

ELECTROMYOGRAPHIC ACTIVITY IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS - A COMPREHENSIVE LITERATURE REVIEW

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ABSTRACT

Aim of the study The aim of this literature review was to assess the difference in muscle activity recorded on electromyography in patients with TMDs before and after receiving different types of treatments. **Materials and method.** The study is the literature review, an electronic search was initiated using PubMed, to identify the relevant literature. The search string comprised a combination of keywords (Medical Subject Headings [MeSH]) and free-text terms. The inclusion criteria were represented by clinical trial and randomized controlled trial, publications available in English and full text publications. **Results.** The final electronic search provided 23 articles. After removing the duplicates, 20 articles were selected for eligibility. According to the inclusion criteria, 16 articles were selected for this review. **Conclusions.** Short term therapeutic effect of the low-level laser therapy improves the pain and sEMG findings in TMD patients, better than soft occlusal splints. Sensorimotor training has a positive effect on pain for patients with myofascial TMD pain and a reduction in muscular activity on sEMG. Splint assisted by transcutaneous electrical nerve stimulation, TENS, had better results than splint alone in EMG recordings.

Key words: Temporomandibular disorder, occlusal splint

INTRODUCTION

The temporomandibular joint (TMJ) is one of the most complex joints in the human body. Temporomandibular joint disorder (TMD) represents a major health concern and a main cause of chronic orofacial pain, with negative impact on daily living activities and life quality [1]. Studies have revealed that more than a quarter of the general population are subject to TMD at some point in their lives [2]. Signs and symptoms of TMD include pain in the masticatory muscles and TMJ, limitations of mandibular movement, and TMJ sounds such as clicking or crepitus [3]. Providing the accurate etiology of TMDs is one of the most important factors, with leads to a correct diagnosis and treatment plan. Nonfunctional occlusal contacts, parafunctions, occlusal trauma, and

psychological factors (emotional stress or anxiety) are often related to TMDs. Clenching and grinding of the teeth, an unconscious mandibular movement, determine the hyperactivity of the masticatory muscles; temporalis and masseter being mainly affected [4]. Nevertheless, systemic diseases, such as autoimmune osteoarthritis or osteoporosis may negatively affect the health of TMJ anatomical structures. Macro- and microtrauma are considered also etiological factors of TMDs. Pain represents one of the important symptoms that increase the patient's addressability for seeking specialized treatment [4].

Anamnesis, clinical examination, and complementary examinations are used by the clinicians to establish an accurate diagnosis and treatment plan. X-ray and a CBCT can

detect bone changes in the TMJ, while MRI is indicated to identify abnormalities in the articular disc and surrounding soft tissues [5].

Nevertheless, muscle activity may be assessed by using electromyography (EMG), which allows the evaluation of the elevator muscles activity, especially of the masseter and temporalis. This paraclinical investigation is used before and after the initiated therapy, to observe the progress of the treatment plan [5]. EMG evaluation represents a very valuable tool used in diagnosis of patients with pain related TMDs [6]. Surface electromyography (sEMG) uses surface electrodes and detects superimposed motor unit action potentials from many fibers, as opposed to the single motor unit recorded intramuscularly, while intramuscular electromyography that uses intramuscular needle electrodes [7]. The sensitivity and selectivity of sEMG are almost the same as those provided by the intramuscular type [7].

One of the most important advantage of

sEMG is its non-invasiveness [8]. It is a painless and harmless method for evaluating muscle function that may conceivably be used in the TMD identification [9, 10].

The aim of this literature review was to assess the difference in muscle activity recorded on electromyography in patients with TMDs before and after receiving different types of treatments.

MATERIAL AND METHODS

Search Strategy

An electronic search was initiated on 1st of June and conducted through 1st of July using PubMed, to identify the relevant literature. Articles published between 1983 and 2023, were considered. The search string comprised a combination of keywords (Medical Subject Headings [MeSH]) and free-text terms. Linkage was achieved using Boolean operators (OR and AND). The search formula used in the PubMed are listed in Tables 1a, 1b, 1c, 1d, 1e.

