



# Initial treatment for patients with temporomandibular disorders: pain relief and muscle tone relief by photobiomodulation therapy using carbon dioxide laser

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## Abstract

**Purpose** To investigate the efficacy of photobiomodulation therapy (PBMT) with a CO<sub>2</sub> laser (Bel Laser, Takara Belmont, CO. Ltd., Osaka, Japan; wavelength 10.6 μm) (tissue surface absorption effects) in conjunction with mouth opening training in patients with temporomandibular disorders (TMDs).

**Methods** This is a retrospective study on TMD patients with pre- and post-treatment assessments. The study included 36 patients (7 men and 29 women, mean age 58.2 years (SD 18.3)) (after excluding 4 patients due to dropouts, loss to follow up or refusal of treatment) with symptoms of pain and muscle tenderness during mouth opening. Treatment included Amfenac sodium (50 mg per day, thrice daily after meals) for 1–2 weeks for acute symptoms. Based on the diagnostic criteria for TMD, we identified the trigger point (muscle contracture site). We implemented muscle massage and stretching therapy as mouth opening training after PBMT. The laser irradiance conditions were as follows: output 1.5 W, on time 0.01 s, off time 0.05 s, and repeat pulse. Distance between the laser source and the skin was approximately 10 cm; irradiation time was 3 min (approximately 56.9 J/cm<sup>2</sup>). Mouth opening training involved massaging the areas of muscle contracture that were the trigger points, as well as muscle stretching to improve temporomandibular joint flexibility. One PBMT cycle and mouth opening training was conducted per week for four cycles. We determined the effects before and after intervention. A numeric rating scale (NRS; range 0–10) was used to evaluate pain, and maximum mouth opening (MMO) capacity was also assessed. Data were analyzed using the Wilcoxon signed-rank test.

**Results** The mean (SD) pain levels, as determined via NRS, were 4.9(3.6) and 2.7 (3.0) ( $p < 0.001$ ), before and after four treatment cycles, respectively. The mean (SD) of MMO was 39.6 (5.9) and 44.6 mm (4.8) ( $p < 0.001$ ), before and after treatment, respectively.

**Conclusion** The current study suggests that PBMT using a CO<sub>2</sub> laser combined with mouth opening training is effective for the treatment of temporomandibular disorders.

**Keywords** Carbon dioxide · CO<sub>2</sub> · Laser · Physical therapy · Temporomandibular disorder

## Introduction

The main symptoms of temporomandibular disorder (TMD) are temporomandibular joint clicking, pain in the temporomandibular joint and muscles of mastication, mouth opening problems, and jaw movement abnormalities [1–8]. The causes of TMD are multifactorial, and anatomical abnormalities and associated functional, structural, and psychological factors have been identified [1–8]. Conservative therapies in the early stages of treatment, rather than irreversible treatments such as aggressive surgery or occlusal adjustment, have recently been recommended in patients with TMD [1–8]. These conservative therapies include pharmacotherapy and physical therapy; laser therapy is included within the broader category of physical therapy and is often administered in conjunction with muscle-stretching exercises [1, 2, 6, 8, 9].

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Muscle massage therapy is reported to improve blood flow and lymphatic flow, and muscle stretch therapy is reported to be effective in increasing the range of motion of the jaw [8, 9]. Mouth opening training, such as muscle massage therapy and muscle-stretching therapy, are sometimes performed alone [8, 9] or are often used in combination with other treatments such as dry needling [8–10] or laser therapy [6, 10–18].

Photobiomodulation therapy (PBMT) is a conservative type of therapy, and the irradiation delivered via PBMT is believed to have photobiomodulatory effects [3, 6, 10, 12, 19]. It reportedly has pain-relieving effects on conditions that involve chronic pain such as TMD and dentin hypersensitivity [1–3, 10–21]. Semiconductor lasers [6, 10–21] and carbon dioxide (CO<sub>2</sub>) lasers [22–33] have both been used to elicit such effects. Among them, the CO<sub>2</sub> laser is used not only for surgical procedures [23–25], such as incision and transpiration of tissue, but also as necessary application for tooth-extraction wounds [26, 27] and promotion of healing of aphthous stomatitis treatment [28–31]. CO<sub>2</sub> laser has a long wavelength and is absorbed by water, so it is considered to only have a reaction on tissue surface [6, 22–30]. Furthermore, recent modalities such as the non-thermal, non-ablative CO<sub>2</sub> laser therapy (NACL<sub>T</sub>) or non-thermal, CO<sub>2</sub> laser therapy (NTCL<sub>T</sub>) have been reported to have pain relief effects on mucosal diseases such as Pemphigus vulgaris and Behcet's disease [31–33].

