Use Of Low-Level Laser Therapy In Conservative Treatment Of Delayed Union Of Human Upper And Lower Limb Fractures

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Abstract

Objective: The current clinical case series assesses the early clinical outcome of the use of low-level laser in the treatment of delayed union of upper and lower extremity fractures.

Materials and Methods: The patient cohort consisted of 17 consecutive unselected patients with delayed union. All patients refused operations. All subjects were given functional Sarmiento brace, together with low-level laser therapy (LLLT) on alternate days for 8weeks in upper limb fracture cases, and 12 weeks in lower limb fracture cases.

Results: All patients had solid union, mean time for union for upper and lower limb fractures were 7 and 10 weeks respectively. The two non-responders include one patient who refused to come for follow up treatment and another who was non-compliant with splint wear The calculated p value was statistically significant at $p < 0.05$.

Conclusion: LLLT markedly shortens the healing time and can be used in treating upper and lower limbs fractures with delayed union.

INTRODUCTION

Delayed union, by definition, in general occurs when there are no signs of bony healing or a delay in bony union of the fracture ends after an adequate period of time had elapsed. In other words, a solid union is not detected within an expected time frame. The exact timing varies according to age, the bony part involved, and extent of soft tissue injury. Traditionally, many clinicians would consider operative intervention in the face of a delayed union. However, not every patient consents for an operative intervention. In such scenarios, we as clinicians still need to seek ways to enhance bony healing using non-invasive methodologies as this group of patients dislikes the idea of invasive intervention or operative intervention.

The use of low-level laser therapy in promoting fracture healing of human fractures had previously been reported by the author [1] and also from clinicians in Taiwan [2]. This study represents the first ever study to assess the clinical use of LLLT in the conservative treatment of delayed fracture union of human upper and lower extremity fractures.

Advantages of the use of LLLT in delayed fracture union is manifold. Firstly, the procedure is non-invasive and spares the patient an operative intervention. Operative intervention in general not only involves higher cost, but also it leaves the patient with a surgical scar and complications sometimes occur after an operation for delayed union such as infection or failure of metallic implants. In addition, a second operation is often required for removal of the metallic implant in younger subjects. The mean age of the patient population is relatively young in the current study. If a subsequent study reveals the same clinical efficacy in the elderly, this would be an extra advantage since older patients have in general a higher operative risk. Secondly, the world literature on LLLT showed it is free of side effects and has been in use in Europe over 30 years. Thirdly, LLLT administration does not involve higher costs with the average cost of administration per session being same as conventional physical therapy in the author's institute. It should be noted that conventional physical therapy machines do not have bio-modulation effects as does LLLT [3] and

thus cannot in effect promote the process of fracture healing.

MATERIALS AND METHODS

The study population consisted of a series of consecutive unselected 17 patients with a mean age of 26 (range 9 to 39) presenting with clinical delayed union of an upper or lower limb fracture. All of the patients had had not less than 6 weeks of casting done in other medical units but there was inadequate bony healing response on serial radiological assessments. All patients who entered the study refused operative intervention which represented the main pre-requisite for study entry and all consented for the use of LLLT as well as Sarmiento functional bracing as the sole treatment modality. Other exclusion criteria included history of psychiatric disorder, history of operative intervention of the same affected bone, history of fracture of the same affected bone, open fracture, pregnancy, and significant associated soft tissue injury.

The study represented a prospective clinical case series. LLLT of 810 nm wavelength emitting from a GaAIAs semi-conductor laser device with 5.4 J per point, power density 20 mW/cm2 was employed. Irradiation was performed on alternate day basis. There was no control group in this study as seldom do patients present with bilateral delayed union of the same bony construct of the extremity. None of the patients consented to the idea of switch-over study where part of the treatment period was LLLT and part of the treatment being sham light source.

The end point of the current study was to assess the rate of fracture healing, if any, on serial clinical and radiological follow up. We also serially assessed the degree of overall satisfaction of the patient with the procedure by a score where 0 represents total dissatisfaction with the procedure and 10 represented total satisfaction. This survey was filled by the patient at the end of the treatment regimen which represented 8 weeks for upper limb fractures, and 12 weeks for lower limb fractures.

RESULTS

The study period spanned from 2012 to 2015 amongst patients attending two different Asia Medical Clinics located in different areas in Hong Kong. The male:female ratio among the study population was 1:2 in this study. The mean time for clinical and radiological fracture union was 7 weeks for patients with upper limb fractures and the mean time for clinical and radiological fracture union was 10 weeks for lower limb fractures. The mean follow up was 18 months.

As for the scoring of the degree of satisfaction, patients were offered brief guidelines of aspects they can take into consideration including: the ability of the procedure for symptom control, the power and use of the limb, the degree of pain, and the activities of daily living. The patients gave an overall score at the end of the LLLT treatment regimen. The mean score of satisfaction was 9 out of 10 for patients with upper limb delayed union, and the mean score of satisfaction was 8 out of 10 for patients with lower limb delayed union. The patient who defaulted follow up after 2 sessions was not counted in the above scoring as she chose to leave the study.

