Original Article

JOMP
Journal of Oral Medicine and Pain

pISSN 2288-9272 eISSN 2383-8493
J Oral Med Pain 2015;40(1):28-34
http://dx.doi.org/10.14476/jomp.2015.40.1.28

A Study on the Change of Occlusal Contacts and Lateral Cephalometric Variables after Stabilization Splint Therapy in Temporomandibular Disorders Patients

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Received January 22, 2015
Revised January 30, 2015
Accepted February 9, 2015

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Purpose: The aim of this study is to assess the relationship between possible occlusal change after stabilization splint therapy and the research diagnostic criteria for temporomandibular disorders (RDC/TMD) Axis I diagnoses and lateral cephalometric variables.

Methods: Clinical and radiographic records of 47 TMD patients wearing stablization splint were reviewed. The number of occluding teeth was recorded and lateral cephalogram was taken at pre-treatment and 6-month post-treatment. They were divided into two groups. The control group consists of patients with the unchanged number of occluding teeth throughout 6-month splint therapy (19 females and 4 males), and occlusal-loss group with the number of occluding teeth decreased (19 females and 5 males). The difference of RDC/TMD diagnoses and cephalometric variables were compared between two groups.

Results: In the control group, RDC group I, muscle disorders, was 39.1% (9/23), group II, disc displacements, was 17.4% (4/23), group III OA, osteoarthritis/osteoarthrosis, was 73.9% (17/23), and group III pain, arthralgia, was 82.6% (19/23). In the occlusal-loss group, group I was 41.7% (10/24), group II was 41.7% (10/24), group III OA was 70.8% (17/24), and group III pain was 83.3% (20/24). The frequency of RDC groups was not different between two groups, analyzed by binomial logistic regression. Pre-treatment cephalometric variables were not different between two groups. However, articular angle, AB to mandibular plane and ODI decreased and gonial angle increased significantly in the occlusal-loss group, implying clockwise rotation of the mandible, between pre-treatment and 6-month post-treatment, while none of cephalometric variables showed any statistical difference in the control group.

Conclusions: Change in the number of occluding teeth was not related to the RDC/TMD diagnoses. Cephalometric values changed only in the occlusal-loss group as a result of mandibular clockwise rotation. None of cephalometric variables before the stabilization splint therapy was statistically different between the control and occlusal loss group.

Key Words: Cephalogram; Occlusal appliance; Occlusion; Temporomandibular joint disorders

INTRODUCTION

Temporomandibular disorders (TMD) are defined as a collective term that embraces a number of clinical problems that involve the masticatory muscles, the temporomandibular joint (TMJ), and the associated structures.[1] Epidemiological study shows two distinct age peaks for internal derangement about at 30-35 years and inflammatory-degenerative disorders about at 50-55 years.[2] And women had higher prevalence rates of TMD than men.[3,4]

Several treatment methods for TMD have been used, including occlusal splints, behavioral treatment, physical therapy, medications and surgical approaches.[5] de Leeuw et al.[6] concluded that nonsurgical treatment is as effective as surgical treatment over the long term. And stabilization splint as conservative treatment is the method of choice for the management of TMD.[7]

The change of occlusion after splint therapy has been reported by several authors. Treatment with anterior repositioning splint usually creates a posterior open bite.[8,9] And significant changes were seen in the disc displacement with reduction group, which was managed with anterior repositioning splint.[10] Fujii et al.[11] investigated a decrease of the number of occluding contact points after full-arch maxillary stabilization splint and the amounts of changes were higher in the bruxer with myofascial pain group than bruxer without it. One study using Gothic arch tracings reported the posterior displacement of mandible in most patients after Michigan splint therapy.[12] However, information still lacks on the cause or physiology of possible occlusal change after stabilization splint therapy. Moreover, lateral cephalometric analysis before and after stabilization therapy has rarely been studied and its relationship with the change of occlusal contacts has never been reported.

The aim of this study is to assess the relationship between possible occlusal change after stabilization splint therapy and the research diagnostic criteria for temporomandibular disorders (RDC/TMD) Axis I diagnoses and lateral cephalometric variables.

