-Square (Chi-Sq) value represents 2∗3 contingency table-analysis for each sign/ symptom.

	N	%	Chi-Sq Value	P Value
Jaw pain Rt	439	55	.328	.849
Jaw pain Lt	439	62	.831	.660
Reported click Rt	439	51	5.770	.057
Reported click Lt	439	52	.930	.628
Grinding	439	28	4.509	.105
Reported lock Rt	439	21	2.565	.277
Reported lock Lt	439	24	7.549	.023*
TMJ pain Rt	439	44	1.496	.473
TMJ pain Lt	439	49	3.488	.175
Click Rt	439	35	2.223	.329
Click Lt	439	35	1.278	.528
Crepitation Rt	439	10	7.388	.025*
Crepitation Lt	439	9	7.901	.019*
TMJ lock Rt	438	4	8.264	.016*
TMJ lock Lt	439	5	7.011	.030*
Masseter Rt	439	65	4.829	.089
Masseter Lt	439	67	5.555	.062
Temporal Rt	439	48	2.342	.310
Temporal Lt	439	52	1.530	.465
Temp. Tendon Rt	439	56	3.388	.184
Temp. Tendon Lt	439	58	2.017	.365
Lat. Pterygoid Rt	439	63	1.000	.607
Lat. Pterygoid Lt	439	64	3.593	.166
Med Pterygoid Rt	439	37	7.541	.023*
Med Pterygoid Lt	439	40	5.322	.070
SCM Rt	439	46	15.196	.001*
SCM Lt	439	45	.292	.864
Valid N (list wise)	438			

* p value < 0.05

In regard to functional occlusion, subjects with aligned frena presented a statistically significant increase in the range of motion to the right side (p = 0.004, Table 4). On the other hand, the lateral excursions to the left side were not significantly different between groups (p = 0.118, Table 5).

Chi-Square tests showed a highly significant association between maxillary plane canting and mandibular frenum position. The majority of subjects with a left sided mandibular frenum deviation had left-sided maxillary canting (Table 6).

Table 4. Distribution of signs and symptoms' percentages (%) that showed a statistically significant differences using Chi-Square (Chi-Sq), along with the relevant p value.

	Mandibular frenum %			Total %	P value
	aligned	to right	to left		
Reported Lock Lt	5.2	6.4	12.8	24.4	.023
Crepitation Rt	1.4	1.6	6.6	9.6	.025
Crepitation Lt	2.5	0.5	6.4	9.3	.019
TMJ lock Rt	0	.7	3	3.7	.016
TMJ lock Lt	0.2	.9	3.4	4.6	.030
Med Pterygoid Rt	13.2	4.8	19.1	37.1	.023
SCM Rt	18	6.6	21	45.6	.001

Table 5. Comparison of mandibular lateral excursion to right means (mm), among the three group of frenum position using ANOVA, with F value of 5.589 and p value of .004.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Aligned	134	8.97	2.516	.217	8.54	9.40	0	15
To right	84	8.18	2.612	.285	7.61	8.75	0	13
To left	221	8.01	2.756	.185	7.65	8.38	1	16
Total	439	8.34	2.685	.128	8.09	8.59	0	16

Table 6. Comparison of mandibular lateral excursion to left means (mm), among the three group of frenum position using ANOVA, with F value of 2.149 and p value of .118.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Aligned	134	8.87	2.591	.224	8.43	9.32	0	16
To right	84	8.57	2.416	.264	8.05	9.10	1	15
To left	221	8.30	2.514	.169	7.97	8.64	1	16
Total	439	8.53	2.526	.121	8.29	8.77	0	16

In regard to transverse static occlusal relationships, only left posterior cross bite was more prevalent in the left frenum deviation group while no such association was noted for the right cross bite (Tables 7 and 8). Finally, molar classification distribution was tested for any significant differences (Table 9) among the frenum groups using Chi-Square test with no apparent statistical difference (p= 0.742).

DISCUSSION

Midline discrepancy and right-left difference of the molar relationship seem to be important occlusal characteristics in patients with TMD (Fushima, Inui, & Sato, 1999). In the current study, 30.5%, 19.1%, and 50.3% of participants had an aligned, right deviated, and left deviated lower labial frenum, respectively. Similarly, Miller et al., 1979, reported that the maxillary and mandibular midlines fail to coincide in almost three fourths of the population (Miller et al., 1979). On the other hand, other study have found that the labial frenum is aligned in approximately 70% of population (Miller, Bodden, & Jamison, 1979). That might explain the high prevalence of TMD, and support the variability of midline deviation prevalence presented according to different anatomical landmarks (dental vs frenum) and studied population groups.