Table 1a. Concept 1 - Electromyography activity

Keywords - "EMG"[tw]
Mesh - "Electromyography"[Mesh]
Final search: "Electromyography"[Mesh] OR "EMG"[tw] - #1

Table 1b. Concept 2- Temporomandibular disorders

Keywords – „TMD”[tw] OR „TMDs”[tw] OR „temporomandibular disease*”[tw] OR „temporomandibular disorder*”[tw]
Mesh - "Temporomandibular Joint Disorders"[Mesh]
Final search : "Temporomandibular Joint Disorders" [Mesh] OR „TMD” [tw] OR „TMDs” [tw] OR „temporomandibular disease*” [tw] OR „temporomandibular disorder*” [tw] - #2

Table 1c. Concept 3- Masticatory muscles

Keywords -"masticatory muscle*”[tw] OR "muscle of mastication"[tw] OR "muscles of mastication"[tw]
Mesh - "Masticatory Muscles"[Mesh]
Final search: "Masticatory Muscles"[Mesh] OR "masticatory muscle*” [tw] OR "muscle of mastication" [tw] OR "muscles of mastication" [tw] - #3

Table 1d. Concept 4- Tipe of treatment -Occlusal Splints

Keywords -" Occlusal Splint*" [tw] OR "Splint*" [tw] OR "Bite Plane" [tw]
Mesh - "Occlusal Splints"[Mesh]
Final : "Occlusal Splints"[Mesh] OR " Occlusal Splint*" [tw] OR "Splint*" [tw] OR "Bite Plane" [tw]- #4

Table 1e . Combination of search terms used in PubMed database

PubMed	Electromyography"[Mesh] OR "EMG"[tw] AND "Temporomandibular Joint Disorders" [Mesh] OR „TMD” [tw] OR „TMDs” [tw] OR „temporomandibular disease*” [tw] OR „temporomandibular disorder*” [tw] AND "Masticatory Muscles"[Mesh] OR "masticatory muscle*" [tw] OR "muscle of mastication" [tw] OR "muscles of mastication" [tw] AND "Occlusal Splints"[Mesh] OR " Occlusal Splint*" [tw] OR "Splint*" [tw] OR "Bite Plane" [tw]
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Final search used in Pubmed was: #1 AND #2 AND #3 AND #4 and inclusion criteria filters: clinical trial, randomized controlled trial and full text publications, searched between years 1983-2023.

Eligibility and exclusion criteria

The inclusion criteria were represented by clinical trial and randomized controlled trial, publications available in English and full text publications. The following exclusion criteria were applied: abstracts, questionnaire-based studies, books and documents, literature reviews and studies which were not published in English.

Study Selection and Data Extraction

Titles were initially screened by two independent reviewers (I.S.M and M.M.M) for inclusion criteria in the review. Any discrepancy during the selection process was resolved by discussion, and a third reviewer

(S.D.B) was consulted as needed to reach a consensus. Only studies with sufficient and specific data available were included for further analysis. Discrepancies and disagreements were resolved through discussion and consensus.

The data extraction form was developed by the authors to collect general information: authors, title, year of publication, journal, study aim, number of participants and outcomes.

RESULTS AND DISCUSSIONS

The final electronic search provided 23 articles. After removing the duplicates, 20 articles were selected for eligibility. According to the inclusion criteria, 20 full-text articles were screened and evaluated thoroughly (Figure 1). Finally, 16 articles were selected for this review, presented in Table 2.