While almost all previously reported studies investigating PBMT for TMD have used semiconductor lasers [1–3, 6, 10–21], very few have used CO<sub>2</sub> lasers [22].

Thus, comparatively little is known about the effects of CO<sub>2</sub> laser-based therapy for TMD. However, there are reports that irradiation with a CO<sub>2</sub> laser reduces pain [23–25, 28, 29, 31–33] and increases blood flow [22]. Therefore, after CO<sub>2</sub> laser irradiation, additional muscle massage or muscle-stretching therapy may be performed [8, 9], and the temporomandibular joint symptoms may be effectively eliminated [3]. In addition, a method involving irradiating a laser to a trigger point has also been often used, which has been reported to have a therapeutic effect [3, 6, 10, 11, 17].

We have been treating temporomandibular joints based on this hypothesis in Fukuoka Dental Office, and in this article, we study the effects retrospectively.

In the present study, physical therapy with a main focus on CO<sub>2</sub> laser PBMT and mouth opening training was administered to patients with TMD symptoms, and the efficacy of the treatment was investigated.

## Methods

### Ethical statement

This was a retrospective study based on review of past electronic medical records. Patient information was anonymized,

and participants' confidentiality was ensured at all times. Intervention was of a naturalistic nature, i.e., intervention was already the most appropriate for patients at the time, with a favorable risk/benefit ratio. Since verbal informed consent for treatment and publication of anonymized data of this study was obtained and registered in their corresponding medical charts, ethics committee approval was not obtained. However, all procedures were carried out in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

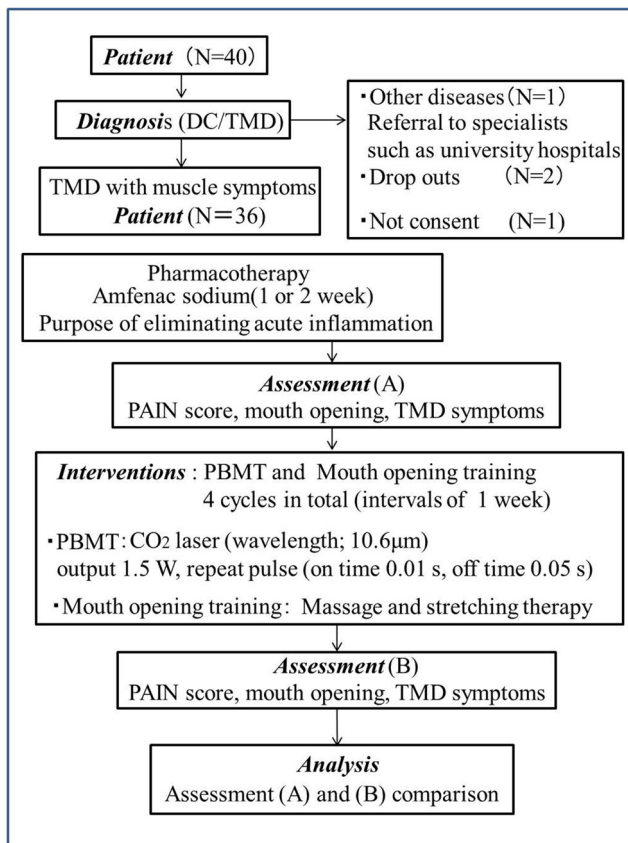
### Study subject

This is a retrospective study on a cohort of patients with TMD with pre- and post-treatment assessments. Verbal informed consent for treatment, publication of this study, and any accompanying images was obtained directly from the patients and recorded on the medical chart.