MATERIALS AND METHODS

1. Subjects

Clinical and radiographic records of the patients who had visited the TMJ and Orofacial Pain Clinic in Seoul National University Dental Hospital for treatment of TMD symptoms in 2010 were reviewed. Among them, the records of the patients who had diagnosed as TMD based on RDC/TMD Axis I and taken stabilization splint therapy by one TMD specialist, J.Y.L., and whose number of occluding teeth and lateral cephalogram at 6-month pre-treatment and post-treatment were available were selected. The records of the patients who were aged under 18 years, had facial deformity, severe malocclusion, rheumatoid disease, or trauma history were excluded.

Finally, records of 47 patients were selected and classified into two groups. The control group consists of patients whose number of occluding teeth did not decrease after wearing stabilization splint for 6 months (19 females and 4 males whose mean age was 40.1 years and 32.7 years, respectively). And occlusal-loss group consists of patients whose number of occluding teeth decreased (19 females and 5 males whose mean age was 40.1 years and 31.8 years, respectively). They had taken conservative treatments including behavior control, physical therapy, medication (e.g., non-steroidal anti-inflammatory drugs) and night-wearing stabilization splint therapy with periodic check-up. This study was approved by the institutional review board of Seoul National University Dental Hospital (#CRI12039).

2. RDC/TMD Axis I Groups

Patients were classified into 4 RDC groups based on RDC/TMD Axis I diagnoses,[13,14] which originally allows a patients classified into multiple RDC groups.

1. Group I, muscle disorder (n=19); pain or ache in the jaw, temples, face, preauricular area, or inside the ear at rest or during function and pain aroused by palpation of the associated muscles; RDC/TMD Ib or Ic
2. Group II, disc displacement (n=14); joint sound during jaw movement or images showing displacement of disc; RDC/TMD IIb or IIc
3. Group III OA, osteoarthritis/osteoarthrosis (n=34); crepitus in the joint or radiological signs of bony change; RDC/TMD IIIb or IIIc
4. Group III pain, arthralgia (n=39); pain in joint sites during jaw movement or by palpation; RDC/TMD IIIa or IIIb

3. Analysis of Lateral Cephalogram

Lateral cephalograms were taken at pre-treatment and 6-month post-treatment examination. After recording the number of occluding teeth, lateral cephalogram was made in an upright position, with the teeth in intercuspation and the patient's head supported by a cephalostat.

A single examiner, H.N., traced all lateral cephalograms. The tracings were done on the digitalized images and analyzed with V-Ceph version 6.0 software (Osstem, Seoul, Korea). Eighteen landmarks were decided on each radiograph, from which eighteen variables were calculated (Fig. 1-3). The variables used can be classified into 3 categories:

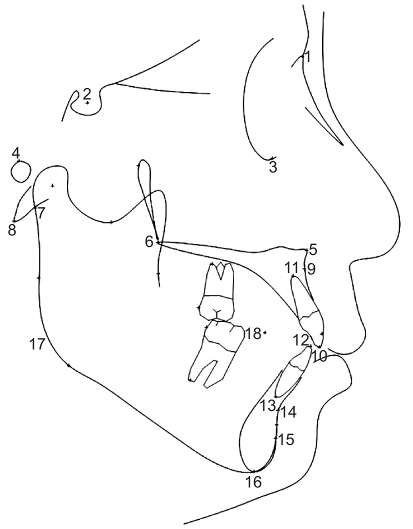

Fig. 1. Landmarks used in this study: 1, nasion (N); 2, sella (S); 3, orbitale (Or); 4, porion (Po); 5, anterior nasal spine (ANS); 6, posteriornasal spine (PNS); 7, articulare (Ar); 8, basion (Ba); 9, point A; 10, incisal endof maxilary incisor; 11, apex of maxillary incisor; 12, incisal end ofmandibular incisor; 13, apex of mandibular incisor; 14, point B; 15, pogonion (Pog); 16, menton (Me); 17, gonion (Go); 18, occlusal plane point.

