Chapter

Management of Bell's Palsy with Phototherapy

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Abstract

Bell's palsy (BP) is a common condition; its incidence rate has increased during the COVID-19 pandemic. The standard treatment for facial nerve palsy includes corticosteroids alone or in combination with antiviral agents. However, the treatment is contraindicated in some patients, including hypertensive or diabetic patients. Also, the medication combination may result in inadequate recovery when complementary and alternative approaches are indicated. This chapter reviewed the literature on managing BP with different types of photobiomodulation (PBM) therapies. Fourteen papers were included. The results show that despite the different kinds of photo energy used, varying laser parameters, and the heterogeneity of patients, the outcome of PBM was similar among studies. Of interest is that acute and subacute BP respond more favorably to PBM than chronic cases. Hence, it is suggested to apply PMB as a complementary treatment in the early stage of the disease to enhance the recovery rate of BP patients. However, the risk of bias in these studies was relatively high. Therefore, further randomized, double-blind placebo-controlled studies are needed to determine the effectiveness of PBM in treating BP.

Keywords: bell's palsy, facial paralysis, low-level laser therapy, infrared laser, phototherapy, COVID-19

1. Introduction

Bell's palsy (BP) is a common condition presented to physicians. It affects 23 people in every 100,000 yearly, and one in every 60–70 people will develop BP in their lifetime [1]. It is the most common acute facial lesion that unilaterally affects the facial nerve. It occurs when the facial nerve is swollen or compressed within the facial canal. The compromised facial nerve results in an array of symptoms, including temporary weakness or paralysis in the facial muscles, difficulty in mastication, loss of taste, drooping eyelid or corner of the mouth, drooling, poor closure of the eye, and pain in the auricular area. With an acute onset, the symptoms can develop within 72 hours and gradually resolve within weeks or months [2, 3]. However, around 30% of patients may not fully recover and experience residue dysfunction [2, 4].

1.1 Etiology of Bell's Palsy

With the exact cause of BP remaining unclear, a recent review summarized five potential clinical etiologies of this condition [5]:

- Anatomical difference – A smaller diameter of the internal acoustic meatus and facial canal and a thicker facial nerve are observed in BP patients [6, 7]. These anatomical differences may be a predisposing factor to facial nerve entrapment.

- Viral infection - Herpes-simplex virus type-1 (HSV-1) is commonly found in BP patients. The reactivation of the HSV-1 in latently infected patients can induce demyelination and degeneration in the facial nerve [8–10]. Besides the infection of HSV-1, an increased incidence rate has been noticed during the coronavirus infectious disease 2019 (COVID-19) pandemic. Several recent studies have discussed the potential causal relationship between vaccination or COVID-19 infection with BP [11–13].

- Autoimmune reaction – Autoimmune reaction is regarded as a possible etiology of BP, as a significantly high level of neutrophil-to-lymphocyte ratio (NLR) and pro-inflammatory cytokines level are detected in BP patients. Also, the autoimmune reaction can induce facial nerve demyelination [14, 15].

- Ischemia - Vasospasm in the stylomastoid artery may be another underlying risk in causing BP. Vasospasm induces ischemia, which can lead to periarteritis and obliterative endarteritis, which in turn can induce facial nerve sheath fibrosis, strangulating the nerve [16].

- Cold stimulation responsivity - The incidence rate of BP is higher in cold seasons [17, 18]. The subcutaneous fat may react to climate change, inducing the immune-inflammatory response and leading to acute facial nerve demyelination [19, 20].

However, the actual cause of BP remains unknown and requires further studies [5].

1.2 Relationship between COVID-19 and Bell's Palsy

Besides the unknown etiology of BP, a statistically significant higher incidence of BP is observed in 2020 compared to 2019. The increased incidence is associated with the COVID-19 pandemic [21]. A systematic review showed significant evidence that BP is the only major neurological manifestation in COVID-19 patients [12]. Another systematic review conducted by the same authors reviewed 46 COVID-19 cases. Around 70% of the cases showed complete recovery from BP symptoms, while over 20% of them had residual symptoms after combination treatment, mainly of corticosteroids and antiviral drugs [11]. Although the evidence of BP being the major neurological symptom in COVID-19 is significant, further studies are required to identify how the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) exactly causes the neurological symptoms [11, 12].

