Laser Physics Letters

Astro Ltd.

LETTER

Synergistic effect of low-level laser and vacuum therapy on the temporomandibular disorder: two cases report

To cite this article: Vitor Hugo Panhóca *et al* 2021 *Laser Phys. Lett.* **18** 105602

IOP Publishing | Astro Ltd Laser Physics Letters

Laser Phys. Lett. **18** (2021) 105602 (6pp) https://doi.org/10.1088/1612-202X/ac20de

Letter

Synergistic effect of low-level laser and vacuum therapy on the temporomandibular disorder: two cases report

Vitor Hugo Panhóca[1,4], Patricia Eriko Tamae[1,2,3,4], Maria Vitória Juffo Silva[2], Alessandra Nara de Souza Rastelli[3,*] and Vanderlei Salvador Bagnato[1]

[1] Department of Physics and Materials Sciences, Physics Institute of São Carlos—IFSC, University of São Paulo—USP, São Carlos, SP, Brazil
[2] Central Paulista University Center—UNICEP, São Carlos, SP, Brazil
[3] Department of Restorative Dentistry, School of Dentistry, Araraquara, São Paulo State University—UNESP, Araraquara, SP, Brazil

E-mail: alessandra.nara-souza-rastelli@unesp.br

Received 3 August 2021
Accepted for publication 17 August 2021
Published 14 September 2021

Abstract

Temporomandibular dysfunction (TMD) can be described as a set of clinical conditions that includes disorders of the temporomandibular joint (TMJ) and/or the masticatory muscles that has a multifactorial origin, like bruxism, sleep alteration, trauma, among others. There are several ways to treat TMD, such as: occlusal splints, physiotherapy, viscosupplementation, among others. The aim of this case report was to show the new possibility in the treatment of TMD by means of a combined therapy using low-level laser (LLL) and vacuum therapies in the recovery process of two patients with TMD. A simultaneous LLL under 660 and 808 nm, 600 mW of power divided into six lasers outputs around the tip was used synergistically with a vacuum device under negative pressure between 100 and 150 mbar. This case report included 2 patients and both of them were diagnosed with TMD according to the research diagnostic criteria for temporomandibular disorders (RDC/TMD). Patients were treated for LLLT and vacuum therapy at the same time. The treatment was applied to the left and right sides of the face on the masseter muscles, temporal muscles on the previous fibers and TMJs. Two sessions per week were performed totaling eight sessions. Oral opening, visual analogue scale (VAS) and OHRQoL (oral health-related quality of life) measurements were evaluated by the Oral Health Impact Profile (OHIP-14) at three moments: pre-treatment (T0), after the eight treatment sessions (T1) and 30 d after the end of treatment (T2). The obtained results showed the improvement of muscle pain and oral opening accompanied by improved quality of life of the volunteers treated with a percentage of 84% in patient 1 and 100% in patient 2. Combined therapies (LLL and vacuum therapies) may be a complementary or alternative treatment to control pain and decrease the recovery time of normality masticatory muscles.

Keywords: low-level laser therapy, vacuum therapy, temporomandibular disorder

(Some figures may appear in colour only in the online journal)

[4] Co-first authors with equal contribution.
[*] Author to whom any correspondence should be addressed.

1. Introduction

The temporomandibular joint (TMJ) has a unique and particular characteristic in the human body, because it presents synchronous interlinked movements, that is, when right joint movement occurs, the left also moves in synchrony through the action of the masticatory muscles during normal mandibular movement [1, 2]. In addition, it performs its movement related to the meshing and proprioception of the teeth of the lower arch with the teeth of the upper arch. Once parafunctional movements involving the masticatory muscles occur, TMJ may develop temporomandibular dysfunctions (TMDs) [3].