The study was carried out in Fukuoka Dental Office from April 2012 to March 2019. Forty patients that reported muscle tenderness and pain on mouth opening were initially included in the study. Out of the 40 patients, one patient was referred to as a higher medical institution to diagnose hyperplasia of the mandibular coronoid process, two patients dropped out, and one did not provide consent for treatment. A total of 4 patients were excluded from the study (Fig. 1). Therefore, the study included 36 patients with TMD (7 men and 29 women, mean age 58.2 years (SD:18.3), range 14–90 years) who presented with mouth opening disorder (Table 1).

### Assessment of TMD

For the diagnosis of TMD, the new diagnostic standard DC/TMD reported in 2014 [1, 4] was used. Patients who were initially assessed before 2014 were examined again accordingly. Through clinical interviewing, we noted the pain site and the problems it represented in daily life. We then performed a tenderness test on the masticatory muscles and temporomandibular joint. The DC/TMD tenderness test is specified at 1 kg/cm<sup>2</sup> for the masticatory muscle and temporal muscles and the mandibular condyle and at 0.5 kg/cm<sup>2</sup> for the lateral temporomandibular condyle and additional palpation sites [4]. The pressing time was 2 s for the purpose of detecting tenderness only and 5 s for detecting the presence or absence of related pain [4]. Using this method, the trigger point was identified. When crepitus was sensed on palpation, complementary imaging tests such as X-ray imaging were performed as necessary. Through X-ray examination, patients with other possible diseases such as hyperplasia of the mandibular coronoid process and Jacob disease were excluded [4, 5, 7] (Fig. 1). Maximum mouth opening capacity differs depending on the age and gender of each individual [4, 5,



**Fig. 1** Study design. CD/TMD Diagnostic Criteria for Temporomandibular Disorders. TMD with muscle symptom: temporomandibular joint patients with muscular symptoms. PBMT: photobiomodulation therapy

34–36]. Therefore, we established a 40-mm threshold, below which we diagnosed “limited opening” [4].

## Therapy sessions

Treatment included Amfenac sodium as pharmacotherapy (50 mg per day, 3 times a day after meals) [1, 2] for 1–2 weeks to treat acute symptoms. All patients took the drug for at least 1 week, and if the acute symptoms were severe, the drug was continued for an additional week. After the acute symptoms had eased in response to pharmacotherapy, trigger points were identified again in each patient [3–6, 8, 11, 17], and PBMT and mouth opening training were initiated. The patients were given instructions for self-care at home, including application of a hot compress to the area of muscle tenderness, information pertaining to tooth-contacting habit, and the mandibular resting position to prevent clenching.

One cycle of PBMT and mouth opening training was conducted per week, and the observation period was set at approximately 6 weeks, from the start of treatment to the completion of 4 treatment cycles to determine the effects of the treatment. Pain and maximum mouth opening capacity were measured before treatment (after acute symptoms had resolved in response to pharmacotherapy: Fig. 1 assessment

A) and after the completion of 4 cycles of PBMT and mouth opening training (Fig. 1 assessment B).

## Laser irradiation

A Takara Belmont CO<sub>2</sub> laser (wavelength; 10.6 μm, Bel Laser, Takara Belmont, CO. Ltd., Osaka, Japan) was used during all laser procedures. The laser irradiance conditions were output 1.5 W, on time 0.01 s, off time 0.05 s, and repeat pulse. The distance between the laser source and the skin was approximately 10 cm. The laser hand piece was moved in an elliptical pattern, and irradiation time was 3 min (approximately 56.9 J/cm<sup>2</sup>: Fig. 2a).

## Mouth opening training

After PBMT, muscle massage and stretching therapy were implemented as mouth opening training. Mouth opening training involved extraoral massaging of the areas of muscle contracture in the masseter, temporal, digastric, and sternocleidomastoid muscles (Fig. 2b, c) that were the trigger points in each patient, as well as stretching therapy to improve the flexibility of the temporomandibular joint (Fig. 2d). In stretching therapy, when the left temporomandibular joint was the affected side, the therapist’s left index finger was placed on the left mandibular molar area, the right index finger was placed on top of the tip of the left index finger, and the right thumb was placed on the left maxillary premolar area. Force was then applied straight down along the masseter muscle. These finger positions were reversed (inverted left to right) if the right temporomandibular joint was affected. These stretch therapies were performed with the patients in a relaxed position.