Along with a higher risk of developing BP with COVID-19 infection, BP has also been recognized as a common adverse event after COVID-19 vaccination. A systematic review recognized BP as one of the most common adverse events after mRNA and viral vector-based immunization [13]. In addition, a study in Hong Kong reported a significantly increased risk of Bell's palsy following the vaccination of inactivated SARS-CoV-2 vaccine but not the mRNA vaccine [22]. However, another systematic review, which studied 61 vaccinated patients immunized with different vaccines, reported that more than half of the cases developed BP after vaccination. Interestingly, BP only occurs in patients who received mRNA and viral vector-based vaccines but not in inactivated SARS-CoV-2 vaccines [23].

Both COVID-19 and COVID-19 vaccination are suspected to be a potential cause of BP. However, the relationship between COVID-19 and COVID-19 vaccine on BP has yet to be determined and requires further investigation.

1.3 Prognosis

The current standard treatment for BP includes corticosteroids alone or combined with antiviral agents, although the condition is considered idiopathic. However, different studies reported conflicting results [3]. Some studies reported inadequate recovery from the treatments [24]. Around 70% of BP patients will recover spontaneously without treatment; 10–29% of patients will have persistent dysfunction in the facial nerve [24] with an 8% recurrence rate for those who had previous episodes of BP [3].

Comparing the standard treatment of corticosteroids alone or in combination with antiviral agents, the effects of corticosteroids alone are found to be no different from placebo [25], while a higher rate of full recovery is observed with the use of antiviral drugs in combination with corticosteroids [24]. The recovery rate of using corticosteroids alone was reported to be 67% while that of the combination treatment was 78% [24]. A randomized controlled trial (RCT) indicated that when the medical treatment was delayed for more than 4 days after the onset of symptoms, the treatment has no benefit to the patients [26].

However, the treatment of corticosteroids and antiviral agents is contraindicated in some patients (e.g., hypertensive or diabetic patients) [27]. Alternative and complementary therapies may thus provide other options.

Along with the standard treatment, physicians have been using other therapeutic methods, for instance, electrical stimulation, facial exercise, massage [28], acupuncture [29], and photobiomodulation (PBM) as supplementary treatments. While the effects of electrical stimulation, facial exercise and massage were insignificant [28], acupuncture treatment potentially showed some benefits in patients with BP [30]. However, exercises, electrical stimulation and acupuncture are not recommended to be used in patients with acute BP in several clinical guidelines due to the lack of good quality evidence [29].

1.4 Role of Photobiomodulation in Bell's Palsy

Among these complementary therapies, PBM is a non-invasive treatment, which has been investigated in recent years for its effect in treating BP. Of the different types of PBM, low-level laser therapy (LLLT) has been the most studied; it is effective in regenerating peripheral nerves in the preclinical study [31]. Our study investigates whether sufficient evidence supports PBM treatment in BP patients.

2. Materials and methods

Papers were searched in PUBMED, using the Boolean search operators ("Laser" AND "Bell's Palsy," "Laser" AND "Facial Palsy," "LLLT" AND "Bell's Palsy," "Infrared" AND "Bell's Palsy"), covering the year 2012 to June 2022. All titles were then screened for relevancy. Non-English articles are excluded. We include only studies conducted on humans. All types of clinical studies evaluating the effectiveness of phototherapy are included, including case reports, case series, prospective studies, and controlled clinical trials. A manual search was also undertaken from the references of the selected papers.

3. Results

We have identified fourteen relevant papers covering the use of phototherapy in the management of Bell's Palsy, including four RCTs [28, 32–34], one prospective study [35], one case series [36], and eight case reports [29, 37–43], which we review.