The appearance of limitation of mandibular movements, joint noises, pain in the muscles of masticatory and TMJ, are the main signs and symptoms of TMD. When TMD-related pain persists for more than three months, a treatment should be performed based on a chronic disease scenario and not as acute pain. TMD is a disease of high prevalence in the American population [4]. TMD can affect the physical and mental health of the patient, leading to a negative impact on the quality of life [5]. Women are more susceptible than men to have TMJ pain and a higher incidence in the population aged between 21 and 50 years has been demonstrated [6]. It is estimated that 40% of the Brazilian population has some sign or symptom of TMD. However, only approximately 25% of this population present TMD-related pain [6].

There are several modalities for pain management and control in the treatment of TMD. These modalities are classified as invasive when it involves surgery, arthroscopy, arthrocentesis, among others; and non-invasive such as occlusal splints, physiotherapy, biofeedback, laser, among others [7]. Scientific evidence has shown the high success rate of noninvasive or minimally invasive treatments [7, 8] Minimally invasive treatments, besides have been cited as the most common in the literature [8, 9] they are also more accepted in the daily clinical practice. The most commonly used treatments in dentistry are: occlusal stabilization plates of TMDs and masticatory muscles, physiotherapy exercises, transcutaneous electrical nerve stimulation (TENS), ultrasound, dry needling, biofeedback therapy, pharmacotherapy and psychological treatment [7]. These noninvasive treatments are preferably selected due to the fact that TMD is considered a self-limiting disease of multifactorial origin. Treatments considered invasive, such as occlusal adjustments and surgical interventions have been less and less used and indicated for very specific cases of TMDs [7].

Several studies have shown the analgesic and anti-inflammatory effect of low-level laser (LLL) in the treatment of temporomandibular disorders [10, 11]. In addition, the effects of LLL have the ability to improve mouth opening and the quality of life of patients who received TMD treatment. The wavelengths most used for this therapy are based on red (660–680 nm) and near infrared (780–808 nm) [10]. In addition, the most recent studies showed that infrared wavelengths could provide better results in the TMD treatments [10, 11].

Vacuum therapy is a noninvasive procedure that uses suction cups and negative pressure to increase peripheral blood irrigation [12]. Thus, it promotes local angiogenesis, leading to an increase in oxygen and nutrients in the applied region, causing anti-inflammatory effect and tissue repair [12–14] (figure 1). The low-power laser has features of accelerating healing time, acting as anti-inflammatory, analgesic and muscle relaxant [12]. In view of these characteristics, the association of low-power laser and vacuum therapy can enhance the recovery of normal movements of the masticatory muscles, TMJs and the quality of life of patients with TMD.

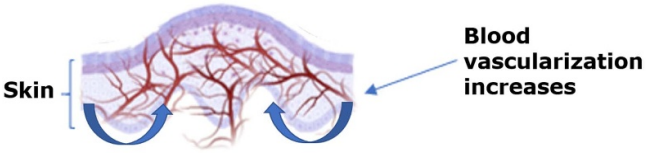

Figure 1. Effect of negative pressure increasing blood circulation. The arrows in this figure show the direction of blood flow during application of the vacuum device.

Previous experiments conducted by our research group have shown that phototherapy combined or not with ultrasound reduced pain and increased the mouth opening capacity of patients with TMD [15, 16], Within this context, therapeutic modalities such as laser and vacuum therapy emerge as a complementary or alternative strategy for the noninvasive treatment of TMD.

The aim of this paper was to present two clinical cases of volunteers diagnosed with TMD who were treated with an innovative device that combines the simultaneous application of laser and vacuum therapy.

2. Case report description

The treated volunteers were selected and evaluated in the dental office of Irmandade da Santa Casa de Misericordia de São Carlos (São Carlos, SP, Brazil) conveniated to the Biophonics Laboratory of the Physics Institute of São Carlos—IFSC, University of São Paulo—USP, São Carlos, SP, Brazil. To treat the patients under TMD, two volunteers were selected according to the "Research Diagnostic Criteria for Temporomandibular Disorders (DrC/TMD)" designed by Dworkin [17]. Mouth opening measurements and pain assessment using a visual analogue scale (VAS) ranging from 0 to 3, where: 0 = no pain, 1 = discomfort with mild pain, 2 = acute pain only during stimulus application, and 3 = pain acute during stimulus application and continuous after its removal; were evaluated at three times: pre-treatment (T0), after the eight treatment sessions (T1) and 30 d after the end of treatment (T2).