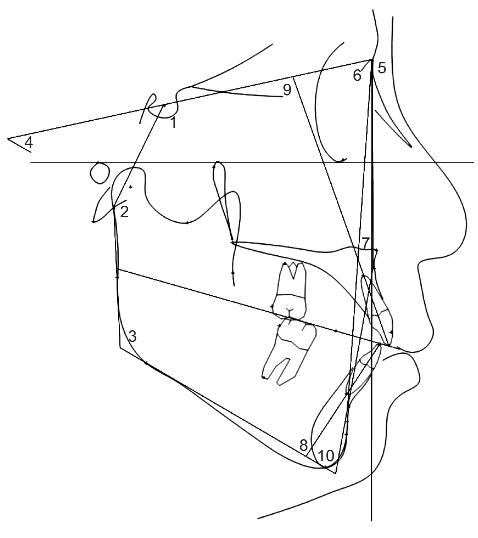

Fig. 2. Angular measurements used in this study: 1, saddle angle (Na-S-Ar); 2, articular angle (S-Ar-Go); 3, gonial angle (Ar-Go-Me); 4, SN tomandibular plane angle; 5, SNA; 6, SNB; 7, ANB; 8, mandibular incisor tomandibular plane angle (IMPA); 9, maxillary incisor to SN plane (U1 to SN); 10, AB to mandibular plane.

1. Vertical skeletal relationships: saddle angle [Na-S-Ar], articular angle [S-Ar-Go], gonial angle [Ar-Go-Me], facial height ratio [S-Go/N-Me], lower anterior facial height ratio [N-ANS/ANS-Me], AB to mandibular plane angle, ODI

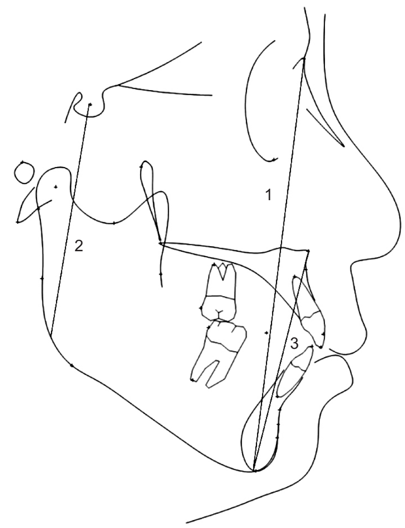

Fig. 3. Linear measurements used in this study: 1, anterior facial height (N-Me); 2, posterior facial height (S-Go); 3, lower anterior facial height (ANS-Me).

2. Maxillary and mandibular skeletal relationships: SNA, SNB, ANB, APDI, Wits, facial convexity
3. Dental relationships: IMPA, upper occlusal plane to U1, lower occlusal plane to L1, U1 to SN

To test the magnitude of the measurement error involved in this study, Dahlberg's formula was used.[15]

4. Statistical Analysis

Binomial logistic regression was performed to evaluate the relationship between the change of the number of occluding teeth and RDC groups. Independent t-test was done to compare the pre-treatment lateral cephalometric values between two groups, while paired sample t-test was done to compare the pre-treatment and 6-month post-treatment lateral cephalometric values for each group, in order to analyze the dento-skeletal alterations after stabilization splint therapy for 6 months. All statistical analysis were done in terms of IBM SPSS Statistics version 22.0 (IBM Co., Armonk, NY, USA).

RESULTS

1. The Number of Occluding Teeth and RDC Group

Subjects were divided into 4 RDC groups depending on the RDC/TMD diagnoses as follows: group I (muscle disorder), II (disc displacements), III OA (osteoarthritis/

Table 1. Incidence of decrease of the number depending on RDC/TMD

		Control	Occlusal-loss	Exp(B)	Significance	95% CI of Exp(B)
Muscle disorders	Yes	9	10	1.091	0.90	0.296-4.016
	No	14	14	Reference		
Disc displacement	Yes	4	10	0.520	0.36	0.127-2.133
	No	19	14	Reference		
Osteoarthritis	Yes	17	17	0.886	0.87	0.220-3.570
	No	6	7	Reference		
Pain in joint sites	Yes	19	20	1.064	0.94	0.214-5.295
	No	4	4	Reference		

RDC/TMD, research diagnostic criteria for temporomandibular disorders; CI, confidence interval.
Analyzed by binomial logistic analysis.