Our review shows that the most studied PBM is LLLT [28, 32, 33, 35, 37, 39, 40, 42, 43]. Others include high-intensity laser therapy (HILT) [29, 32, 36, 41], monochromatic infrared energy (MIRE) [38] and laser acupuncture [34]. Rubis [41] combined PBM with cervical manipulation. Alayat et al. [32] compared the effectiveness of HILT and LLLT combined with facial massage and exercise. Ordahan and Karahan [33] studied the effect of LLLT on top facial exercises. Kuzmičić et al. [29] combined HILT with acupuncture and mirror book therapy, and Shoman et al. [28] compared LLLT with electrical stimulation.

Most subjects were adults, except for a case report on a pediatric patient [37] and two case reports on adolescents [40, 42]. We categorized the papers into acute, subacute, chronic, and unspecified, according to the time patients received PBM treatments. We defined "acute" as onset within 1 week of consultation, "subacute" as one to 12 weeks, and "chronic" as cases that present for more than 3 months. We found different laser protocols were used in the studies. The number of treatments varies, from as few as two to 45. Most studies last 6 weeks, and PMB treatment was performed three times a week. Laser parameters, including wavelengths, power, power density, frequency, and energy density, also differed vastly among studies. Most studies utilized House-Brackmann Scale (HB Scale) as an outcome measure. It is a facial nerve grading system that grades upon functional impairment, ranging from I (normal) to VI (total paralysis) [44]. Facial Disability Index (FDI), a patient-rated outcome measure, was also commonly used to assess the functional disability and quality of life in patients with facial palsy [45]. The more recent studies utilized the Sunnybrook Facial Grading System (SB System), a physician-graded scale, which includes the synkinesis section. The scale permits recognition of minor improvements in the range of movement, thus helping quantify the progress feedback to patients [46]. Other outcome measures included electromyography and nerve conduction study. Please refer to the table in **Appendix 1** for detailed characteristics of the included papers.

Despite the different types of photo energy used, marked varying laser parameters, and the heterogeneity of the patients, the outcome of laser treatment was similar among the studies.

4. Discussion

A review of the search results showed that acute and subacute Bell's palsy respond favorably to PBM [32, 33, 37–42]. Chronic Bell's palsy, however, responds less satisfactory [34, 36, 38]. Therefore, PBM seems to be a good complementary treatment to the standard treatment with medication. A RCT by Shoman et al. [28] compared the effectiveness of LLLT with electrical stimulation in conjunction with medicine, facial massage, and exercise. Results showed that combination treatment with LLLT was more efficient than electrical stimulation in facial nerve regeneration, as determined by the nerve conduction velocity measurement and SB System scoring [28]. Several studies also recruited patients non-responsive to steroids and antivirals to investigate their response to PBM treatment [29, 36, 38]. Aghamohamdi et al. [35] studied 30 poorly controlled diabetic patients who did not receive other medications for the palsy, especially corticosteroids, due to their underlying disease. The results showed complete recovery in 18 patients (60%) and partial recovery in 6 patients (20%) [35], showing that LLLT could be a safe alternative approach for BP patients with other medical condition that is contraindicated to traditional medication treatment. However, more studies are warranted to justify its effectiveness.

4.1 Mechanism of actions

PBM involves the application of red and near-infrared light, with wavelengths ranging from 600 to 1000 nm, over the area of injury or lesion. It is a non-invasive and painless therapy for patients contraindicated to corticosteroids or antiviral medication treatments [32]. PMB has anti-inflammatory effects. Light absorbed by cellular photo-receptors modulates reactive oxygen species (ROS) and promotes adenosine triphosphate (ATP) formation. Moreover, it increases micro and macro-circulation, thus increasing tissues' oxygen saturation. These improve cellular metabolism and promote faster regeneration or proliferation of the damaged tissue [47]. Furthermore, PBM can photo-dissociate the nitric oxide, which inhibits mitochondrial respiration, thus reversing mitochondrial inhibition [48]. Through these mechanisms, PBM thus dilates blood vessels, improves oxygenation, and increases immune cell traffic to the targeted structure [49].