Expression of signs and symptoms was more prevalent on the side of the face toward which the frenum was deviated, however this was not statistically significant (p=0.075). This might be due to the fact that clinical (and sub-clinical) expression of symptoms and signs is governed by multiple anatomical and developmental factors. A study on 31 subjects with mandibular deviation found that there is specific relationship between condylar movement and mandibular deviation.

Table 7. The distribution of different maxillary plane canting categories among frenum deviation groups.*

			Mandibular Frenum			
			aligned	to right	to left	Total
Maxillary Plane	leveled	Count	87	23	64	174
		% of Total	19.8%	5.2%	14.6%	39.6%
	Higher right	Count	16	31	26	73
		% of Total	3.6%	7.1%	5.9%	16.6%
	Higher left	Count	31	30	131	192
		% of Total	7.1%	6.8%	29.8%	43.7%
Total		Count	134	84	221	439
		% of Total	30.5%	19.1%	50.3%	100.0%

*Pearson Chi-Square = 83.287 (p= 0.000)

Table 8. The distribution of right posterior cross bite presentation among frenum deviation groups.*

			Mandibular Frenum			
			aligned	to right	to left	Total
Right cross bite	Absent	Count	122	71	195	388
		% of Total	27.8%	16.2%	44.4%	88.4%
	Present	Count	12	13	26	51
		% of Total	2.7%	3.0%	5.9%	11.6%
Total		Count	134	84	221	439
		% of Total	30.5%	19.1%	50.3%	100.0%

*Pearson Chi-Square = 2.148 (p= 0.342)

Table 9. The distribution of left posterior cross bite presentation among frenum deviation groups.*

			Mandibular Frenum			
			aligned	to right	to left	Total
Left cross bite	Absent	Count	126	73	188	387
		% of Total	28.7%	16.6%	42.8%	88.2%
	Present	Count	8	11	33	52
		% of Total	1.8%	2.5%	7.5%	11.8%
Total		Count	134	84	221	439
		% of Total	30.5%	19.1%	50.3%	100.0%

*Pearson Chi-Square = 6.572 (p= 0.037)

The patients with mandibular deviation not only have morphological asymmetry but asymmetric condylar movement length and inclination in lateral movements (Zhang, Zhang, Liu, & Fu, 2006).

Signs and symptoms that were significantly related to frenum position status involved TMJ crepitation sounds and locking. The muscles that demonstrated such significant relationship were the right medial pterygoid and the right sternocleidomastoid (SCM). Given the known higher prevalence of TMD on the left side, it might be logical to focus on the role of the right medial pterygoid due to its action in the opposite lateral excursion movement. The most prevalent sign in the present sample was the masseter muscle tenderness (65 and 67% for the right and left side respectively), however that was not accompanied by a statistically significant difference between the frenum deviation groups. The association of mandibular deviation with masseter muscle activity was tested using electromyography (EMG), and it was revealed that most subjects showed no significant change about 3 mm from the reference position in the background activity (Yoshino, 1996).

As for the right lateral excursion range of motion, the study showed a statistically significant decrease in the deviated frenum group, with the left deviation group showing the most restricted motion. This can be related to the higher signs reported on the left side on the studied subjects. It was shown in the literature that midline displacement was associated with asymmetrical maximal protrusion (Sonnesen, Bakke, & Solow, 1998). It has also been demonstrated that moderate deviations from

symmetric movements (mean: 1.2 mm for women, 2.1 mm for men) appear to be the normal even in healthy individuals (Turp, Alpaslan, & Gerds, 2005).

The maxillary plane canting showed the most consistent results. The present study showed a statistically significant correlation toward a higher occlusal plane on the side towards which the mandibular frenum was deviated (i.e. subjects with deviated frenum to the left more likely have a higher maxillary plane cant on the left side). This shed light on the interaction of occlusal factor and how the vertical dimension landmarks might play a role. Ali, Yamada, Alkhamrah, Vergara, and Hanada (2003) have touched on that issue from a different perspective earlier. They showed that a deeper occlusal curvature on the deviated side in pre-orthodontic female patients with temporomandibular disorders.

