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The Effects of Phototherapy of an 808 nm Diode Laser on Bone Fracture

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Abstract. [Purpose] This study investigated the effects of low-level laser phototherapy on hand and forearm fractures. [Subjects and Methods] This was a one-group pretest-posttest design study. We recruited 9 patients with hand or forearm fracture, and they received diode laser treatment (808 nm, 10 Hz, 60 mW). Evaluation of pain on a visual analog scale (VAS) and radiographic assessments were made pre-intervention, post-intervention, and at two weeks of follow-up. [Results] There were significant differences in VAS scores between pre-intervention and post-intervention and between pre-intervention and 2 weeks of follow up. In the radiographic assessment, the percentage of detectable cortical bridging also increased significantly after phototherapy. [Conclusions] We consider that low-level laser phototherapy is effective for human bone healing and pain relief.
Key words: Phototherapy, Bone healing, Visual analog scale

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INTRODUCTION

Non-displaced or other relatively stable types of hand or forearm fracture are often managed with splinting or conservative treatment to support the bone healing[1)]. For patients with fractured hand or forearm who do not receive operational fixation, their rehabilitation goals are usually maintenance of range of motion, reduction of edema, promotion of bone healing, and reduction of pain[1)]. Generally, conservation treatments for non-open fractures of the hands are mainly conducted with casts, plastic splints, and medication. Such treatments cause few aggressive involvements at the fracture areas. Thus, orthopedists endeavor to search for other suitable treatment methods or tools, e.g. phototherapy, and ultrasound. Low-level laser therapy has been suggested for clinical use as a phototherapeutic method in rehabilitation[2)]. Many animal and cellular studies have shown that low-level laser phototherapy has a positive effect in bone cells, but its effects on clinical use have rarely been studied[3–5)]. Moreover, no treatment protocols for low-level laser phototherapy for fractures have been reported. Hence, we conducted this study to clarify the effect of applying a low-level laser phototherapy to hand and forearm fractures.

SUBJECTS AND METHODS

The study procedure was a one-group pretest-posttest design, and it was approved by the Institutional Review Board on Human Subjects Research of Da-Chien Hospital. The volunteers were nine patients of the Department of Orthopedics of our hospital. The inclusion criteria were patients with hand or forearm fracture who did not receive surgery. The volunteers were recruited from July 2010 to August 2011, and their fractures were classified according to the gradation of fracture classification of the Orthopaedic Trauma Association (OTA)[6)]. Each volunteer patient was provided with a laser instrument as a therapeutic home device. The low-level laser instrument (LA-400, United Integrated Service Co., Ltd., Taiwan) emitted light beams of 808 nm (10 Hz, 60 mW). The laser dosage was 12 J/cm^2, and the laser was used to directly irradiate the skin of the fracture site. After determining the fracture site by X-ray and completion of the clinical assessments by physicians, the researchers taught the patients the suitable exposure site for the laser, and how to operate the laser instrument at home. The laser head has an air-removal apparatus, and it was used to fix the laser above the fracture site. In addition, the laser instrument was equipped with a timer, so that it would automatically turn off the laser after ten minutes, and issue an audible signal to alert the patient to when the treatment course was finished. Each patient applied the low-level laser once a day, five days per week, and each treatment course continued for two weeks.

Assessments were made pre-intervention, post-intervention and at two weeks of follow-up. Pain was assessed on a visual analog scale (VAS), which was a calibrated scale ranging from zero (no pain) to ten (the worst imaginable pain). We also took X-rays to examine the healing progress. The fracture sites of patients were evaluated by a digital imaging system (Nu Film Versions 4.05, Thinking System

Table 1. Characteristics of the 9 patients with fractures

Subject	Sex	Age	Onset (days)	Diagnosis	OTA classifications
Case 1	male	70	5	R 5th metacarpal fracture	77-A1.1
Case 2	male	20	2	L radial fracture	23-A2.1
Case 3	male	25	4	R radial fracture	23-B1.1
Case 4	female	37	2	L distal radial fracture	23-A2
Case 5	male	39	5	R ulna fracture	22-A1.2
Case 6	female	42	4	L third metacarpal bone fracture	77-B2.2
Case 7	female	42	3	L fourth proximal phalange fracture	78-A2.2
Case 8	female	56	4	R 5th metacarpal fracture	77-B1.1
Case 9	male	61	5	R radial fracture	23-A2.1

Corporation, USA), to observe absence of the fracture line (FL) and the presence of cortical bridging (CB), to evaluate signs of bone healing[7]. The radiographic measures and their differences were evaluated and recorded by two physicians (orthopedists with more than 10 years professional experience). The inter-rater agreement for the assessments was analyzed with Cohen's kappa coefficient[8]. The two orthopedists were blinded to each other's assessments. They viewed 24 X-ray films of 8 cases, and Cohen's kappa for FL and CB was 0.93 and 0.92, respectively, showing very high inter-rater agreement ($k > 0.91$)[8].