This case report was approved by the ethics committee for human studies of Irmandade da Santa Casa de Misericordia de São Carlos, under the protocol number C.A.A.E. 09096219.0.0000.8148. All questions from the two volunteers were clarified, and it was explained that the participation in the study was voluntary. Both volunteers read and signed the informed consent form (TCLE). Oral opening and Oral

Figure 2. VacumLaser® equipment (MMOptics, São Carlos, SP, Brazil) (a), the suction cup used (b), the display of the device (c) and (d) close-up view of the display with treatment protocol.

Health-Related Quality of Life (OHRQoL) measurements were evaluated using the Oral Health Impact Profile (OHIP-14) at three moments: pre-treatment (T0), after the eight treatment sessions (T1) and 30 d after the end of treatment (T2). The patients were treated with the VacumLaser® (MMOptics, São Carlos, SP, Brazil) that synergistically applies LLL and negative pressure through suction cup. The system is shown in figure 2. The two volunteers received the same treatment. The treatments applied were based on the LLL with 6 laser diode outputs being 3 under 660 nm and 3 under 808 nm wavelength concomitantly; each laser has the power output of 100 mW producing a total power output of 600 mW, <72 J (discounting lost energy according to the spot distance from the tissue surface that varies with the size of the suction cup per region) and laser spot area is 1.76 mm^2. The suction cup was applied punctually to the face synergistically to the laser, as shown in figure 3 on both sides of the face. In case of unilateral pain, the application is also unilateral. Whether any other masticatory or face muscle shows pain, the application of LLL and vacuum therapy can be applied under the same protocols. The suction cups were adjusted with negative pressure from 100 to 150 mbar under pulsed mode (MP7 = 40 pulses per minute). The suction cup used was the smaller one with a diameter of 40 mm. Previously the application of suction cups, vegetable oil was applied to the patient's facial surface so that the suction cup could glides over the skin tissue. The application was made for 120 s per region (figure 3).

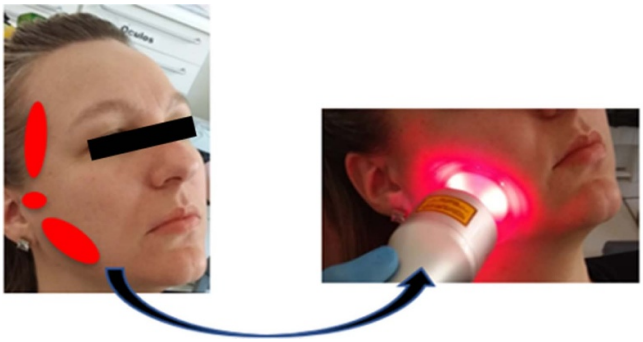

Figure 3. Vacumlaser® application areas (over the previous fibers of the muscles, temporal and masseter, and TMJ).

3. Cases report

Both patients in these case report attended to the dental office of the Brotherhood of the Santa Casa de Misericórdia Hospital (São Carlos, SP, Brazil). The TMD treatment was performed at the Biophonics Laboratory of the Physics Institute of São Carlos—IFSC, University of São Paulo—USP (São Carlos, SP, Brazil). Both patients were diagnosed with TMD, where the patient 1 presented only muscle TMD and patient 2 presented muscle TMD and joint involvement on the left side with the presence of click.

3.1. Case report 1

Patient A.A.M., 38 years-old, female (figure 4), complaining of pain for 3 months in the preauricular left side region, pain during the masticatory function, limitation of oral opening, headaches and she also reported the habit of grinding teeth. The patient was submitted to intra- and extra-oral clinical examination using the RDC/TMD questionnaire and was diagnosed with muscle TMD and absence of clicks during TMJ palpation. The free and informed consent form was signed and the questionnaire on the Impact of Oral Health OHIP-14 was completed.