Cross bite, which clinically leads to mid-line deviation as the teeth settle in centric occlusion and on function, was found to be statistically more prevalent in TMD populations (Egermark-Eriksson, Carlsson, Magnusson, & Thilander, 1990; Egermark-Eriksson, Ingervall, & Carlsson, 1983; Miyazaki et al., 1994; Riolo, Brandt, & TenHave, 1987; Thilander et al., 2002). That can be also of developmental origin as disk displacement in the TMJ with an onset during the growth period can cause mandibular lengthening and midline asymmetry in growing rabbits (Legrell & Isberg, 1999). In addition, in cases with cross bite accompanied with mandibular shift, studies have indicated that the molar in the cross bite side showed partial of full Class II relationship (Hesse, Artun, Joondeph, & Kennedy, 1997), that has a 50% of spontaneous correction if the cross bite is resolved (Ben-Bassat, Yaffe, Brin, Freeman, & Ehrlich, 1993). With such findings in the literature on the probable cross bite causality and TMD pathogenesis, the present study showed a significantly high prevalence of left posterior cross bite in cases with left frenum deviation. That finding similarly showed high correlation adding the prominent expression on the left side findings in TMD population.

In the present study, most of the significant findings were evident only on the left side. It would have been more convincing to see similar shift of the pattern in the right frenum deviation group. This can be due to the retrospective nature of the study that would support the conduction of new prospective study specifically design to research documented trends. Although many statistical significant differences resulted, one would consider the exploratory nature of the study and the fact that it dealt with many secondary variables. Therefore, caution must be taken in place while attempting to generalizing the comparisons' results on general population.

CONCLUSION

Signs and symptoms of TMD tend to occur more likely on the side of the frenum deviation. Most of TMD patients in the current study presented with mandibular frenum deviation to the left side from the maxillary frenum. TMJ crepitation sounds and locking, right muscles pain on palpation (medial pterygoid and sternocleidomastoid), “reported locking on the left TMJ”, left posterior cross bite, and restriction of right lateral excursion were significantly more prevalent in cases with left frenum deviation. Maxillary plane canting demonstrated a statistical significate pattern of higher occlusal plane side following the mandibular frenum deviation side.

CONTACT AUTHOR:

Moshabab A. Asiry

Associate Professor, Division of Orthodontics

Department of Paediatric Dentistry and Orthodontics

College of Dentistry, King Saud University

P.O. P.O. Box 62324, Riyadh 11585

Fax: +966-1- 4679017

E-mail: masiry@gmail.com

Naif A. Bindayel

Associate Professor, Division of Orthodontics

Department of Paediatric Dentistry and Orthodontics

College of Dentistry, King Saud University

P.O. P.O. Box 62324, Riyadh 11585

Fax: +966-1- 4679017

E-mail nbindayel@ksu.edu.sa

Georgios Kanavakis

Assistant Professor

Department of Orthodontics and Pediatric Dentistry,

University School of Dental Medicine, University of Basel, Switzerland

E-mail:gkanavak@gmail.com

REFERENCES

Ali, I. M., Yamada, K., Alkhamrah, B., Vergara, R., & Hanada, K. (2003). Relationship between occlusal curvatures and mandibular deviation in orthodontic patients with temporomandibular disorders. *J Oral Rehabil, 30*(11), 1095-1103.

American Dental Association. (1983). The President's Conference on the Dentist-Patient Relationship and the Management of Fear, Anxiety and Pain. *American Dental Association, Chicago*.

Andrew S. Kaplan, & Leon A. Assael (1991). Temporomandibular Disorders- Diagnosis and Treatment. W.B. Saunders Co, Philadelphia.

Ben-Bassat, Y., Yaffe, A., Brin, I., Freeman, J., & Ehrlich, Y. (1993). Functional and morphological-occlusal aspects in children treated for unilateral posterior cross-bite. *Eur J Orthod, 15*(1), 57-63.

Bernal, M., & Tsamtsouris, A. (1986). Signs and symptoms of temporomandibular joint dysfunction in 3 to 5 year old children. *J Pedod, 10*(2), 127-140.

Creagh, P. G., & Smith, R. G. (1989). The effects of conservative treatment on temporomandibular joint sounds and mandibular deviation during opening and closing movement of the mandible. *Aust Prosthodont J, 3*, 9-19.

Egermark-Eriksson, I., Carlsson, G. E., Magnusson, T., & Thilander, B. (1990). A longitudinal study on malocclusion in relation to signs and symptoms of cranio-mandibular disorders in children and adolescents. *Eur J Orthod, 12*(4), 399-407.

Egermark-Eriksson, I., Ingervall, B., & Carlsson, G. E. (1983). The dependence of mandibular dysfunction in children on functional and morphologic malocclusion. *Am J Orthod, 83*(3), 187-194.

Fleiss, J., Tytun, A., & Ury, S. (1980). A simple approximation for calculating sample sizes for comparing independent proportions. *Biometrics, 36*, 343-346.

