Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/poamed

Original research article

The immediate effect of temporary silicone splint application on symmetry of masticatory muscle activity evaluated using surface electromyography

Marcin Berger [a], *Michał Ginszt* [b,*], *Marta Suwała* [b], *Jacek Szkutnik* [a], *Piotr Gawda* [b], *Apolinary Ginszt* [b], *Zbigniew Tarkowski* [c]

[a] *Department of Functional Masticatory Disorders, Medical University of Lublin, Poland*
[b] *Chair and Department of Rehabilitation, Physiotherapy and Balneotherapy, Medical University of Lublin, Poland*
[c] *Department of Pathology and Rehabilitation of Speech, Medical University of Lublin, Poland*

ARTICLE INFO

Article history:
Received 17 February 2016
Received in revised form
14 July 2016
Accepted 10 November 2016
Available online 9 February 2017

Keywords:
Electromyography
Masticatory muscles
Occlusal splints

ABSTRACT

Introduction: Muscle activity is regarded as an important factor associated with the temporomandibular disorder (TMD). Detecting muscle imbalance is an essential part of a treatment strategy.

Aim: The aim of the present study was to evaluate the influence of temporary silicon splint application on the symmetry of masticatory muscle activities during clenching using surface electromyography.

Material and methods: Thirty-five full dentate, normo-occlusion and similarly aged (25.1 ± 2.3 years old) female subjects were recruited. The electrical activity of the temporalis anterior (TA) and masseter muscle (MM) of the right and left side was recorded simultaneously during clenching isometric activity. The eight-channel electromyograph BioEMG III, compatible with BioPAK Measurement System, was used for the recording. To describe the asymmetry of the TA, MM muscles and TA–MM asymmetry for right and left side, a symmetry index (SI) was calculated.

Results and discussion: Mean SI of MM was significantly higher during splint application measurement (SAM), in comparison to non-splint measurement (NSM) (NSM: 67.28 ± 19.63%; SAM: 78.26 ± 17.68%; mean difference: 10.97%; $P < 0.05$).

Conclusions: Application of temporary silicon splint reduces double-sided imbalance of MMs during clenching. The mechanism of action of silicone splints may be partly explained by their effect on masticatory muscles activity. Chair-side fabricated silicone splint may be used as a cost-effective, simple method for initial treatment of TMD. The influence of temporary silicon splint application on long-term effects of treatment requires further research.

* *Correspondence to*: Nadbystrzycka 14a, 20-618 Lublin, Poland. Tel.: +48 602 533 723.
E-mail address: michalginszt@umlub.pl (M. Ginszt).

http://dx.doi.org/10.1016/j.poamed.2016.11.006

1. Introduction

Temporomandibular disorder (TMD) is a collective term embracing a number of clinical conditions involving temporomandibular joints (TMJs), muscles of mastication and associated structures.[1] TMD is the second, after dental pain, most common source of orofacial pain.[2] Other signs and symptoms of TMD are a limitation of jaw movement and acoustic symptoms from TMJ. The etiology of TMD is multifactorial, factors such as parafunctional oral habits, bruxism, occlusal features, genetic factors, age, gender, stress and psychological factors may play an important role in development, perpetuation or exacerbation of the disease.[3] Females have TMD signs and symptoms more frequently than males, which can be related to female reproductive hormones, especially estrogen.[4] Muscle activity is also regarded as an important factor associated with TMD. Asymmetric activity is commonly seen in healthy subjects, who have a prevalent side on which they display higher muscle activity.[5] Patients with TMD exhibit higher asymmetry of masticatory muscle activity than healthy controls,[6] which can be explained by the influence of pain on motor control.[7] This change in motor control has short term benefit enabling resolution of pain, but it may also have negative long-term effects.[8] The asymmetry between left and right muscle groups reflected by torque index may be responsible for a laterodeviating effect on the mandible causing uneven loading on TMJs.[9] This, in consequence, may lead to the development of TMJ disorders, such as internal derangement and osteoarthritis.[10,11]

Therefore, correct muscular balance is essential in eliminating dysfunctions within the musculoskeletal system.[12] Frequently, the method of choice is occlusal splint therapy.[13] Occlusal appliances used for the treatment of TMD can be fabricated from both hard and soft materials. Hard acrylic stabilization splints are commonly used treatment modality. However, their fabrication is time-consuming and usually takes from two to three visits. Temporary splints made of silicone impression material can be fabricated during one appointment and can be used as initial treatment or be an alternative for the stabilization splint, when long-term use of the appliance is not indicated.