3.2. Case report 2

Patient M. F. R. S., 43 years-old, female (figure 5), complaining of pain in the pre-auricular region and TMT bilaterally. The patient reported that 23 years ago, the use of a stabilizing plate for 5 years and it was in disuse in the last 5 years. The patient reports absence of headache. The patient also reports that at 21 years of age she had mandibular locking that limited the mouth opening since then. The patient has nocturnal bruxism and feels painful the lateral region of the face when she wakes up in the morning. She was submitted to intra- and extra-oral clinical examination using the RDC/TMD questionnaire and she was diagnosed with muscular TMD with the presence of clicking on the left side of the TMJ at 25 mm during the mouth opening movement. The free and informed consent form was signed and the questionnaire on the Impact of Oral Health OHIP-14 was completed.

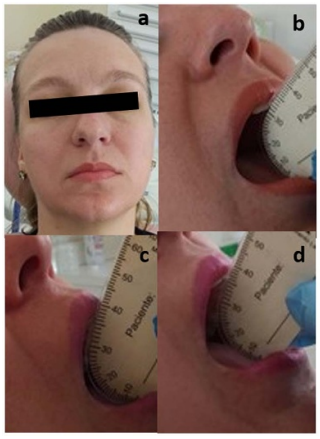

Figure 4. Anterior view of the patient's face (a), oral mouth opening of 31 mm in T0 (b), oral mouth opening of 36 mm in T1 (c) and oral mouth opening of 38 mm after 30 d (d).

Figure 5. Anterior view of the patient's face (a); oral mouth opening of 35 mm in T0 (b); oral mouth opening of 38 mm in T1 (c) and oral mouth opening of 42 mm after 30 d (d).

4. Results

The results based on the VAS scale regarding the pain score and for OHIP-14 are listed in tables 1 and 2, respectively. Patient 1 presented in the first session ($T = 0$) 31 mm of maximum oral mouth opening without pain, after the eighth session ($T = 1$) of application, 36 mm of oral mouth opening and 38 mm in the return of 30 d, evidencing an evolution regarding the mouth opening even after the return of 30 d. Patient 2 in the first session ($T = 0$) presented 35 mm of maximum oral opening without pain, 38 mm in the eighth session ($T = 1$) and 42 mm after 30 d was observed. In addition, an improvement in the maximum oral mouth opening without pain was observed. The condition of clicking on the left side at 25 mm of the oral mouth opening movement in the first session was eliminated in the eighth treatment session and remained after 30 d in the evaluation after the end of treatment. After TMD treatment, patients 1 and 2 showed improvement of pain bilaterally in the TMJ, masseter and temporal regions from the first to the eighth session and maintained the same clinical behavior after 30 d, as shown in table 1.

Table 1. Vas evaluation (pain score) before, after treatment and 30 d after the end of TMD treatment of patients 1 and 2, showing a score that goes from 0 to 3 on the right and left side.

VAS patients $^1/_2$	$T = 0$	$T = 1$	$T = 2$
TMJ	3 R−3 L/ 3 R−3 L	0 R−0 L/ 0 R−0 L	0 R−0 L/ 0 R−0 L
Masseter	3 R−3 L/ 2 R−2 L	0 R−0 L/ 0 R−0 L	0 R−0 L/ 0 R−0 L
Temporal	1 R−1 L/ 0 R−1 L	0 R−0 L/ 0 R−0 L	0 R−0 L/ 0 R−0 L

Note: VAS stands for visual analog scale (0 = no pain, 1 = mild pain, 2 = moderate pain, 3 = severe pain). R means right and L means left. $T = 0$ means initial evaluation, $T = 1$ evaluation after treatment and $T = 2$ evaluation after 30 d of end of treatment.

5. Discussion

In this manuscript, we presented two cases report based on the use of LLLT combined with vacuum therapy in a synergistic way. Our findings showed positive and promising results for the treatment of temporomandibular disorders., which can be seen in tables 1 and 2.