Also, laser therapy is shown to have direct beneficial effects on the regeneration of peripheral nerves in sensory and motor deficits, such as trigeminal neuralgia, herpes zoster, and sciatica. The therapy improves the recovery of injured nerves, slows motor neuron degeneration, and promotes axonal growth and myelination. The treatment can also lower the pro-inflammatory cytokine level and raise the anti-inflammatory cytokine level [32, 35, 40]. In addition, evidence shows that the HSV-1 can be effectively suppressed by PBM [50]. Laser therapy is also found to affect tissues differently depending on the prescribed wavelengths, pulse duration, energy density, delivery system, and duration of the whole treatment [32].

4.2 Parameters of PBM treatment

Of interest is that Bell's palsy responds to light therapy with vastly different parameters, which include wavelengths, power, power density, frequency, and energy density (**Appendix 2**). The wavelengths used in the different studies vary

from 660 nm [37, 43] to 1064 nm [29, 32], with most of the studies using lasers with a wavelength of 830 nm [32, 33, 42]. Also, the power of the laser used differs significantly, with some using low-level laser with a power lower than 500 mW [33, 35, 42, 43] while others use high power laser (up to 3 kW) [32]. The energy density of laser applied in different studies also varies widely, from 10 J/cm^2 [32, 33, 37] to 120 J/cm^2 [39].

Existing evidence suggests that LLLT acts on the mitochondria and cell membrane chromophores to initiate the biological response [51]. Studies have suggested the possibility of using defined wavelengths for particular biological responses, hence achieving specific therapeutic effects [52, 53]. Barbosa et al. [52] compared the effects of LLLT at 660 nm and 830 nm on sciatic nerve regeneration following crushing injuries in rat models. They found that laser at 660 nm provided early functional nerve recovery compared to other groups. Another animal study by Lee et al. [53] also showed that rats with facial nerve injuries responded positively to 633 nm light, with better facial palsy scores, larger axon diameter, and higher expression of Schwann cells, but not to 804 nm light. One of our included studies used a laser at 780 nm during the early stage of treatment, aiming for a deeper penetration [37]. Starting from the fifth session, they changed to a wavelength of 660 nm to accelerate neural recovery. Alternating the two wavelengths was suggested to balance the stimulatory and inhibitory effects and avoid plateau situations due to extended use of a single wavelength [37]. However, the standardization of laser wavelength has yet to be defined, as our review showed that BP patients respond positively to different wavelengths.

One study showed that HILT is significantly more effective than LLLT in improving the symptoms of Bell's palsy [32]. In addition, HB Scale and FDI improved more with the HILT than with LLLT [32]. Kuzmičić et al. [29] reported a case of Bell's palsy, which was treated medically with corticosteroid and antivirals 18 months prior with minimal improvement. They employed HILT, acupuncture, and mirror book therapy to treat the patient for 7 weeks. Mirror book therapy is an adapted version of the mirror box method used to treat phantom pain and paralysis. It consists of a bi-fold mirror to reflect twice the unaffected patient's face so that the patient sees a full, unaffected face. The patient then performs a series of facial exercises. The intervention resulted in significant improvement of the facial palsy. The HB Scale reduced from IV to II, the SB System improved from 24/100 to 71/100, and the FDI improved from 43/200 to 173/200 [29]. The latter study did not compare the effects of HILT with LLLT. Also, the combination therapy makes it difficult to draw conclusions relating to the effectiveness of HILT in chronic Bell's palsy. Thus, whether HILT is superior to LLLT in managing Bell's palsy requires further investigation.

4.3 Irradiation area

Apart from the different parameters of the laser applied, the treatment method differed in various studies. Six studies used the laser on seven to nine points (**Figure 1**) along the facial nerve branches of the affected side [28, 32, 33, 35, 36, 41]. A laser is applied near the mastoid process in the stylomastoid foramen, where the facial nerve exits. Also, light is used on points along the facial nerve branches, including the temporal branch across to forehead, the zygomatic branch along the zygomatic arc, the buccal nerve in the middle portion of the cheek, and the mandibular branch along the chin [35, 41]. Ton et al. [34] applied lasers on the acupuncture points; seven were on the affected face, covering all the facial nerve branches, while two were on both sides of the extremities. Other than facial nerve branches, some studies irradiate