Fricton JR, & Schiffman EL. The craniomandibular index: validity. J Prosthet Dent 1987;58:222-228.

Fu, A. S., Mehta, N. R., Forgione, A. G., Al-Badawi, E. A., & Zawawi, K. H. (2003). Maxillomandibular relationship in TMD patients before and after short-term flat plane bite plate therapy. *Cranio, 21*(3), 172-179.

Fukazawa, H., Endo, N., Kurita, S., & Mitani, H. (1990). [Changes of frontal facial form occurred after correction of anterior reversed occlusion in children with TMJ dysfunction]. *Nippon Kyosei Shika Gakkai Zasshi, 49*(3), 199-206.

Fushima, K., Inui, M., & Sato, S. (1999). Dental asymmetry in temporomandibular disorders. *J Oral Rehabil, 26*(9), 752-756.

Gesch, D., Bernhardt, O., Alte, D., Schwahn, C., Kocher, T., John, U., & Hensel, E. (2004). Prevalence of signs and symptoms of temporomandibular disorders in an urban and rural German population: results of a population-based Study of Health in Pomerania. *Quintessence Int, 35*(2), 143-150.

Goto, T. K., Nishida, S., Nakayama, E., Nakamura, Y., Sakai, S., Yabuuchi, H., & Yoshiura, K. (2005). Correlation of mandibular deviation with temporomandibular joint MR dimensions, MR disk position, and clinical symptoms. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 100*(6), 743-749.

Hesse, K. L., Artun, J., Joondeph, D. R., & Kennedy, D. B. (1997). Changes in condylar postition and occlusion associated with maxillary expansion for correction of functional unilateral posterior crossbite. *Am J Orthod Dentofacial Orthop, 111*(4), 410-418. doi: S0889540697000607 [pii]

Legrell, P. E., & Isberg, A. (1999). Mandibular length and midline asymmetry after experimentally induced temporomandibular joint disk displacement in rabbits. *Am J Orthod Dentofacial Orthop, 115*(3), 247-253.

Manfredini, D., Chiappe, G., & Bosco, M. (2006). Research diagnostic criteria for temporomandibular disorders (RDC/TMD) axis I diagnoses in an Italian patient population. *J Oral Rehabil, 33*(8), 551-558.

Miller, E. L., Bodden, W. R., Jr., & Jamison, H. C. (1979). A study of the relationship of the dental midline to the facial median line. *J Prosthet Dent, 41*(6), 657-660.

Miyazaki, H., Motegi, E., Isoyama, Y., Konishi, H., & Sebata, M. (1994). An orthodontic study of temporomandibular joint disorders. Part 2: Clinical research in orthodontic patients. *Bull Tokyo Dent Coll, 35*(2), 85-90.

Nilner, M. (1981). Prevalence of functional disturbances and diseases of the stomatognathic system in 15-18 year olds. *Swed Dent J, 5*(5-6), 189-197.

Pagano, M., & Gauvreau, K. (2000). Principles of Biostatistics; Hypothesis Testing. *Duxbury Press; 2 edition* 246-249.

Pradham, N. S., White, G. E., Mehta, N., & Forgione, A. (2001). Mandibular deviations in TMD and non-TMD groups related to eye dominance and head posture. *J Clin Pediatr Dent, 25*(2), 147-155.

Riolo, M. L., Brandt, D., & TenHave, T. R. (1987). Associations between occlusal characteristics and signs and symptoms of TMJ dysfunction in children and young adults. *Am J Orthod Dentofacial Orthop, 92*(6), 467-477.

Solberg, W. K., Woo, M. W., & Houston, J. B. (1979). Prevalence of mandibular dysfunction in young adults. *J Am Dent Assoc, 98*(1), 25-34.

Sonnesen, L., Bakke, M., & Solow, B. (1998). Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion. *Eur J Orthod, 20*(5), 543-559.

Thilander, B., Rubio, G., Pena, L., & de Mayorga, C. (2002). Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development. *Angle Orthod, 72*(2), 146-154.

Turp, J. C., Alpaslan, C., & Gerds, T. (2005). Is there a greater mandibular movement capacity towards the left? Verification of an observation from 1921. *J Oral Rehabil, 32*(4), 242-247.

Yoshino, T. (1996). [Effects of lateral mandibular deviation on masseter muscle activity]. *Kokubyo Gakkai Zasshi, 63*(1), 70-87.

Zhang, R. F., Zhang, D., Liu, Y., & Fu, M. K. (2006). [Condylar lateral movements in patients with mandibular deviation]. *Zhonghua Kou Qiang Yi Xue Za Zhi, 41*(10), 606-609.