Table 2. Longitudinal comparison of cephalometric variables of the control group (n=23)

Variable	Pre-treatment	6-Month	p-value
Vertical skeletal relationships			
Saddle angle (°)	124.04±4.83	124.52±4.73	0.338
Articular angle (°)	154.56±7.59	154.36±8.18	0.779
Gonial angle (°)	121.16±5.51	121.35±6.06	0.709
Anteroposterior FHR	62.70±6.59	62.38±6.62	0.205
Lower anterior FHR	53.72±2.42	53.76±2.23	0.786
AB to Mn. plane (°)	72.15±4.65	72.43±5.04	0.533
ODI	71.50±5.59	71.76±5.99	0.640
Mn. plane angle to SN (°)	39.76±8.35	40.24±8.20	0.180
Maxillary and mandibular relationships			
SNA (°)	79.49±3.63	79.59±3.78	0.689
SNB (°)	74.74±4.21	74.42±4.45	0.183
ANB (°)	4.74±2.80	5.16±2.68	0.085
APDI	78.37±5.96	77.67±6.04	0.072
Wits	0.37±4.23	0.72±3.70	0.431
Facial convexity (°)	8.61±6.85	9.46±6.26	0.148
Dental relationships			
UOcc. plane to U1 (°)	55.59±5.83	55.29±5.28	0.622
LOcc. plane to L1 (°)	64.63±8.97	64.99±7.75	0.770
U1 to SN (°)	101.8±7.81	101.54±7.58	0.592
IMPA (°)	96.08±5.58	96.30±5.60	0.721

FHR, facial height ratio; Mn., mandibular; UOcc., upper occlusal; U1, upper incisor; LOcc., lower occlusal; L1, lower incisor.
Values are presented as mean±standard deviation.
Analyzed by paired t-test.

Table 3. Longitudinal comparison of cephalometric variables of the occlusal-loss group (n=24)

Variable	Pre-treatment	6-Month	p-value
Vertical skeletal relationships			
Saddle angle (°)	126.49±5.72	127.16±5.39	0.123
Articular angle (°)	151.37±8.12	149.74±7.71	0.025*
Gonial angle (°)	120.67±6.98	122.33±7.27	0.000***
Anteroposterior FHR	63.17±3.48	62.95±4.11	0.490
Lower anterior FHR	54.91±2.37	54.98±2.08	0.813
AB to Mn. plane (°)	71.03±4.77	70.03±4.61	0.002**
ODI	69.73±5.60	68.53±5.76	0.025*
Mn. plane angle to SN (°)	38.53±4.58	39.23±5.34	0.080
Maxillary and mandibular relationships			
SNA (°)	79.36±4.35	79.32±4.42	0.899
SNB (°)	75.72±3.45	75.77±3.55	0.880
ANB (°)	3.64±2.36	3.55±2.17	0.526
APDI	80.55±4.50	81.15±4.62	0.083
Wits	−0.24±3.00	−0.46±2.66	0.437
Facial convexity (°)	6.01±5.84	5.81±5.69	0.414
Dental relationships			
UOcc. plane to U1 (°)	54.35±4.63	54.20±5.35	0.839
LOcc. plane to L1 (°)	65.88±7.47	64.92±5.52	0.386
U1 to SN (°)	104.46±6.86	105.14±6.92	0.239
IMPA (°)	94.48±7.91	94.56±7.37	0.905

FHR, facial height ratio; Mn., mandibular; UOcc., upper occlusal; U1, upper incisor; LOcc., lower occlusal; L1, lower incisor.
Values are presented as mean±standard deviation.
Analyzed by paired t-test.
*p<0.05; **p<0.01; ***p<0.001.

osteoarthrosis), III pain (arthralgia). In the control group, RDC group I was 39.1% (9/23), group II was 17.4% (4/23), group III OA was 73.9% (17/23), and group III pain was 82.6% (19/23). In the occlusal-loss group, group I was 41.7% (10/24), group II was 41.7% (10/24), group III OA was 70.8% (17/24), and group III pain was 83.3% (20/24). The frequency of RDC groups was not different between two groups, analyzed by binomial logistic regression (Table 1).