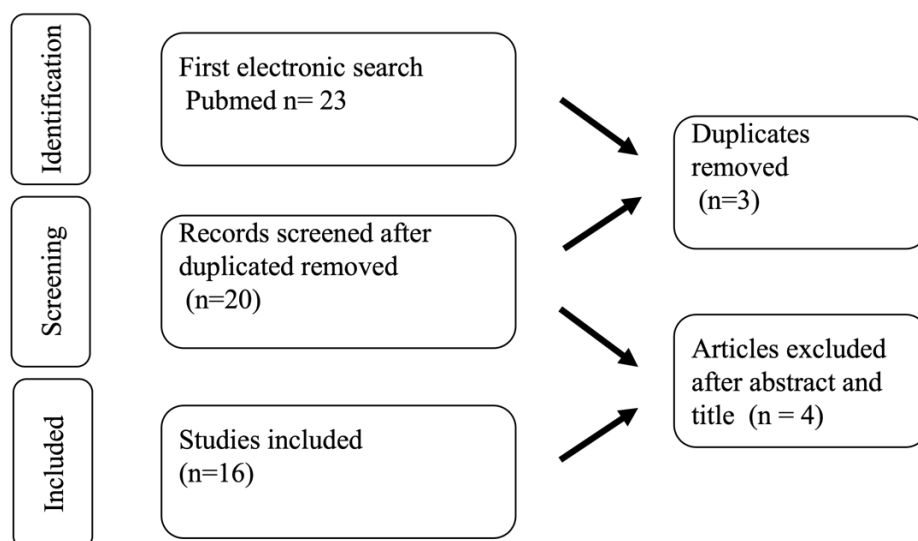


Figure 1. Flow diagram for research stages

Table 2. Primary features of the 16 included studies

Authors	Title	Year of publication	Journal	Study aim	Number of participants	Outcomes
Shousha et al.	Effects of low-level laser therapy versus soft occlusive splints on mouth opening and surface electromyography in females with temporomandibular dysfunction	2021	Plos One Journal	To assess the efficacy of low-level laser therapy (LLLT) as compared to occlusive splint therapy	112 TMD female subjects	An evident short term therapeutic effect of the LLLT on improving TMD symptoms.
Grillo et al.	Could Acupuncture Be Useful in the Treatment of Temporomandibular Dysfunction?	2014	Journal of acupuncture and meridian studies	To compare the effect of Acupuncture in comparison with flat occlusal plane appliance	40 TMD female subjects	Both treatments reduced the pain intensity of myogenic TMD in the short term
Erlandson et al.	Electromyographic biofeedback and rest position training of masticatory muscles in myofascial pain-dysfunction patients.	1989	The Journal of prosthetic dentistry	Biofeedback therapy versus biofeedback and splints	24 TMD female subjects	The instruction and prosthesis groups obtained significantly greater electromyographic reductions in masseter activity and increases in mandibular range of motion compared with the biofeedback-only group.
Turk et al.	Effects of intraoral appliance and biofeedback/stress management alone and in combination in treating pain and depression in patients with	1993	The Journal of prosthetic dentistry	To assess the differential efficacy of two commonly used treatments for temporomandibular disorders (TMD), intraoral appliances	80 TMD subjects	The results of this study demonstrated that the combined treatment approach was more effective than either of the

	temporomandibular disorders			(IAs) and biofeedback (BF), separately and in combination		single treatments alone
Giannakopoulos et al.	Comparison of device-supported sensorimotor training and splint intervention for myofascial temporomandibular disorder pain patients.	2018	Journal of oral rehabilitation	This study was to compare the short-term therapeutic efficacy of device-supported sensorimotor training with that of standard splint therapy	45 TMD subjects	The results of this study confirm the pain-reducing effect of sensorimotor training
Manns et al.	Influence of the vertical dimension in the treatment of myofascial pain-dysfunction syndrome	1983	The Journal of prosthetic dentistry	Occlusal splints constructed at three different vertical heights were used to study the influence of vertical dimension in the etiology of bruxism and MPD (myofascial pain dysfunction) syndrome.	75 TMD subjects	It can be concluded that elongation of elevator muscles to or near the vertical dimension of least EMG activity by means of occlusal splints is more effective in producing neuromuscular relaxation.
Manns et al.	Influence of vertical dimension on masseter muscle electromyographic activity in patients with mandibular dysfunction.	1983	The Journal of prosthetic dentistry	Occlusal splints were adjusted to different vertical heights and used to single out the influence of vertical dimension of occlusion in increments on BT-EMG activity of the masseter muscle in patients with mandibular dysfunction.	60 TMD subjects	This study suggests that an increase of vertical dimension of occlusion to or near the vertical dimension of least EMG activity by means of occlusal splints can be an effective way to obtain a reduction in masseteric muscle activity.
Carlson et al.	Comparison of muscle activity between conventional and neuromuscular splints.	1993	The Journal of prosthetic dentistry	The purpose of this study was to investigate the effect of two muscle relaxation appliances(a centric relation MRA, neuromuscular orthotic) and a placebo (cotton rolls) on EMG activity	12 female subjects	No statistical difference was found between the centric relation mandibular MRA and neuromuscular orthotic. A statistically significant difference was found between the mean EMG values of the placebo and two treatment appliances.
Weggen et al.	Clinical and electromyographic follow-up of myofascial pain patients treated with two types of oral	2013	International journal of computerized dentistry	The objective of this study was to monitor the therapeutic effects of two different splint concepts	40 subjects	The therapeutic effects of splints of different clinical complexity differed