## Assessment of pain perception

A numeric rating scale (NRS) was used to assess pain before and after treatment. Patients used the scale to rate pain on a scale of 0–10, with 0 being no pain and 10 being the worst pain imaginable.

## Mouth opening

Maximum mouth opening capacity was measured in millimeters, as previously described [14–17]. Briefly, the patients opened their mouth as wide as possible, and the distance between the mesial corner of the maxillary right central incisor and that of the mandibular right central incisor was measured with calipers.

## Statistical analysis

These measurements were used to derive means (standard deviation), and the Wilcoxon signed-rank test was used to

**Table 1** List of patients. *TP* trigger point, *JD* Joint disk displacement, *OA* temporomandibular joint osteoarthritis. *M* masticatory muscle, *S* sternocleidomastoid, *D* digastric muscle, *T* temporal muscle

No.	Gender	Age	Site	TP	JD	OA	Before treatment		After 4 cycles	
							NRS	MMO	NRS	MMO
1	M	68	R	S	+	–	9	35	9	46.4
2	M	15	B	M, S	+	–	9	32	0	49.4
3	M	58	L	M	+	–	7	44.5	6	45.8
4	F	68	B	D	+	–	10	30.6	6	32
5	F	14	B	M, T	–	–	3	42.7	2	43.6
6	F	72	L	T, S, D	+	+	5	39.2	2	43.4
7	F	76	B	M	–	–	8	39.5	4	47.8
8	M	81	R	M, S	–	–	10	36.4	5	47.2
9	F	36	L	T	+	–	9	42.4	0	46.2
10	F	45	B	M, T, D	–	–	5	41.6	4	50.1
11	F	68	R	M, T	+	–	10	33.1	8	38.6
12	F	56	L	M, S	+	–	9	31.1	8	36.6
13	F	75	B	S, T	–	–	6	36.3	6	46.2
14	F	78	R	M	–	–	0	31.6	0	40.5
15	F	58	B	M, T	–	–	2	42.6	0	46.2
16	F	90	B	M, S	–	–	5	45.6	5	47.8
17	F	50	B	M, T, S	–	+	10	31.6	8	34
18	F	49	B	M	–	–	0	42.4	0	43.9
19	F	51	B	M, T, S	–	+	5	25	2	40.4
20	F	45	R	M	–	–	2	51.6	1	51.7
21	F	43	B	M, T, S	–	–	8	45.8	6	48.8
22	M	49	R	M	–	–	8	34.6	4	36.1
23	F	74	R	M, S	–	–	0	41.7	0	44.4
24	M	74	L	T, D	+	–	3	41.5	0	50
25	F	58	B	S, D	–	–	5	43.7	0	45.2
26	F	75	B	M, S	+	–	5	42.9	0	43.1
27	F	54	L	M, T	+	–	3	43	0	44.6
28	M	68	R	S	–	–	0	41.5	0	43.6
29	F	16	R	M	–	–	1	46.4	1	50.1
30	F	72	R	M, S	–	+	0	36.5	0	47.2
31	F	61	B	M	+	–	5	42.2	2	45.8
32	F	62	B	M	+	–	0	43.6	0	47.3
33	F	58	B	M, T, S	–	+	3	40.5	3	43.9
34	F	53	L	M, T	–	+	2	49.8	0	51.2
35	F	79	R	M	–	+	8	35.2	6	38
36	F	46	R	M	–	+	0	42	0	47

assess the significance of differences.  $P < 0.05$  was considered to indicate statistical significance.