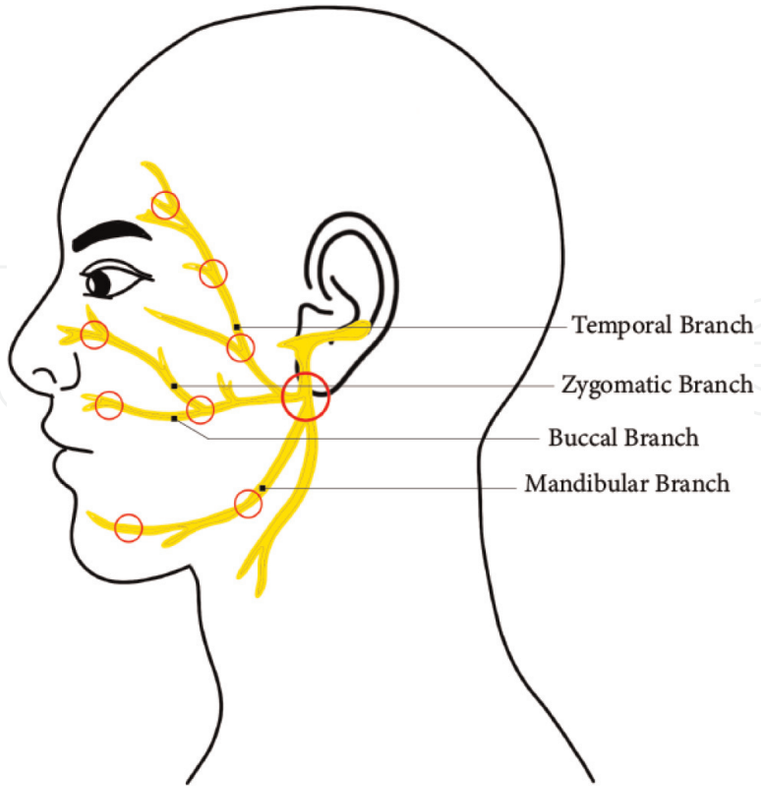

Figure 1.
Common laser application points along the facial nerves.

the facial muscles. Tanganeli et al. [39] applied laser on ten points, including the frontal, temporal, zygomatic, buccinator, lip elevator, orbicularis of the lips, lip depressor, and masseter muscles. Poloni et al. [42] only applied laser at the origin and insertion of the masseter muscle, and Fornaini et al. [40] also irradiated only the parotid gland area about the former. Bernal Rodriguez et al. [43] and Fontana and Bagnato [37] applied laser on 59 points and up to 80 points, respectively, covering all the area on the affected face. The treatment was applied to many application points because the laser beam spot is small [37, 43]. In Ng and Chu's [38] report, the four pads for MIRE therapy were placed in the post-auricular area, pre-auricular area, the temple, and the mandibular area of the affected side.

While laser therapy at the site of compression in the facial canal is understandable, the same applied over the peripheral nerve branches and muscles over the face requires further justification. Moriyama et al. [54] observed a change in gene expression in BP with the degree of facial nerve palsy. Most genes in energy and muscle categories of severe BP (HB Scale V) were downregulated, while they were upregulated in moderate BP (HB Scale III). The facial nerve conduction is largely abolished in severe BP, hence there is very little regeneration and energy production in the affected muscles and nerves [54]. This may partly explain the total or partial unresponsiveness of patients to medication [36]. On the basis of these molecular biological findings, treatment to promote muscle regeneration and energy production is hence considered. Given the ability of PBM to improve cellular metabolism and promote ATP formation [47], irradiation of the affected facial muscles and nerve branches could potentially improve the muscle regeneration and enhance the paralytic condition. Further investigations are required to compare the effects of PBM on different irradiation areas.