	splint: a randomized controlled pilot study			(standard method and a complex splint procedure assisted by transcutaneous electrical nerve stimulation, TENS) by use of clinical outcome criteria and EMG recordings.		significantly between the patient groups, in favor of the complex oral appliances
Baad Hansen et al.	Effect of a nociceptive trigeminal inhibitory splint on electromyographic activity in jaw closing muscles during sleep.	2007	Journal of oral rehabilitation	The present study was designed to address the question about EMG-changes during sleep in patients with splint treatment	10 subjects	This short-term study indicated a strong inhibitory effect on EMG-activity in jaw closing muscles during sleep of the NT(nociceptive trigeminal inhibitory)splint, but not the OS(occlusal splint).
Dahlstrom et al.	Bite plates and stabilization splints in mandibular dysfunction. A clinical and electromyographic comparison	1985	Acta odontologica Scandinavica	Comparison of EMG activity in TMD patients treated with bite plates with a frontal plateau or full-coverage stabilization splints .	20 subjects	Use of occlusal appliances at night for 6 weeks did not change the EMG activity in comparison with pretreatment recordings.The clinical signs improved, significantly.
Ferrario et al.	Immediate effect of a stabilization splint on masticatory muscle activity in temporomandibular disorder patients	2002	Journal of oral rehabilitation	Effects of stabilization splints in EMG recordings in patients with TMD .	14 subjects	Overall, the splint reduced the electrical activity of the analysed muscles and made it more equilibrated both between the left and right side (larger symmetry in the masseter muscle POC, and between the temporal and masseter muscles (activity index)
Hersek et al.	Effect of anterior repositioning splints on the electromyographic activities of masseter and anterior temporalis muscles	1998	CRANIO® The Journal of Craniomandibular & Sleep Practice	The effect of anterior repositioning (AR) splint therapy on masticatory muscle activity was investigated through integrated electromyography (EMG) recordings	17 subjects	AR splint therapy did not cause any significant modification of the EMG activity in the recorded muscles.
Tecco et al.	Surface electromyographic patterns of	2008	European journal of orthodontics	The aim of this study was to investigate the	34 adults subjects	Splint therapy in subjects with internal disk

	masticatory, neck, and trunk muscles in temporomandibular joint dysfunction patients undergoing anterior repositioning splint therapy			surface electromyographic (sEMG) activity of neck, trunk, and masticatory muscles in subjects with temporomandibular joint (TMJ) internal derangement treated with anterior mandibular repositioning splints		derangement seems to affect sEMG activity of the masticatory, neck, and trunk muscles, such that after treatment, sEMG activity revealed no statistically significant difference when compared with the control group.
Zhang et al.	Effect of occlusal splints for the management of patients with myofascial pain: a randomized, controlled, double-blind study.	2013	Chinese medical journal	The aim of this study was to give objective evidence to the assessment of treatment effect of occlusal splints for myofascial TMDs patients by clinical assessments and surface electromyography (sEMG) measurements of masseter muscles (MM).	36 subjects	Occlusal splint could eliminate or improve the signs and symptoms of TMD patients with myofascial pain. sEMG analysis indicates that the wearing of occlusal splints may reduce the degree of fatigue of the masticatory muscles. The splint therapy outcome has a correlation with the electromyographic changes in the masticatory muscles.
Daif et al.	Correlation of splint therapy outcome with the electromyography of masticatory muscles in temporomandibular disorder with myofascial pain.	2011	Acta odontologica Scandinavica	The aim of this study was to assess the effect of occlusal splint therapy on the electromyographic amplitude records (μ V) of masticatory muscles in temporomandibular disorder (TMD)	40 subjects	Occlusal splint could eliminate or improve the signs and symptoms of TMD patients with myofascial pain. It reduces the electromyographic amplitude records (μ V) of the masticatory muscles.

Temporomandibular disorders and their treatment options is a widely discussed topic among worldwide clinicians. New rigorous clinical evaluation criteria and treatment possibilities are continuously introduced [1]. In this literature review, the most appropriate strategies to manage temporomandibular disorders were evaluated. The results showed

that different types of occlusal splints are considered the standard procedure in the management strategy for TMDs, due to their capacity to determine masticatory muscle relaxation, which was evaluated by using the electromyographic investigations. Nowadays, clinicians use different types of multidisciplinary therapies, in addition to

occlusal splint therapy, to treat the patients diagnosed with TMD.

Although the effectiveness of low-level laser therapy in temporomandibular joint dysfunction (TMD) treatment is not well established, due to its analgesic, anti-inflammatory, and biomodulation effects of the physiological cell functions, the effect of low laser therapy used as an alternative therapy option to relief the muscle and TMJ pain, was studied by Shousha et al. [11]. In their study, it was assessed the efficacy of low-level laser therapy (LLLT) compared to occlusive splint therapy (OST) on the TMJ opening index (TOI) and sEMG of masticatory muscles. The results showed that a significant reduction of pain was reported within the LLLT and OST groups and concluded that there is an evident short term therapeutic effect of the LLLT in females suffering from myogenous TMD in pain and on sEMG findings, that is better than soft occlusive splints. However, this finding had a short term therapeutic effect.