Occlusal appliances proved to be effective in the treatment of various TMDs.[14,15] However, their mechanisms of action are largely unknown.

2. Aim

The aim of the present study was to evaluate the influence of temporary silicon splint application on the symmetry of masticatory muscle activities during clenching using surface electromyography.

3. Material and methods

3.1. Ethics statement

This study was approved by the ethical committee of Medical University of Lublin, Poland (KE-0254/331/2015). All participants were informed about the procedures they would undergo and gave their informed consent to participate in the tests.

3.2. Subjects description

The study comprised 35 healthy women aged 25.1 ± 2.3. All the participants were examined clinically by the same dentist and answered the Polish version of the RDC/TMD questionnaire for TMD.[16]

Inclusion criteria were no signs or symptoms of TMD based on an RDC/TMD examination, no missing teeth, absence of muscle tenderness.

Exclusion criteria were periodontal pathology, pain, caries or damaged dental tissues, fixed restorations, past or ongoing orthodontic therapy, neuropathic conditions, botulinum toxin therapy, psychological disorders and pregnancy.

3.3. Measurement plan

The electrical activity of the temporalis anterior (TA) and masseter muscles (MMs) of the right and left side was recorded simultaneously during clenching isometric activity. The eight-channel electromyograph BioEMG III, compatible with BioPAK Measurement System, was used for the recording. The sample rate was 2 000 Hz for each channel. The filtering is to a bandwidth from 30 Hz to 1 000 Hz.

The skin under the electrodes was cleaned with 95% alcohol. The pairs of surface electrodes (Ag/AgCl) were distributed on the TA and MM muscles in relation to the muscle fiber direction (bilaterally parallel: TA – vertically along the anterior muscular margin, approximately over the coronal suture; MM – with the upper pole of the electrode at the intersection between the tragus-labial commissure and the exocanthion-gonion lines) according to the technique described by Wieczorek et al.[5] The reference electrode was placed on the processus spinosus of C7 compiled from SENIAM standards as shown in Fig. 1.[17]

Subjects performed two tasks: non-splint clenching (NSM) and clenching after splint application (SAM).

(1) NSM: For each participant, the maximal (as hard as possible) clench measurements were recorded three times for 3 s each, with 2 s of rest between clenching.
(2) SAM: The full arch splint was fabricated for each patient from A-silicone impression material (Elite HD+ Putty Soft Fast Set, Zhermack). Splints were made directly in patients' mouth in centric relation with vertical dimension increased by 3 mm (measured on first premolars).

After a 120 s recovery period and temporary silicon splint application (Fig. 2), the maximal (as hard as possible) clench measurements (three times for 3 s each, with 2 s of rest between clenching) were recorded.

To describe the asymmetry of the TA, MM, and TA-MM asymmetry for right and left side, a symmetry index (SI) was calculated using the following formula:

$$SI = \frac{\text{lower RMSv}_{\text{muscle}} \times 100\%}{\text{higher RMSv}_{\text{muscle}}},$$

Fig. 1 – Surface electrodes placement for sEMG measurement during clenching isometric activity.

where RMSv – average root mean square value of NSM/SAM measurements.

3.4. *Statistical analysis*

IBM SPSS Statistics program was used to prepare the statistical analysis. To compare the variables between the conditions (with and without temporary silicon splint), *t*-test paired samples were used. Differences were regarded as statistically significant if the level of probability value was lower than the statistical significance, $P < 0.05$.

Fig. 2 – Temporary silicone splint application.

4. Results

As presented in Table 1, mean SI of MMs was significantly higher during splint application measurement (SAM), in comparison to non-splint measurement (NSM): SAM: 78.26 $\pm$ 17.68%; NSM: 67.28 $\pm$ 19.63%; mean difference: 10.97%; $P < 0.05$.

Mean SI of TA muscles and TA-MM right and left side was higher during SAM, in comparison to NSM, but did not quite achieve significance ($P > 0.05$).

5. Discussion

Seifeldin and Elhayes reported that both soft and hard splints are equally effective in reduction of TMD symptoms.[18] The findings of Wright et al. study suggest that soft splint is an effective short-term treatment for reducing the signs and symptoms of masticatory muscle pain in patients.[19] The aim of the present study was to evaluate the immediate effect of temporary silicone splint application on the symmetry of

Table 1 – Mean SI of electrical activity temporalis anterior and MMs between non-splint (NSM) and SAM.