The initial evaluation, after treatment and 30 d after the treatment, based on VAS scale showed improvement in pain in the masticatory muscles (table 1). VAS scale is a psychometric response scale that was used in the initial, final questionnaire and 30 d after the end of treatment for the two volunteers. VAS scale was used as a measuring instrument for subjective characteristics because they cannot be measured directly. Oral health conditions are an inseparable part of people's overall health and quality of life, and OHIP was performed in both patients to measure the social impact on each volunteer.

In addition, an improvement in the extent of mouth opening after the end of treatment was also observed. Patient 1 had an initial opening of 31 mm and the opening after 30 d was 38 mm. The same behavior was observed for the patient 2, where the mouth opening increased from 35 mm for 42 mm. Functional limitation for both patients was not present at the beginning of treatment and remained absent until the end of treatment. Social limitation for patient 2 was also not a problem, just as disability was not and remained for patient 1. However, for patient 2, physical pain and psychosocial discomfort were high, which evolved to zero at the end of treatment. Thus, compared to the results obtained in the first session, after the eighth session and after 30 d, both patients presented improvement of the condition related to the other questions addressed in the OHIP-14 questionnaire, as show in table 2.

These cases report shows a new system for synergistic application of LLL and vacuum therapy to treat TMD. Based on the obtained results, the expectation of the efficacy of this innovative equipment was shown. The results after LLL and vacuum therapy evaluated through the visual analog scale showed analgesia in the painful sensitivity of patients after palpation of TMJ, masseter and temporal muscles. In quality-of-life evaluation based on OHIP-14, which evaluates the impact of TMD treatment on the patient's quality of life, it

Table 2. Evaluation by OHIP-14 before and after TMD treatment of patients 1 and 2.

OHIP-14 patients 1/2	Initial $T = 0$ (1st S)	Final $T = 1$ (8th S)	Final after 30 d $T = 2$	% Percentage of improvement after therapy
Functional limitation	0/0	0/0	0/0	0/0
Physical pain	5/8	2/0	0/0	65/100
Psychological discomfort	7/7	1/0	0/0	86/100
Physical limitation	3/1	0/0	0/0	100/100
Psychological limitation	3/4	0/0	0/0	100/100
Social limitation	1/0	0/0	0/0	100/0
Disability	0/4	0/0	0/0	0/100
Total	19/24	3/0	0/0	84/100

Note: maximum score of OHIP-14 = 56, S = session.

was possible to observe that there was an improvement of 84% for patient 1 and 100% for patient 2 in the total quality of OHIP-14.

The use of LLL separately from vacuum therapy for TMD treatment has been accepted as a valid noninvasive therapy for this morbidity. Chen *et al* in a meta-analysis of 14 randomized clinical trials concluded that LLL can significantly improve the functional results of patients with TMD [18]. In another systematic review published in 2016 [19], the authors concluded that LLL seems to be effective in reducing pain in TMDs. Xu *et al* suggesting that LLL effectively relieves pain and improves functional results in patients with TMD [20]. In these case report, the LLL under 660 and 808 nm was used. The use of both wavelengths simultaneously can improve the photon receptor chromophores in living tissue promoting photobiomodulation effect.

The LLL acts by transferring energy mainly to cytochrome peroxidase c [21]. The photoreceptors in the mitochondrial respiratory chain are excited producing photochemical and photophysical effects, increasing membrane potential and consequently changing mitochondrial properties [21] This change results in increased production of ATP and molecular oxygen, which stimulates the activity of DNA and RNA for the synthesis of cell cycle regulatory proteins and thus the speed of mitosis can be increased [22–25]. LLL therapy modulates several biological processes, stimulating the healing and synthesis of collagen, promoting the musculoskeletal regeneration, decreasing the inflammatory response and increasing angiogenesis. In addition, it is hypothesized that LLL can promote photo-shutdown of nitric oxide (NO) which is an inflammatory flag. Recent evidence has shown that NO participates in muscle physiology modulating the processes of vasodilation, metabolism and contraction of the musculature [26].