Other studies [12-14] revealed the important effects of acupuncture on the control of musculoskeletal pain in the orofacial region. The effects of acupuncture on patients with myogenic pathology were compared with the results obtained by using a flat occlusal appliance [15]. The results indicated that both, flat splints and acupuncture, reduced the pain intensity in short term, thus it may be considered valuable alternatives in controlling the chronic pain related to TMDs. However, muscle activity was also evaluated on electromyography, which indicated the decreased value of the right temporal muscle contraction, in the rest position, during the final stage of the splint therapy [15]. They concluded that acupuncture is efficient exclusive in pain management, not in decreasing the muscle activity assessed by using electromyography [15].

Other researchers investigated the effects of biofeedback therapy, used by itself or in combination with intraoral appliances. In addition to the biofeedback procedure, subjects received instructions and demonstrations regarding the lower jaw position, which should be held in an open rest position, to minimize tension on the masticatory muscles and occlusal splints. Erlandson et al. [16] demonstrated that the patient who received a combined treatment (biofeedback and occlusal splints), correlated with a good posture, obtained significantly greater electromyographic reductions in masseter muscle activity and increased the mandibular range of motion, compared with the patient who received exclusive biofeedback therapy [16].

Turk et al [17] compared the results of intraoral appliances treatment (IA), in association with biofeedback and stress management (BF/SM). Their results demonstrated that IA treatment appliance was more effective compared to BF/SM therapy, achieving a considerable pain reduction at the end of the treatment. However, the 6-month follow-up showed that the IA group significantly relapsed, especially in depression, whereas the BF/SM maintained the achieved results, improving the pain tolerance and depression. They also evaluated the effects of IA and BF/SM. The obtained results revealed that at 6-month follow-up, the combined treatment approach proved to be more effective in reducing the pain, than using a single treatment possibility. It was concluded that after using biofeedback and intraoral appliances, an improvement in electromyographic activity on masseter muscle was obtained. Thus, biofeedback and intraoral appliance clinical therapies should be combined to achieve the best results in pain management of patients diagnosed with TMD, although their result in electromyographic activity is not yet

demonstrated (16).

Giannakopoulos et al. [18] investigated the effect of device-supported sensorimotor training vs splint therapy in pain reduction and sEMG findings for TMDs patients. Their results confirm the pain-reducing effect of sensorimotor training for patients with myofascial TMD pain. Also the reduction in muscular activity was registered on the electromyography, when using the bite-controlled force in maximum intercuspation, to evaluate the masseter and temporalis muscles activity [18].

Another topic correlated with the activity of the masticatory muscles is vertical dimension of occlusion (VDO). The decreased VDO is very often correlated with muscle hyperactivity. Due to emotional stress, wear of the occlusal surfaces of lateral and anterior teeth may occur, with may lead to a decreased VDO [19]. This clinical situation is also considered an etiologic factor in the development of TMDs. After the treatment with occlusal splints and clinical remission of TMDs' signs and symptoms, a complex prosthetic treatment should be performed to maintain the optimal health status [19].

Other studies investigated the effect of neuromuscular splints in muscle relaxation. The results showed no significant difference between the results obtained by using conventional or neuromuscular splints. Splints of different thicknesses determined elongation of the elevator muscles. The EMG activity showed the effect of neuromuscular relaxation determined by the splints fabricated with an increased thickness [20-22]. Manns et al [20] assessed the EMG activity of 75 patients, who were randomly divided into three groups according to different values of vertical dimension at which the occlusal splint was constructed. Group I occlusal splints were constructed at 1 mm from the occlusal vertical dimension,

group II splints at 4.42 mm, and group III splints at 8.15 mm. Results showed a faster and more complete reduction in clinical symptoms for groups II and III than for group I.