4.4 Timing of treatment

Also of interest is that the outcome of chronic cases is less favorable than acute and subacute cases. Ng and Chu [38] described a chronic BP case that only partially responded to MIRE. The 46 years old lady with systemic lupus erythematosus and BP for two and a half years was treated by MIRE. After 45 treatment sessions, the patient reported 50% improvement compared with baseline. Residual facial palsy was still evident [38]. Pasquale et al. [36] reported similar findings; the researchers applied HILT to a cohort of 14 patients who were non-responsive to standard treatments. The number of treatments varied from 6 to 20. Of the fourteen patients, eleven who had subacute BP improved uneventfully. However, three patients with chronic BP did not improve [36]. Similarly, Ton et al. [34] showed that LLLT did not improve chronic Bell's palsy. Seventeen chronic BP patients were randomized to treatment by laser acupuncture and sham laser. The patients were treated three times a week for 6 weeks. The outcome was measured by HB Scale, FDI, and SB System. Results showed that only HB Scale improved slightly after 3 weeks of laser acupuncture treatment compared to sham laser treatment. No significant differences were detected for HB Scale and FDI at 6 weeks between the intervention group and the sham laser treatment group [34]. One study, however, showed that LLLT improved the symptoms of chronic BP [43]. The female patient had 8 years of history of BP. LLLT treated fifty-nine points on the face of the affected side; each point was treated for 20 seconds, with 4 J per point. The patient was treated three times a week for 8 weeks. After the treatment, the HB Scale was reduced from IV to II, suggesting a partial response to LLLT [43]. Kuzmičić et al. [29] reported a chronic BP responding to combination therapy of HILT, acupuncture, and mirror book therapy.

As the outcome of these studies on chronic BP differs significantly, with some reporting favorable outcomes and others minimal changes, the use of laser therapy in chronic BP remains undetermined.

Clinically, we suggest combining phototherapy with the standard treatment to manage acute and subacute cases. Medical practitioners can refer patients to other healthcare practitioners for PBM treatment while prescribing the medications. Though chronic BP does not respond as reliably as acute and subacute cases, they should be treated for three to 6 weeks by LLLT, as some patients may respond favorably to the treatment [43]. As we are unaware of any studies on the effects of PBM on BP caused by COVID-19, we cannot provide any recommendations. However, we consider the method worth trying, particularly when the medication treatment is contraindicated.

4.5 Possibility of self-administered PBM

PBM treatments are time-consuming [55]. Clinical practice usually requires patients to return for short treatment sessions about three times a week to achieve a satisfactory result. Although laser treatments administered by trained professionals were shown to be good options for accelerating the recovery of BP [56], several studies have proposed the use of "at home" PBM devices [40]. One study prescribed a patient with a self-administered class II laser device, emitting at 808 nm and 250 mW output power, to be used twice daily, each for 15 minutes [40]. The patient simply placed the device in contact with the skin on the designated areas. After 2 weeks of treatment, the patient reported a complete recovery (HB Scale improved from IV to I) [40]. Another study reported the effects of MIRE, an array of 60 gallium aluminum

arsenide light-emitting diodes, on patients with BP; it showed positive results, especially in acute patients [38]. The pads of this MIRE device could irradiate a larger area at one time compared with an infrared laser, hence reducing the need for accurate localization of facial nerve [38]. In both studies, no adverse events were reported for the devices used, and protective glasses are unnecessary, making them more favorable for self-application [38, 40]. Nevertheless, patient evaluation by practitioners before its use remains mandatory.

4.6 Contraindications and adverse effects of PBM

Phototherapy is a generally safe and non-invasive treatment. Yet, the North American Association for Laser Therapy Conference 2010 issued cautionary statements and stipulated several contraindications [48]. The operator must not point the laser beam at the eyes, and all participants in the treatment should wear appropriate safety spectacles. Practitioners must pay extra attention while operating the device as a low frequency pulsed visible light of less than 30 Hz may trigger a seizure in photosensitive and epileptic patients.

Also, it is recommended not to apply light therapy on any known primary carcinoma or secondary metastasis site, as its effects on cancer have not been elucidated [48]. Animal studies have shown PBM can be detrimental to cancer. However, other studies have shown that PBM benefits cancer treatment. It can directly damage the tumor, enhance the effects of cancer therapies, stimulate the host immune system, and increase cancer patients' survival rate [57]. In addition, if the patient is receiving chemotherapy or is defined as terminally- ill, PBM can be used to relieve the side effects of treatment and for palliative relief [48].