## Results

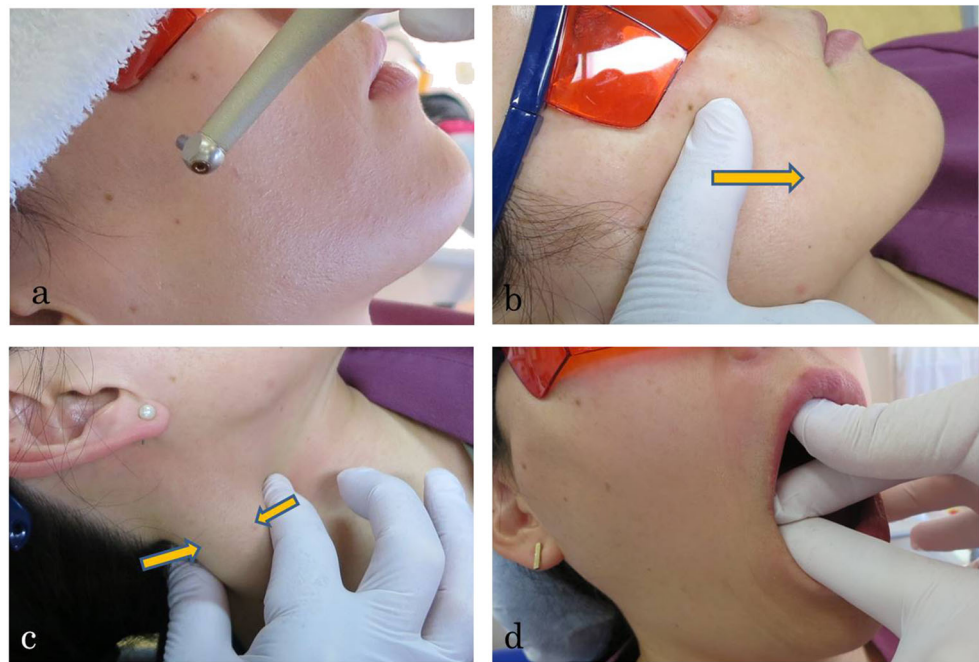
The symptoms of TMD had disappeared in 28 of the 36 patients (78%) after the 4 cycles of physical therapy. Symptoms resolved in all of the remaining 8 patients after an additional 2–5 cycles of PBMT and mouth opening training, and 4 of

these remaining 8 patients required splinting treatment to address tooth-contacting habit.

## Pain perception

The mean (SD) pain levels, as determined via NRS, were 4.9 (3.6) and 2.7 (3.0) ( $p < 0.001$ ) before and after four treatment cycles with physical therapy using PBMT and mouth opening training, respectively.

**Fig. 2** **a** Photobiomodulation therapy being applied to a trigger point. **b** Massage of the masseter muscle. **c** Massage of the sternocleidomastoid muscle. **d** Muscle-stretching therapy



## Mouth opening

The mean (SD) of MMO before treatment was 39.6 mm (5.9) and 44.6 mm (4.8) before and after 4 cycles of treatment with physical therapy using PBMT and mouth opening training, respectively ( $p < 0.001$ ).

## Discussion

In TMD, wrong timing when introducing physiotherapy muscle massage therapy or muscle-stretching therapy may worsen symptoms [8]. Furthermore, using a semiconductor laser for irradiation in patients may yield different results in patients depending on whether they are in the acute or chronic phase, and differences also exist on the maximum mouth opening capacity increase that could be achieved when comparing acute and chronic patients [14]. Therefore, we started pharmacotherapy first with Amfenac sodium to avoid starting treatment in the acute phase.

Sprinting treatment has been reported to be effective in preventing clenching and protecting teeth and temporomandibular joints; however, the effects are not constant according to the literature [1, 2, 8], and changes in occlusion such as open bite are feared [2]. Therefore, sprinting treatment was not administered as part of the initial treatment. In this study, only 4 patients whose symptoms did not improve with laser treatment and mouth opening training received sprinting treatment, and the symptoms improved after the sprint was attached. Considering these cases, factors such as clenching and tooth contacting habit (TCH) are significant, and splint therapy may be effective if clenching or TCH does not improve even after patient education.

For muscle massage therapy and muscle-stretching therapy, there is a method involving extraoral and intraoral application [8, 9]. However, in this study, as it is difficult for patients to maintain mouths opened, a method involving extraoral application was used. Considering that the CO<sub>2</sub> laser was of the tissue surface absorption type, irradiation was hindered in cases where hair was present, for example, when there was a trigger point in the temporal muscle. Therefore, laser irradiation was not performed on the temporal muscle, and only muscle massage therapy was performed.