Transcutaneous Electrical Nerve Stimulation (TENS) has been used to control pain in patients with chronic TMDs [23-26]. However, the influence of this therapy on the tonus of masticatory muscles should be further investigated, considering that the evidence regarding the improvement of clinical parameters, e.g., reported pain, jaw movement and electromyography (EMG) activity, are divergent and controversial. Studies showed that the main effects of TENS on the muscular tonus of patients with TMD were: 1) reduction in muscle activity of the anterior portion of the anterior temporalis muscle, during resting posture of the jaw, and 2) increased muscle activity of the masseter muscles, during maximal voluntary contraction (clenching) [27]. Other study also confirmed TENS as effective in reducing the EMG activity of the anterior temporalis and masseter muscles during resting posture of the jaw [28]. The study included in this review showed the difference between a complex splint procedure assisted by transcutaneous electrical nerve stimulation, (TENS) and a conventional one in sEMG recordings [29]. After final results, it could be concluded that the complex splint procedure had better results than standard splint method on the EMG recordings [29].

The nociceptive trigeminal inhibitory (NTI) splint has been claimed to decrease the electromyographic (EMG) activity of elevator muscles and relieve symptoms of various types of temporomandibular disorders (TMD) and bruxism [30]. The Nociceptive Trigeminal Inhibition Clenching Suppression System (NTI-tss) device is an intraoral device, developed to produce an inhibitory stimulus, which is a reflex of the body to

protect the teeth from excessive forces, preventing parafunctional habits [31,32]. According to the manufacturer, NTI-tss allows for optimum musculoskeletal stability (anterior-superior) in the proper condylar position, allowing the condyle to sit posteriorly/superiorly in the glenoid fossa, during resolution of the symptoms. It could be used in patients with TMD, including those with TMJ and muscular pain, headaches, or migraines. Another short-term study indicated a strong inhibitory effect on EMG-activity in jaw closing muscles during sleep of the NTI (nociceptive trigeminal inhibitory), but not the occlusal standard flat splint [30].

However, there are also several distinct types of splints such as stabilization or flat plane splint, anterior biteplane and repositioning splint.

Stabilization or flat plane splint covers the occlusal surfaces of the upper teeth, and its flat surface is intended to help reduce tooth grinding and relax the sore masticatory muscles. However, it does not prevent tooth clenching because the lower teeth can still contact on it. Therefore, in some patients, their condition can be aggravated by the splint [33]. Anterior biteplane fits on the upper jaw and makes contact with only the six lower anterior teeth. Thus, it prevents the posterior teeth from touching and prevents both clenching and grinding. It is generally worn only at night because constant wear may allow the posterior teeth to shift [33]. The repositioning splint is used to move the lower jaw either forward or backward, either

to “recapture” a displaced (clicking) disc or to establish a “better” jaw position [33].

When comparing anterior bite plates versus stabilization splints, the EMG activity didn't change, but it was an improvement in clinical and subjective symptoms in stabilization splint group [34]. The stabilization splint versus a control group study, it was demonstrated that stabilization splint had an effect on sEMG findings compared to control group, it reduced the electrical activity of the analyzed muscles: temporal and masseter [35].

Other studies that investigated the anterior repositioning splint therapy versus control group. AR splint therapy resulted in reduction of the pain, jaw joint sounds and mean vertical opening, so clinical and subjective symptoms were improved, but no EMG improvement was detected [36]. The conclusion of the study was that splint therapy affected the sEMG activity of the masticatory muscle and the EMG activity was the same as in the control group at the end of the treatment, that means that was an efficient treatment [37]. Therefore, splint therapy improved the effect on sEMG in patients with temporomandibular disorders, and reduced the electromyographic amplitude records (μV) of the masticatory muscles. Thus, the splint therapy outcome has a correlation with the electromyographic amplitude changes of the masticatory muscles [38,39].

CONCLUSIONS

1. Short term therapeutic effect of the low-level laser therapy improves the pain and sEMG findings in TMD patients, better than soft occlusive splints.
2. Biofeedback and intraoral appliances are a good treatment option for pain management in TMD patients.
3. Sensorimotor training has a positive effect on pain for patients with myofascial TMD pain and a reduction in muscular activity on sEMG.
4. Splint assisted by transcutaneous electrical

nerve stimulation, TENS, had better results than splint alone in EMG recordings. NTI (nociceptive trigeminal inhibitory) splints present a stronger inhibitory effect on EMG-activity in jaw closing muscles during sleep, compared to flat occlusal splint.

5. Based on the studies from this review, it can be concluded that acupuncture,

biofeedback and low-level laser therapy have better effects on pain management, compared to occlusal splint alone and their therapeutical effect can be evaluated on sEMG.

6. Considering the various results obtained, it is difficult to choose an unique treatment option for the patients diagnosed with temporomandibular disorders.

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