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Enhanced Healing and Bone re-Modelling by Low-Level Laser Therapy for Rapid Pain Control in Pediatric Fractures

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Abstract

Objective: The current clinical case series assess the clinical outcome of the use of low-level laser in the treatment of painful pediatric fractures not solidly consolidated and re-modelled after casting for a standard of 4-6 weeks

Materials and Methods: The patient cohort consisted of 17 consecutive unselected patients in pediatric age group with delayed fracture consolidation and/or undesirable angulation despite casting for a standard period of 4-6 weeks in whom the parents refused any surgical intervention and/or bone grafting options. All subjects were referred from other medical centers after inadequate healing of the fracture ends upon repeating the x ray after the cast was off at the 4-6 weeks mark. Low-level laser therapy (LLLT) on alternate days for 8weeks in upper limb fracture cases, and 12 weeks in lower limb fracture cases were administered with a view of enhancing bone healing and/or re-modelling since both previous clinical and basic science studies on LLLT showed a stimulatory effect on fracture healing.

Results: All patients had solid union, mean time for union for upper and lower limb fractures were 6 and 10 weeks respectively. The calculated p value is statistically significant at $p < 0.05$. No patient defaulted follow up. All parents were satisfied with the clinical and radiological result of the LLLT treatment.

Conclusion: LLLT was found not only to enhance bone healing potential but in fact improved bone re-modelling when used in the proper wavelength and energy density in pediatric upper and lower limbs fractures, thereby also rapidly resolve the intolerable pain in paediatric fracture population

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Introduction

It is not infrequent for pediatric surgeons to encounter inadequately consolidated pediatric fractures albeit after an adequate period of casting thereby prolonging pain and suffering for the child. The problem is even more challenging if there is concomitant element of fracture angulation and/or mal-alignment. This study explores whether newer technologies such as low-level laser therapy [LLLT] can tackle such clinical problems without even resorting to operative intervention. This is because if such problems can be tackled non-operatively, it will be a blessing for the child in pain, especially since many a times even the parents are reluctant to subject the child for operative intervention.

The use of low-level laser therapy in promoting fracture healing of human fractures had previously been reported by authors from Taiwan [1]. This study represents the first ever study to assess the clinical use of LLLT in the conservative treatment of delayed union of pediatric fractures with a view not only for enhancing bone healing, but also enhancement of bone re-modelling especially since bony injury in the pediatric age group has marked potential of re-modelling.

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 a surgical scar. To add to this, complications sometimes occur after operation for delayed union such as infection, failure of metallic implants. In addition, a second operation is often required for removal of metallic implant in younger subjects. All of the patients in the study population belonged to the pediatric age group in the current study. It should also be noted that the world literature on LLLT showed it is free of side effects, and have been in use in Europe for over 30 years. Thirdly, LLLT administration does not involve higher cost in the author's institution, with the average cost of administration per session 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 [2], 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 12 (range 9 to 16) presenting with clinical delayed fracture consolidation of upper or lower limb fractures despite casting done by orthopedic surgeons in public hospitals. All of the patients had inadequate bony healing response on serial radiological assessments. All patients who enter the study were offered operative intervention but were refused by the parents. All the parents of the children consented to the use of LLLT as well as Sarmiento functional bracing as the sole treatment modality. This represented an unselected prospective patient cohort study spanning the period from 2014 to 2019. Exclusion criteria included history of operative intervention of the same affected bone, history of fracture of the same affected bone, open fracture, significant associated soft tissue injury, active infection near the fracture site.