In this case report, there was a significant improvement in pain of the regions of the temporomandibular joint and masseter muscle from the first to the eighth session, maintaining the result even after 30 d of the final session. LLL therapy associated with vacuum therapy promoted the overall improvement in OHIP-14 indicators and VAS for both cases. Application of LLLT with vacuum therapy showed effective results for both patients. Further studies with a greater number of volunteers (clinical trials) would be necessary to obtain more robust results proving the analgesic, restorative and quality of life improvement in the treatment of patients with TMD.

6. Conclusion

In view of the results showed in these case report, it was possible to show that LLLT therapy combined with vacuum therapy improves blood circulation, tissue repair, analgesic and anti-inflammatory in patients with TMD. LLLT and combined vacuum therapy may be a complementary or alternative treatment to control pain and decrease the recovery time of normality masticatory muscles.

Acknowledgments

The authors would like to thank CNPq (Grant No. 465360/2014-9) and São Paulo Research Foundation (FAPESP) Grants No. 2014/50857-8, INCT FAPESP), 2013/07276-1 (CePID—CePOF) for the financial support.

Conflict of interest

None declared.

References

[1] Kuntamukkula S, Sinha R, Tiwari P K and Paul D 2018 Dynamic stability assessment of the temporomandibular joint as a sequela of open reduction and internal fixation of unilateral condylar fracture *J. Oral Maxillofac. Surg.* **76** 2598–609

[2] Dandekeri S, Kavassery P B, Hegde C, Kumar S M and Bharathraj S 2019 Basic understanding of temporomandibular joint and its dysfunction among undergraduate students—a survey report *J. Health Allied Sci. NU* **9** 51–6

[3] Acharya S, Pradhan A, Chaulagain R and Shah A 2018 Temporomandibular joint disorders and its relationship with parafunctional habits among undergraduate medical and dental students *J. Coll. Med. Sci.* **14** 154–9

[4] Bond E C, Slade G and Durham J 2020 Prevalence, impact, and costs of treatment for temporomandibular disorders *Temporomandibular Disorders: Priorities for Research and*

Care vol 12, ed Bond E C, Mackey S, English R, Liverman C T and Yost O (Washington, DC: The National Academies Press) Appendix C National academies of sciences, engineering, and medicine Health and medicine division board on health care services board on health sciences policy Committee on temporomandibular disorders (TMDs): from research discoveries to clinical treatment (https://doi.org/10.17226/25652)

[5] De La Torre Canales G, Câmara-Souza M B, Lora V R M M, Guarda-Nardini L, Conti P C R, Garcia R M R, Del Bel Cury A A and Manfredini D 2018 Prevalence of psychosocial impairment in temporomandibular disorder patients: a systematic review *J. Oral Rehabil.* **45** 881–9

[6] Gonçalves D A G, Dal Fabbro A L, Campos J A D B, Bigal M E and Speciali J G 2010 Symptoms of temporomandibular disorders in the population: an epidemiological study *J. Orofac. Pain.* **24** 270–8

[7] Gil-Martínez A, Paris-Alemany A, López-de-Uralde-Villanueva I and La Touche R 2018 Management of pain in patients with temporomandibular disorder (TMD): challenges and solutions *J. Pain Res.* **11** 571–87

[8] Abouelhuda A M, Khalifa A K, Kim Y-K and Hegazy S A 2018 Non-invasive different modalities of treatment for temporomandibular disorders: review of literature *J. Korean Assoc. Oral Maxillofac. Surg.* **44** 43–51

[9] Randhawa K, Bohay R and Côté P *et al* 2016 The effectiveness of noninvasive interventions for temporomandibular disorders *Clin. J. Pain* **32** 260–78

[10] Panhoca V H, Lizarelli R F Z, Nunez S C, Pizzo R C D A, Grecco C, Paolillo F R and Bagnato V S 2015 Comparative clinical study of light analgesic effect on temporomandibular disorder (TMD) using red and infrared led therapy *Lasers Med. Sci.* **30** 815–22