Muscle	Measurement	*n*	Mean SI (%)	SD	Mean difference	*t*	P
TA	Non-splint	35	78.28	18.81	3.74	−1.69	0.099
	Splint	35	82.03	16.13			
MM	Non-splint	35	67.28	19.63	10.97	−3.19	0.003*
	Splint	35	78.26	17.68			
TA-MM Right side	Non-splint	35	64.8	21.58	3.97	−0.93	0.357
	Splint	35	68.77	23.66			
TA-MM Left side	Non-splint	35	69.54	22.75	3.31	−0.95	0.349
	Splint	35	72.86	20.11			

* Significant differences ($P < 0.05$).

masticatory muscle activity evaluated using surface electromyography. Studies report that application of occlusal splints can decrease, increase or have no effect on the level of muscle activity.[20] Therefore, it is likely that their effectiveness is associated with the influence on muscle balance. Exact mechanisms for the effectiveness of splint therapies are not yet well understood. One of the potential mechanisms may be a change in masticatory muscle activity, which arises from increase of vertical dimension caused by the splint. Terebesi et al. showed that small changes in vertical jaw relations influence motor unit recruitment in the MM.[21] Many studies assessed the effect of hard stabilization splints on masticatory muscles activity while there are few reports on soft silicone splints. Botelho et al. assessed the immediate effect of resilient silicone splint on the SI values in TMD patients and controls. They showed that the improvement in muscle symmetry after installation of the appliance,[22] which is in accordance with our results.

Hard stabilization splints have a positive effect on the improvement in the symmetry of masticatory muscle activity.[23–26] A study by Vieira and Silva on patients with disk displacement (according to RDC/TMD) showed improvement in masseter symmetry after stabilization splint therapy, which is similar to our result where a significant increase in masseter symmetry was found.[26] Similar results were obtained by Humsi et al.[24] Other study showed that the improvement in muscle balance after insertion of the splint was generally higher in temporalis than in masseter, which stands in contrast with our result.[23] These differences can be explained by the fact that this study was evaluating the effect of the stabilization splint on TMD patients with pain while we examined healthy subjects without pain. In our group asymmetry was highest in MMs, while in TMD patients with pain, highest asymmetry is observed in temporalis muscle.[27] Therefore, it is possible that the effect of the splint is most pronounced in the muscle group with the highest asymmetry.

The use of the splint promoted a balance of the EMG activities during its use, relieving symptoms for TMD patients.[26] EMG activity during maximum voluntary clenching decreased in the MM after an hour using the occlusal appliance and maintained the same level for the three-month period.[28] The influence of temporary silicon splint application on long-term effects of treatment requires further research.

6. Conclusions

1. Application of temporary silicon splints reduces double-sided imbalance of MMs.
2. The mechanism of action of silicone splints may be partly explained by their effect on masticatory muscles activity.
3. Chair-side fabricated silicone splint may be used as a cost-effective, simple method for initial treatment of TMD.
4. The influence of temporary silicon splint application on long-term effects of treatment requires further research.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

The results of the present study do not constitute endorsement of the product by the authors or the journal.

REFERENCES

1. Dworkin SF, LeResche L, DeRouen T, Von Korff M. Assessing clinical signs of temporomandibular disorders: reliability of clinical examiners. *J Prosthet Dent*. 1990;63(5):574–579.
2. Manfredini D, Guarda-Nardini L, Winocur E, Piccotti F, Ahlberg J, Lobbezoo F. Research diagnostic criteria for temporomandibular disorders: a systematic review of axis I epidemiologic findings. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;112(4):453–462.
3. 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(7):539–544.
4. Berger M, Szalewski L, Bakalczuk M, Bakalczuk G, Bakalczuk S, Szkutnik J. Association between estrogen levels and temporomandibular disorders: a systematic literature review. *Prz Menopauzalny*. 2015;14(4):260–270.
5. Wieczorek A, Loster J, Loster BW. Relationship between occlusal force distribution and the activity of masseter and