2. Lateral Cephalometric Variables

In the control group, none of cephalometric variables showed any significant differences between pre-treatment and 6-month post-treatment images ($p>0.05$; Table 2). Meanwhile, articular angle (S-Ar-Go), AB to mandibular plane and ODI decreased while gonial angle (Ar-Go-Me) increased significantly in the occlusal-loss group ($p<0.05$; Table 3). Pre-treatment cephalometric variables were not different between the control and occlusal-loss group (Table

Table 4. Comparison of pre-treatment cephalometric variables of the control and occlusal-loss group

Variable	Non-loss group	Loss group	p-value
Vertical skeletal relationships			
Saddle angle (°)	124.04±4.83	126.49±5.72	0.120
Articular angle (°)	154.56±7.59	151.37±8.12	0.171
Gonial angle (°)	121.16±5.51	120.67±6.98	0.789
Anteroposterior FHR	62.70±6.59	63.17±3.48	0.761
Lower anterior FHR	53.72±2.42	54.91±2.37	0.094
AB to Mn. plane (°)	72.15±4.65	71.03±4.77	0.420
ODI	71.50±5.59	69.73±5.60	0.285
Mn. plane angle to SN (°)	39.76±8.35	38.53±4.58	0.539
Maxillary and mandibular relationships			
SNA (°)	79.49±3.63	79.36±4.35	0.912
SNB (°)	74.74±4.21	75.72±3.45	0.388
ANB (°)	4.74±2.80	3.64±2.36	0.148
APDI	78.37±5.96	80.55±4.50	0.164
Wits	0.37±4.23	−0.24±3.00	0.573
Facial convexity (°)	8.61±6.85	6.01±5.84	0.167
Dental relationships			
UOcc. plane to U1 (°)	55.59±5.83	54.35±4.63	0.424
LOcc. plane to L1 (°)	64.63±8.97	65.88±7.47	0.606
U1 to SN (°)	101.8±7.81	104.46±6.86	0.220
IMPA (°)	96.08±5.58	94.48±7.91	0.431

FHR, facial height ratio; Mn., mandibular; UOcc., upper occlusal; U1, upper incisor; LOcc., lower occlusal; L1, lower incisor.
Values are presented as mean±standard deviation.
Analyzed by independent t-test.

4). The cephalometric variables describing the position of the maxilla and dentition did not change. It implies that occlusal change was caused by mandibular movement in clockwise rotation.

DISCUSSION

In this study we investigated the relationship of the RDC/TMD diagnoses and dento-skeletal patterns with the occlusal changes after stabilization splint therapy. Firstly, the change of the number of occluding teeth was not statistically different among the RDC/TMD diagnoses, even in RDC III OA group. Normally, it is very well known and appreciated that the occlusal change, especially anterior open bite, is clearly related to OA of the TMJ. On this point, the results of this study can look in contrast to the fact accepted generally. But in this study, because the aim was not to investigate the effect of bony change of the TMJ but the effect of stabilization splint therapy on the occlusal change, presence of clinical or radiological sign of OA was just recorded at pre-treatment examination for RDC diagnosis, while severity or progression of OA were not considered in any further analysis. In other words, if OA had not got worse since the pre-treatment examination so that the number of occluding teeth did not change any more, the case could be classified into the RDC III OA group in the control group.

In the results of cepahlometric analysis, pre-treatment cephalometric variables were not different between two groups. However, articular angle (S-Ar-Go), gonial angle (Ar-Go-Me), AB to mandibular plane and ODI showed significant differences in the occlusal-loss group, implying clockwise rotation of the mandible, between pre-treatment and 6-month post-treatment, while none of cephalometric variables showed any statistical difference in the control group. The cephalometric variables describing the position of the maxilla and dentition did not changed at all.

Previous study using Gothic arch reported a mean posterior displacement of the mandible of 0.3 mm was found after therapy. Displacement ranged from 0.1 to 0.5 mm.[12] It has also been suggested that a change of occlusal condition after short-term use of a splint is thought to be due to displacement or inclination of teeth, a change of masticatory muscle activity or condyle-fossa relationship.[11] In this study, both groups show no significant change in dental relationships (Table 2, 3). Based on these results of the study, decrease of the number of occluding teeth must be because of mandibular positional change not because of teeth movement.