We used SPSS 13 software to analyze data collected pre-intervention, post-intervention, and at two weeks of follow-up. The continuous variables were analyzed by the repeated measures analysis of covariance (RMANCOVA). The VAS values were analyzed using Pillai's trace test for the multivariate approach and the results of each test were compared by a post hoc test for multiple comparisons. The categorical variables including the percentage of absent FL and detectable CB were analyzed by the McNemar test to compare pre-intervention with post-intervention values. Values of $p<0.05$ were considered statistically significant.

RESULTS

A total of 9 patients (5 men, and 4 women) with hand or forearm fracture were recruited for this study, and the average age of the patients was 43.56 ± 16.30 years (Table 1). The prevalence of fracture of the right side upper extremity was slightly higher than that of the left side (5: 4), and all right side fractures were on the dominant side. The average duration since fracture of the patients recruited for this study was 3.77 ± 1.20 days. All the participants were patients with closed and stable bone fractures. Four patients had radial fractures, 3 patients had metacarpal bone fractures, 1 patient had fracture of the ulna and 1 patient had fracture of a phalange.

Table 2. Measured items before and after treatment, and at follow-up

	Before	After	Follow-up
VAS	5.89 ± 1.65*	1.44 ± 0.76†	0.51 ± 0.53‡
FL	9/9 (100%)	8/9 (89%)	8/9 (89%)
CB	1/9 (11%)*	8/9 (89%)	9/9 (89%)

VAS, visual analog scale; FL, fracture line; CB, cortical bridging. * Before vs. after treatment, $p<0.05$. † After treatment vs. follow-up, $p<0.05$. ‡ Follow-up vs. before treatment, $p<0.05$.

There were significant differences among the mean values of VAS at the three test times, as summarized in Table 2. There were significant differences between the VAS scores of pre-intervention and post-intervention, and between pre-intervention and 2 weeks follow up ($p < 0.05$). The comparisons of FL and CB observations in radiographs are shown in Tables 2 and 3. Only the percentage of detectable CB between pre-intervention and post-intervention, showed a significant difference ($p < 0.05$). Post-intervention FL was not seen in the radiographs of Case 1.

DISCUSSION

In physical therapy, the He-Ne laser (with wavelength of 630 nm) and Ga-As laser (with wavelength of 940 nm) have

Table 3. The radiographic signs of bone healing

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
Fracture line^{BT}	+	+	+	+	+	+	+	+	+
Fracture line^{AT}	–	+	+	+	+	+	+	+	+
Fracture line^{FU}	–	+	+	+	+	+	+	+	+
Cortical bridging^{BT}	+	–	–	–	–	–	–	–	–
Cortical bridging^{AT}	+	+	+	+	+	+	+	–	+
Cortical bridging^{FU}	+	+	+	+	+	+	+	+	+

+, had observable sign; –, no observable sign; BT, before treatment; AT, after treatment; FU, follow-up.

often been used for phototherapy[9]. In the present study, we used a laser with wavelength of 808 nm to treat patients with hand and forearm fractures. Nicola et al. reported that the relative absorption of laser energy is proportional to its wavelength[10]. Long wavelengths of laser are absorbed more easily, but have lower penetration of tissues. Since the energy reaching the target tissues is greatly reduced, the treatment dosage is also reduced. Therefore, a class III B low-level laser is not harmful to skin. Subsequently, Nicola et al. suggested that a laser of wavelength between 800 and 900 nm would have better penetration of human tissue[10, 11]. Therefore, we investigated the effects of a low-level laser with a wavelength of 808 nm. This laser instrument is different from He-Ne and Ga-As lasers, and our experimental results indicate that our chosen laser instrument choice was effective in treatment.

In the therapeutic methods of phototherapy, laser irradiation is either conducted at a certain distance from the skin or directly over the skin. The former method uses a scanner with a distance of 30 to 50 centimeters to scan a large area. Because of the scattering of light, the dosage of treatment per unit of area is greatly reduced[12]. On the other hand, a single point of laser light, such as laser acupuncture, is usually used in Chinese medicine. An acupuncture point or a local tender point is the target of treatment, with the laser in direct contact on a single spot of skin or mucous membrane[13]. In our study, a laser irradiating a rectangular area of 3 cm^2 was placed in direct contact with the skin over the fracture area so that the radiation could penetrate more efficiently. We found that the treatment effect was favorable and has potential as an alternative treatment method.

This research was the first study of to investigate the effects treating fractured human bone with contact band irradiation of the fracture site and was different from past animal researches[5, 14]. In our study, after the first recruited patient had received phototherapy, bone healing was found to be complete on the 19th day after onset. However, we didn't observe significant recovery of bone fractures on the radiographs of the other patients. Moreover, although low-level lasers could be used to increase the activity of osteoblasts in the early stage after fracture, the changes were not easy to observe from the gross and radiographic appearances[15]. After phototherapy, the absence of FL on the radiograph of the first recruited patient was observed. A possible explanation for this is that osteoblasts had already started repair, and low-level laser radiation increased the rate of repair[15]. We consider that phototherapy with low-level laser radiation is effective for human bone healing and pain relief. The small number of subjects was a limitation of this study, and larger randomized controlled trials are needed.

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