The evidence on the use of LLLT on cancer is limited. However, practitioners should be aware of this in the management of BP. If the patient is suffering from BP and has a known medical history of cancer somewhere else in the body, other than directly on the face, we would still consider treating the patient with LLLT. The adverse effects of the PBM are reported to be no different from placebo treatment [48].

5. Limitation of the study

Although there is an increasing number of studies investigating the effects of PBM in treating BP, the number of research in this area is still limited, and the risk of bias in these studies is relatively high. Therefore, further randomized, double-blind placebo-controlled studies are required to determine the effectiveness of PBM in treating BP, including those that are COVID-19 related.

6. Conclusion

The results of the included studies suggest that phototherapy may be a safe and promising treatment to be used in conjunction with standard medication. Earlier implementation of phototherapy could enhance the recovery rate of Bell's palsy patients. However, further high-quality studies are needed to determine its effectiveness and establish a standardized treatment protocol for this treatment option.

Conflict of interest

The authors declare no conflict of interest.

Abbreviation

BP	Bell's palsy
PBM	Photobiomodulation
LLLT	Low-level laser therapy
HILT	High-intensity laser therapy
MIRE	Monochromatic infrared energy
HB Scale	House-Brackmann Scale
FDI	Facial Disability Index
SB System	SunnyBrook Facial Grading System
HSV-1	Herpes-simplex virus type-1
NLR	Neutrophil-to-lymphocyte ratio
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
ROS	Reactive oxygen species
ATP	Adenosine triphosphate
NO	Nitric oxide
RCT	Randomized controlled trials

A. Appendices

Stage	Paper	Study design	Sample (Patient no.; age)	Treatment	Number of sessions	Outcome measures	Outcome
Acute	Fontana and Bagnato [37]	Case report	1; 3	LLLT	11 in 3wks (4/wk. in first 2 wks)	HB Scale	Improved from Grade 5 to 1
	Ng and Chu [38]	Case report	1; 32	MIRE	19 in 6wks (daily in first 2 wks, except weekend; 3rd-5th wk., 2/wk.; after that 1/wk)	Clinical presentation	95% improvement, with mild weakness in the closure of left eyelid; Complete recovery 8 months after last treatment
	Tanganeli et al. [39]	Case report	1; 71	LLLT	10 in 6.5wks	HB Scale	Improved from Grade 5 to 1
	Fornaini et al. [40]	Case report	1; 15	"At-home PBM" class II laser	Twice a day for 2wks	HB Scale	Improved from Grade 4 to 1
Subacute	Rubis [41]	Case report	1; 40	HILT + cervical manipulation	2 in 4 days	HB Scale	Improved from Grade 5 to 1
	Alayat et al. [32]	RCT	48; 43 ± 9.8	1. HILT + facial massage and exercise 2. LLLT + facial massage and exercise 3. Facial massage and exercise	18 in 6wks (3/wk)	FDI and HB Scale	Both HILT and LLLT are more effective than the control group, with HILT showing greater improvement
	Ordahan and Karahan [33]	RCT	46; 41 ± 9.7	1. LLLT + facial exercise 2. Facial exercise	18 in 6wks (3/wk)	FDI	Combined treatment with LLLT and facial exercise therapy significantly improved FDI compared with exercise alone
	Poloni et al. [42]	Case report	1; 13	LLLT	3 in 3wks	Clinical presentation	Total recovery without recurrence after 3 years
Chronic	Ng and Chu [38]	Case report	1; 46	MIRE (Previous treatment with corticosteroid and electro-acupuncture)	45 in 9.5mths	Clinical presentation	50% improvement; condition was stable 5 months after last treatment with mild synkinesis
	Bernal Rodriguez et al. [43]	Case report	1; 25	LLLT	24 in 8wks (3/wk) Phase 1: 18; Phase 2: 6	HB Scale and electroneur-omyography	Improved from Grade 4 to 2; The amplitude of motor conduction velocity improved