Several studies have shown that splints improve the balance of masseter muscle activities in myogenous patients.[16,17] Daif[18] reported splint therapy reduces the electromyographic amplitude records of the masticatory muscles. And in a previous study, splint therapy was regarded as a method of equilibrating masseter and anterior temporalis muscular activity between right and left sides, reaching values close to the asymptomatic control groups.[19] In addition, Helkimo and Ingervall[20] proposed mandibular displacement after splint therapy can be explained by a hyperactivity of the lateral pterygoid muscles. Based on these, it can be assumed that some degree of change in muscle activity after the use of a splint is possible to bring about the clockwise rotation of the mandible resulting in the occlusal change.

In other point of view, several authors has reported that condyles of patients with anterior disc displacement were situated more posterior in the fossa than those in the control group.[21,22] It has been also reported in a previous study using magnetic resonance imaging that a reduction of the anterior disc position and a dorsal repositioning of the condyles in the glenoid fossa of joints with disc displacement with reduction took place.[23] Ekberg et al.[24] reported that the stabilization splint changed the condyle-fossa position and suggested that a positive treatment effect could be the unloading of the TMJ. Therefore, if any change of condylar position more posterior or upward in the fossa occurs because of any possible change in the shape or position of the disc, even if bony change does not occur, during the stabilization splint therapy, it can theoretically cause the clockwise rotation of the mandible observed in this study.

Collectively, the clockwise rotation of the mandible can occur in some patients resulting occlusal change after wearing stabilization splint regardless of bony change of the joint, disk displacement, or pain at the moment of the beginning of therapy. Even though it should be supported by further study in a controlled prospective design, based on the results of this study and previous studies, at least, it can be concluded that the clockwise rotation of the mandible resulting in the loss of anterior occlusal contacts can occur after use of the stabilization splint during the night. And it can be carefully assumed that the cause of such clockwise rotation of the mandible must be the comprehensive result of change of the muscle activity controlling the position of the mandible and the tissue change in the joint such as change of thickness of the tissue, whatever it is, disk or retrodiscal tissue, or flattening of the joint surface without apparent destructive change.

Lastly, dento-skeletal patterns of pre-treatment state in two groups show no significant differences in this study. The reason is regarded due to limitation of lateral cephalogram. A cephalogram is a two-dimensional image which does not show variations of the transverse dimension. Although there is controversy, transverse problem such as unilateral posterior crossbite may have association with TMD.[25-27] Further research using three-dimensional image can target the measurement of the variables mentioned in addition to horizontal and vertical relationships. And a study including asymptomatic control group can provide further clues to find predisposing factors, if any, of occlusal change after stabilization splint therapy.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. de Leeuw R, Klasser GD. Orofacial pain: guidelines for assessment, diagnosis, and management. Chicago: Quintessence; 2008.
2. Manfredini D, Piccotti F, Ferronato G, Guarda-Nardini L. Age peaks of different RDC/TMD diagnoses in a patient population. J Dent 2010;38:392-399.
3. Pedroni CR, De Oliveira AS, Guaratini MI. Prevalence study of signs and symptoms of temporomandibular disorders in university students. J Oral Rehabil 2003;30:283-289.
4. Bagis B, Ayaz EA, Turgut S, Durkan R, Özcan M. Gender difference in prevalence of signs and symptoms of temporomandibular joint disorders: a retrospective study on 243 consecutive patients. Int J Med Sci 2012;9:539-544.
5. Okeson JP. Management of temporomandibular disorders and occlusion. St. Louis: Mosby Elsevier; 2008.
6. de Leeuw JR, Steenks MH, Ros WJ, Lobbezoo-Scholte AM, Bosman F, Winnubst JA. Assessment of treatment outcome in patients with craniomandibular dysfunction. J Oral Rehabil 1994;21:655-666.
7. Al-Ani MZ, Davies SJ, Gray RJ, Sloan P, Glenny AM. Stabilisation splint therapy for temporomandibular pain dysfunction syndrome. Cochrane Database Syst Rev 2004;(1):CD002778.
8. Tallents RH, Katzberg RW, Macher DJ, Roberts CA. Use of protrusive splint therapy in anterior disk displacement of the temporomandibular joint: a 1- to 3-year follow-up. J Prosthet Dent 1990;63:336-341.
9. Kai S, Kai H, Tabata O, Tashiro H. The significance of posterior open bite after anterior repositioning splint therapy for anteriorly displaced disk of the temporomandibular joint. Cranio 1993;11:146-152.
10. Al-Ani Z, Davies S, Sloan P, Gray R. Change in the number of occlusal contacts following splint therapy in patients with a temporomandibular disorder (TMD). Eur J Prosthodont Restor Dent 2008;16:98-103.
11. Fujii T, Torisu T, Nakamura S. A change of occlusal conditions after splint therapy for bruxers with and without pain in the masticatory muscles. Cranio 2005;23:113-118.
12. Carossa S, Di Bari E, Lombardi M, Preti G. A graphic evaluation of the intermaxillary relationship before and after therapy with the Michigan splint. J Prosthet Dent 1990;63:586-592.
13. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. J Craniomandib Disord 1992;6:301-355.
14. Manfredini D, Chiappe G, Bosco M. Research diagnostic criteria