Multiple clinical studies have investigated the use of tissue-penetrating semiconductor lasers [10–17], and they have also been the subject of basic research reports [18]. Clinical studies using semiconductor lasers in patients with TMD have reportedly yielded pain-relieving effects [10–17], increased maximum mouth opening [10, 14–17], anatomical changes including altered facial heights [15], and increased range of motion in left and right temporomandibular joints [16].

Peimani et al. [18] used a rat TMD model to investigate the effects of semiconductor lasers histologically in an irradiated group and a control group. They reported that although there was a significant increase in the number of inflammatory cells 3 days after treatment initiation, after 7 days of treatment initiation, there was a significant reduction of inflammatory cells. Furthermore, arthritis had improved in the irradiated group compared with the control group. The authors concluded that the treatment had exerted anti-inflammatory effects.

There are few published reports on the effects of tissue surface absorption CO<sub>2</sub> lasers in patients with TMD. In the present study, we observed both pain reduction and an increase in maximum mouth opening capacity, as has been reported after semiconductor laser treatments [11–17]. Makihara et al. [22] used a

Doppler flowmeter to measure vascular diameter and blood flow before and after irradiation of the temporomandibular joint with CO<sub>2</sub> PBMT. They reported increased vascular diameter and blood flow on the irradiated side 10 min after irradiation compared with before irradiation. They also reported an increase in blood flow compared with the contralateral side. There may have been changes in blood flow in the maxillofacial area due to the CO<sub>2</sub> PBMT, with muscle tension relief and pain relief effects achieved in the early stage of PBMT. These may have facilitated smooth muscle movement and efficient mouth opening training. Therefore, we believe that CO<sub>2</sub> PBMT and mouth opening training play a role as a conservative treatment option for TMD.

Regarding the pain relief effect of lasers, there are many and very few reports of semiconductor [23–25, 28, 29] and CO<sub>2</sub> laser, respectively. As a CO<sub>2</sub> laser is mostly absorbed on the tissue surface [22–33], it is not considered to cause a direct pain-relieving effect but rather to have a secondary effect, such as increased blood flow [22]. Nevertheless, the irradiation method called NACL T or NTCL T, which also use CO<sub>2</sub> lasers, has been reported to have a pain-relieving effect [31–33], so the possibility of analgesic relief for temporomandibular disorders cannot be ruled out.

Prior to this study, the authors exacerbated the pain of a few patients with peak pain in the acute phase when they were CO<sub>2</sub> laser-treated without drug administration. It was considered that this was due to hypersensitivity and increased blood flow at the time of inflammation [6], and the nerves were pressed because the increased blood flow was promoted [22]. For that purpose, all patients were given pharmacotherapy during the acute phase.

Moreover, the semiconductor laser can irradiate the temporal muscle region even with hair present [23–25, 28, 29], but it is difficult to irradiate the same region with a CO<sub>2</sub> laser [22–33]. This is a drawback of tissue absorption lasers such as CO<sub>2</sub> lasers.

In this study, there is one treatment arm which received a combination of three treatment modalities, including pharmacotherapy, stretching therapy, and laser therapy. The combination of all treatment modalities into one treatment arm precludes us from differentiating the individual effect of each [19–21, 37, 38]. Moreover, we cannot rule out the placebo effect. As this study did not divide the participants into four groups (placebo [no treatment], opening training only, PBMT only, and PBMT and opening training), it was not possible to clarify the effect of each of PBMT and opening training [3, 19–21, 37, 38]. Further research is needed in the future.

## Conclusion

The present findings suggest that CO<sub>2</sub> PBMT combined with mouth opening training is effective for the treatment of TMD.

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## Compliance with ethical standards

Since verbal informed consent for treatment and publication of anonymized data of this study was obtained and registered in their corresponding medical charts, ethics committee approval was not obtained. However, all procedures were carried out in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

**Conflict of interest** The authors declare that they have no conflict of interest.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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