Table 1 below serves to summarize the characteristics of the patient population and the mean time for fracture union, if any. Fig 1 and 2 showed serial radiological appearance of one of the patients with upper limb delayed union while Fig 3 and 4 showed serial radiological appearance of one of the patients presenting with lower limb delayed fracture union. Fig 5 showed a typical walking cast

Table 1

Patient population demographics, fracture characteristics, and clinical outcome

Location of Fracture and Age of Patient	Age & Site of Fracture at presentation	Length of LLLT treatment	Clinical Outcome
Patient 1 [UL/9]	6 weeks/ Humerus	8 weeks	# united at 4 weeks
Patient 2 [LL/39]	7 weeks/ Jones	12 weeks	# united at 9 weeks
Patient 3 [LL/22]	6 weeks/ DF	12 weeks	# united at 10 weeks
Patient 4 [LL/29]	7 weeks/ DF	12 weeks	# united at 11 weeks
Patient 5 [UL/18]	6 weeks/ DR	8 weeks	# united at 5 weeks
Patient 6 [LL/34]	8 weeks/ DF	< 1 week	Defaulted
Patient 7 [UL/15]	7 weeks/ Humerus	8 weeks	# united at 8 weeks
Patient 8 [LL/32]	6 weeks/ Jones	12 weeks	# united at 9 weeks
Patient 9 [LL/28]	6 weeks/ DT	12 weeks	# united at 7 weeks
Patient 10 [UL/19]	6 weeks/ DR	8 weeks	# united at 8 weeks
Patient 11 [UL/25]	8 weeks/ Humerus	8 weeks	# united at 9 weeks
Patient 12 [LL/29]	8 weeks/ Talus	12 weeks	# not united
Patient 13 [LL/33]	6 weeks/ Jones	12 weeks	# united at 10 weeks
Patient 14 [UL/27]	7 weeks/ DR	8 weeks	# united at 8 weeks
Patient 15 [LL/32]	6 weeks/ DT	12 weeks	# united at 10 weeks
Patient 16 [LL/27]	8 weeks/ DF	12 weeks	# united at 12 weeks
Patient 17 [LL/20]	7 weeks/ Jones	12 weeks	# united at 11 weeks

UL = Upper Limb fracture delayed union LL = Lower Limb fracture delayed union
DR = distal radius DF = distal fibula DT = distal tibia # = fracture

Figure 1

Young boy with a large void in the humerus fracture fragments despite initial cast treatment

Figure 2

Humerus fracture healed rapidly with solid union after LLLT

Figure 3

Fracture Distal Tibia still with scanty callus after casting for months; Notice relative osteopenia from non-weight bear walking on crutches

Figure 4

Same patient with solid union od distal tibia fracture after combined use of LLLT and walking cast, osteopenia now disappeared

Figure 5

Showing a patient wearing a walking cast to prevent fracture deformity

DISCUSSION

Low-level laser therapy (LLLT) involves directing near infra-red light to tissues with a purpose to improve healing and reduce pain in the field of Orthopedics. The main mechanism of LLLT involves its biochemical and circulatory effects. The incident radiant energy of LLLT is being absorbed by the cell's chromophore and this process usually involves the cytochrome system [4] which in turn triggers a cascade of events stimulating ATP synthesis [5]; thus in this way the laser energy is transformed to cellular energy in the form of ATP and this aids in healing the injured body's cells which are usually under oxidative stress. In addition, other LLLT actions include inducing an increase in DNA repair gene expression [6] and also producing local vasodilatation which is believed nowadays to be mediated via the nitric oxide pathway [7].

As far as the role of LLLT in fracture healing is concerned, in the past decade, abundant laboratory animal studies had elucidated the possible mechanism whereby LLLT enhances bone healing. The mechanism involved is manifold including the induction of osteoblast formation and differentiation via increase in bone morphogenic protein BMP2-induced phosphorylation of the Smad 1/5/8 pathway [8]. The same author Hirata also demonstrated that LLLT could stimulate BMPs-induced expression of type 1 collagen, osteonectin, and octeocalcin mRNA. Histological studies [9] also confirmed intense new bone formation surrounded by highly vascularized connective tissue indicative of increased osteogenic activity on LLLT exposure. Lastly, other authors [10] also demonstrated improvement in the mineralization process via enhanced IGF-1 and BMP production.

The author is not aware of any previous clinical studies on the use of LLLT in the management of delayed fracture union in the upper and lower extremities. The result of the current study is promising and future studies can be directed to the potential use of LLLT in treating delayed fracture union in the elderly.

CONCLUSION

The current prospective study of a clinical case series of patients presenting with delayed union of fractures involving the upper and lower extremities who refused operative intervention indicated that low-level laser therapy if administered correctly can on the one hand initiate the bone healing process and on the other hand shorten the time for fracture union. All patients tolerated this non-invasive form of conservative management very well at an affordable costs comparable to conventional physical therapy.

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