for temporomandibular disorders (RDC/TMD) axis I diagnoses in an Italian patient population. J Oral Rehabil 2006;33:551-558.
15. Dahlberg G. Statistical methods for medical and biological students. London: G. Allen & Unwin Ltd.; 1940.
16. Humsi AN, Naeije M, Hippe JA, Hansson TL. The immediate effects of a stabilization splint on the muscular symmetry in the masseter and anterior temporal muscles of patients with a craniomandibular disorder. J Prosthet Dent 1989;62:339-343.
17. Naeije M, Hansson TL. Short-term effect of the stabilization appliance on masticatory muscle activity in myogenous craniomandibular disorder patients. J Craniomandib Disord 1991;5:245-250.
18. Daif ET. Correlation of splint therapy outcome with the electromyography of masticatory muscles in temporomandibular disorder with myofascial pain. Acta Odontol Scand 2012;70:72-77.
19. Scopel V, Alves da Costa GS, Urias D. An electromyographic study of masseter and anterior temporalis muscles in extra-articular myogenous TMJ pain patients compared to an asymptomatic and normal population. Cranio 2005;23:194-203.
20. Helkimo M, Ingervall B. Recording of the retruded position of the mandible in patients with mandibular dysfunction. Acta Odontol Scand 1978;36:167-174.
21. Gateno J, Anderson PB, Xia JJ, Horng JC, Teichgraeber JF, Liebschner MA. A comparative assessment of mandibular condylar position in patients with anterior disc displacement of the temporomandibular joint. J Oral Maxillofac Surg 2004;62:39-43.
22. Ren YF, Isberg A, Westesson PL. Condyle position in the temporomandibular joint. Comparison between asymptomatic volunteers with normal disk position and patients with disk displacement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;80:101-107.
23. Badel T, Marotti M, Kern J, Laskarin M. A quantitative analysis of splint therapy of displaced temporomandibular joint disc. Ann Anat 2009;191:280-287.
24. Ekberg EC, Vallon D, Nilner M. Occlusal appliance therapy in patients with temporomandibular disorders. A double-blind controlled study in a short-term perspective. Acta Odontol Scand 1998;56:122-128.
25. Farella M, Michelotti A, Iodice G, Milani S, Martina R. Unilateral posterior crossbite is not associated with TMJ clicking in young adolescents. J Dent Res 2007;86:137-141.
26. Iodice G, Danzi G, Cimino R, Paduano S, Michelotti A. Association between posterior crossbite, masticatory muscle pain, and disc displacement: a systematic review. Eur J Orthod 2013;35:737-744.
27. Thilander B, Bjerklin K. Posterior crossbite and temporomandibular disorders (TMDs): need for orthodontic treatment? Eur J Orthod 2012;34:667-673.