[11] Tunér J, Hosseinpour S and Fekrazad R 2019 Photobiomodulation in temporomandibular disorders *Photobiomod. Photomed. Laser Surg.* **37** 826–36

[12] Panhóca V H, Nogueira M S and Bagnato V S 2021 Treatment of facial nerve palsies with laser and endermotherapy: a report of two cases *Laser Phys. Lett.* **18** 015601

[13] dos Santos A V, dos Santos T V, Zampieri K R, Tamae P E, de Aquino Júnior A and Bagnato V S 2019 Negative pressure and phototherapy: use of combined and localized therapy to improve life's quality in Parkinson disease in a case study *J. Alzheimers Dis. Parkinsonism* **9** 1–4

[14] Tamae P E, dos Santos A V, Simão M L S, Canelada A C N, Zampieri K R, dos Santos T V, de Aquino Júnior A E and Bagnato V S 2020 Can the associated use of negative pressure and laser therapy be a new and efficient treatment for Parkinson's pain? A comparative study *J. Alzheimers Dis. Parkinsonism* **10** 1–6

[15] Panhóca V H, Lopes L B, Paolillo F R and Bagnato V S 2018 Treatment of temporomandibular disorder using synergistic laser and ultrasound application *Oral Health Dent. Manage.* **17** 1–5

[16] Panhóca V H, Bagnato V S, Alves N, Paolillo F R and Deana N F 2019 Increased oral health-related quality of life postsynergistic treatment with ultrasound and photobiomodulation therapy in patients with temporomandibular disorders *Photobiomodul. Photomed. Laser Surg.* **37** 694–9

[17] Dworkin S F and LeResche L 1992 Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique *J. Craniomandib. Disord.* **6** 301–55

[18] Chen J, Huang Z, Ge M and Gao M 2015 Efficacy of low-level laser therapy in the treatment of TMDs: a meta-analysis of 14 randomised controlled trials *J. Oral Rehabil.* **42** 291–9

[19] Shukla D and Muthusekhar M R 2016 Efficacy of low-level laser therapy in temporomandibular disorders: a systematic review *Natl J. Maxillofac. Surg.* **7** 62–6

[20] Xu G-Z, Jia J, Jin L, Li J-H, Wang Z-Y and Cao D-Y 2018 Low-level laser therapy for temporomandibular disorders: a systematic review with meta-analysis *Pain Res. Manage.* **2018** 4230583

[21] Osipov A N, Machneva T V, Buravlev E A and Vladimirov Y A 2018 Effects of laser radiation on mitochondria and mitochondrial proteins subjected to nitric oxide *Front. Med.* **5** 112

[22] Karu T I 1987 Photobiological fundamentals of low-power laser therapy *IEEE J. Quantum Electron.* **23** 1703–17

[23] Karu T I, Pyatibrat L V and Afanasyeva N I 2004 A novel mitochondrial signaling pathway activated by visible-to-near infrared radiation *Photochem. Photobiol.* **80** 366–72

[24] Jówko E, Płaszewski M, Cieśliński M, Sacewicz T, Cieśliński I and Jarocka M 2019 The effect of low level laser irradiation on oxidative stress, muscle damage and function following neuromuscular electrical stimulation. A double blind, randomised, crossover trial *BMC Sports Sci. Med. Rehabil.* **11** 38

[25] Khairnar S, Bhate K, S N S K, Kshirsagar K, Jagtap B and Kakodkar P 2019 Comparative evaluation of low-level laser therapy and ultrasound heat therapy in reducing temporomandibular joint disorder pain *J. Dent. Anesth. Pain Med.* **19** 289–94

[26] Li Y, Xu Q, Shi M, Gan P, Huang Q, Wang A, Tan G, Fang Y and Liao H 2020 Low-level laser therapy induces human umbilical vascular endothelial cell proliferation, migration and tube formation through activating the PI3K/Akt signaling pathway *Microvasc. Res.* **129** 103959