anterior temporalis muscles in asymptomatic young adults. *Biomed Res Int*. 2013;2013:354017.
6. De Felício CM, Ferreira CL, Medeiros AP, Rodrigues Da Silva MA, Tartaglia GM, Sforza C. Electromyographic indices, orofacial myofunctional status and temporomandibular disorders severity: a correlation study. *J Electromyogr Kinesiol*. 2012;22(2):266–272.
7. Murray GM, Peck CC. Orofacial pain and jaw muscle activity: a new model. *J Orofac Pain*. 2007;21(4):263–278.
8. Hodges PW, Tucker K. Moving differently in pain: a new theory to explain the adaptation to pain. *Pain*. 2011; 152(3 suppl):S90–S98.
9. Ferrario VF, Sforza C, Colombo A, Ciusa V. An electromyographic investigation of masticatory muscles symmetry in normo-occlusion subjects. *J Oral Rehabil*. 2000;27(1):33–40.
10. Matsumoto R, Ioi H, Goto TK, et al. Relationship between the unilateral TMJ osteoarthritis/osteoarthrosis, mandibular asymmetry and the EMG activity of the masticatory muscles: a retrospective study. *J Oral Rehabil*. 2010;37(2):85–92.
11. Lodetti G, Marano G, Fontana P, et al. Surface electromyography and magnetic resonance imaging of the masticatory muscles in patients with arthrogenous temporomandibular disorders. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2014;118(2):248–256.
12. Hadała M, Gryckiewicz S. Movement pattern and muscle balance as a source of lumbar spine health according to the concept of kinetic control. *Pol Ann Med*. 2014;21(2):152–157.
13. Annusewicz-Kot Z, Kot G. Methods of functional diagnosis of the temporomandibular joint with the electronic face bow. *Pol Ann Med*. 2011;18(suppl 1):54–55.
14. Srivastava R, Jyoti B, Devi P. Oral splint for temporomandibular joint disorders with revolutionary fluid system. *Dent Res J (Isfahan)*. 2013;10(3):307–313.
15. Al-Ani Z, Gray RJ, Davies SJ, Sloan P, Glenny AM. Stabilization splint therapy for the treatment of temporomandibular myofascial pain: a systematic review. *J Dent Educ*. 2005;69(11):1242–1250.
16. Osiewicz MA, Lobbezoo F, Loster BW, Wilkosz M, Naeije M, Ohrbach R. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): the Polish version of a dual-axis system for TMD diagnosis. *Protet Stomatol*. 2010;60(6):433–444 [in Polish].
17. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. *J Electromyogr Kinesiol*. 2000;10 (5):361–374.
18. Seifeldin SA, Elhayes KA. Soft versus hard occlusal splint therapy in the management of temporomandibular disorders (TMDs). *Saudi Dent J*. 2015;27(4):208–214.
19. Wright E, Anderson G, Schulte J. A randomized clinical trial of intraoral soft splints and palliative treatment for masticatory muscle pain. *J Orofac Pain*. 1995;9(2): 192–199.
20. Suvinen TI, Kemppainen P. Review of clinical EMG studies related to muscle and occlusal factors in healthy and TMD subjects. *J Oral Rehabil*. 2007;34(9):631–644.
21. Terebesi S, Giannakopoulos NN, Brüstle F, Hellmann D, Türp JC, Schindler HJ. Small vertical changes in jaw relation affect motor unit recruitment in the masseter. *J Oral Rehabil*. 2015;43(4):259–268.
22. Botelho AL, Silva BC, Gentil FH, Sforza C, da Silva MA. Immediate effect of the resilient splint evaluated using surface electromyography in patients with TMD. *Cranio*. 2010;28(4):266–273.
23. Alajbeg IZ, Valentić-Peruzović M, Alajbeg I, Illes D. Influence of occlusal stabilization splint on the asymmetric activity of masticatory muscles in patients with temporomandibular dysfunction. *Coll Antropol*. 2003;27(1):361–371.
24. 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 (3):339–343.
25. 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 (3):194–203.
26. Vieira e Silva CA, da Silva MA, Melchior Md , de Felício CM, Sforza C, Tartaglia GM. Treatment for TMD with occlusal splint and electromyographic control: application of the FARC protocol in a Brazilian population. *Cranio*. 2012;30 (3):218–226.
27. Tartaglia GM, Lodetti G, Paiva G, De Felicio CM, Sforza C. Surface electromyographic assessment of patients with long lasting temporomandibular joint disorder pain. *J Electromyogr Kinesiol*. 2011;21(4):659–664.
28. Villalón P, Arzola JF, Valdivia J, et al. The occlusal appliance effect on myofascial pain. *Cranio*. 2013;31(2):84–91.