Stage	Paper	Study design	Sample (Patient no.; age)	Treatment	Number of sessions	Outcome measures	Outcome
	Pasquale et al. [36]	Case series	14; 56.07 ± 15.21	HILT (Non-responsive to standard treatment of corticosteroid and acyclovir)	From 6 up to 20; Every 2 days until complete resolution	HB Scale	11 patients, with BP max. of 6 months, completely recovered. The remaining 3 patients with BP for years show no improvement.
	Ton et al. [34]	RCT	17; 1. 37.83 2. 47.75	1. Laser acupuncture 2. Sham laser	18 in 6wks (3/wk)	FDI, HB Scale, SB System, stiffness scale	A significant difference in HB score, borderline significance in SB and stiffness score, and no significant difference in FDI
	Kuzmičić et al. [29]	Case report	1; 30	HILT + acupuncture, mirror book therapy (Non-responsive to corticosteroid, facial exercises, and electrostimulation)	19 (3/wk. for 3wks, then 2/wk. for 5wks)	HB Scale, SB System, FDI	Improvement in all outcome measures HB Scale: 4/6 to 2/6 SB System: 24/100 to 71/100 FDI: 43/200 to 173/200
Un-specified	Aghamohamdi et al. [35]	Prospective study	30; ∼40	LLLT	12 in 4wks (3/wk)	HB Scale, electromyography, and nerve conduction study	Complete recovery in 18 patients and partial recovery in 6 patients after 3 months.
	Shoman et al. [28]	RCT	45; ∼33	1. LLLT + medication, massage, facial exercise 2. ES + medication, massage, facial exercise 3. medication, massage, facial exercise	12 in 6wks (2/wk)	Nerve conduction study, SB System	LLLT is more efficient than ES in facial nerve regeneration for Bell's palsy patients.

LLLT, low-level laser therapy; HILT, high-intensity laser therapy; MIRE, monochromatic infrared energy; PBM, photobiomodulation; ES, electrical stimulation; HB Scale, House-Brackmann Scale; FDI, Facial Disability Index; SB System, SunnyBrook Grading System; BP, Bell's Palsy.

Appendix 1.
The interventions and outcome measures of included studies.

Stage	Paper	Type of photo-energy	Wavelength (nm)	Output power (mW)	Energy density (J/cm^2)	Treatment
Acute	Fontana and Bagnato[37]	LLLT	660 and 780	40–70	10–17.5	Up to 80 points; 15–30 min; 10 s/point
	Ng and Chu [38]	MIRE	890	60 mW/cm^2	108	40mins
	Tanganeli et al. [39]	LLLT	808	100	120 (3.3 J/point)	10 points, 10 s/point
	Fornaini et al. [40]	"At-home PBM" class II laser	808	250	48	Twice a day, each of 15mins
Subacute	Rubis [41]	HILT	910	Up to 100,000	47.6 x 10 J	17mins; 30–60s/point
	Alayat et al. [32]	HILT	1064	Up to 3 kW	10	8 points; 7 s/point
		LLLT	830	100	10	8 points; 125 s/point
	Ordahan and Karahan [33]	LLLT	830	100	10	8 points; 2mins/point
	Poloni et al. [42]	LLLT	830	100	100	2 points; 28 s/point
Chronic	Ng and Chu [38]	MIRE	890	60 mW/cm^2	108	45mins
	Bernal Rodriguez et al. [43]	LLLT	660 and 808	200	Phase 1: 40.65 Phase 2: 60.97	59 points; Phase 1: 20s Phase 30s
	Pasquale et al. [36]	HILT	808	1000	60	7 points; 60 s/point
	Ton et al. [34]	LLLT (Laser acupuncture)	810	Up to 150	45	9 points; 40/80s for local/distal acupuncture points
	Kuzmičić et al. [29]	HILT	1064	7000	80	—
Unspecified	Aghamohamdi et al. [35]	LLLT	980	334	5 J/point	9 points; 1 min/point
	Shoman et al. [28]	LLLT	850	1 W/cm^2	_	8 points; 1 min/point

Appendix 2.
Laser parameters of the included studies.

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