The study employed LLLT of 810 nm wavelength emitting from GaAIAs semi-conductor laser device with 5.4 J per point, power density 20 mW/cm2 was employed. Irradiation was performed on alternate daily basis. There was no control group in this study as seldom do patients present with bilateral delayed healing of the same bony construct. None of the patients' parents consent 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, as well as evidence of bone re-modelling if any, on serial clinical and radiological follow up. We also serially assessed the degree of overall satisfaction of the patient and parents with the procedure by a score where 0 represents total dissatisfaction with the procedure, and 10 represented total satisfaction to be filled by the parent 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 was done in two pain centers in different areas in Hong Kong attended by the author. The male:female ratio among the study population was 2:1 in this study. The mean time for clinical and radiological solid fracture union was 6 weeks for patients with upper limb fractures in this study; and the mean time for solid clinical and radiological fracture union was 10 weeks for lower limb fractures. The mean follow up was 22 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, the activities of daily living. The parents gave an overall score at the end of the LLLT treatment regimen after discussing with the injured child. The mean score of satisfaction was 9 out of 10 for patients with upper limb delayed fracture consolidation, and the mean score of satisfaction was 8 out of 10 for patients with lower limb delayed fracture consolidation. No patient defaulted follow up.

Table 1 below serve to summarize the characteristics of the patient population and the mean time for fracture union. Fig 1 and 2 showed serial radiological appearance of one of the patients with upper limb delayed fracture consolidation of mid-shaft of the humerus despite casting for 5 weeks in a public hospital. Fig 2 was taken after LLLT administration showing not only obvious solid bony healing, but also very good re-modelling.

Discussion

Low-level laser therapy (LLLT) involves directing near infra-red lights to tissues with a view to improving healing and reduce pain in the field of Orthopedics. The

Figure 1. Partially united and angulated humerus shaft fracture prior to LLLT administration in one patient

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 7 weeks
Patient 2 [UL/13]	7 weeks/ DR	8 weeks	# united at 6 weeks
Patient 3 [UL/12]	6 weeks/ DR	8 weeks	# united at 6 weeks
Patient 4 [LL/14]	7 weeks/ DF	12 weeks	# united at 9 weeks
Patient 5 [UL/11]	6 weeks/ DR	8 weeks	# united at 5 weeks
Patient 6 [LL/14]	8 weeks/ DF	12 weeks	# united at 11 weeks
Patient 7 [UL/15]	7 weeks/ Humerus	8 weeks	# united at 8 weeks
Patient 8 [LL/12]	6 weeks/ DR	8 weeks	# united at 6 weeks
Patient 9 [LL/11]	6 weeks/ DR	8 weeks	# united at 7 weeks
Patient 10 [UL/9]	6 weeks/ DR	8 weeks	# united at 6 weeks
Patient 11 [UL/15]	7 weeks/ Humerus	8 weeks	# united at 7 weeks
Patient 12 [UL/9]	6 weeks/ DR	8 weeks	# united at 4 weeks
Patient 13 [UL/13]	6 weeks/ Humerus	8 weeks	# united at 7 weeks
Patient 14 [UL/10]	7 weeks/ DR	8 weeks	# united at 5 weeks
Patient 15 [UL/12]	6 weeks/ DR	8 weeks	# united at 5 weeks
Patient 16 [UL/11]	8 weeks/ DR	8 weeks	# united at 6 weeks
Patient 17 [LL/16]	7 weeks/ DF	12 weeks	# united at 10 weeks

UL = Upper Limb fracture delayed healing LL = Lower Limb fracture delayed healing DR = distal radius DF = distal fibula # = fracture

Figure 2. Same patient after LLLT administration. Notice the fracture ends re-modelled nicely and fracture had solidly healed

main mechanism of LLLT involves its biochemical and circulatory effects, viz: the incident radiant energy of LLLT is being absorbed by the cell's chromophore and this process usually involves the Cytochrome system [3], which in turn triggers a cascade of events stimulating ATP synthesis [4]; thus in this way the laser energy is transformed to cellular energy in the form of ATP and this aid 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 [5], besides also producing local vasodilatation believed nowadays to be mediated via the nitric oxide pathway [6].

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 [7]. The same author Hirata also demonstrated that LLLT could stimulate BMPs-induced expression of type 1 collagen, osteonectin, and octeocalcin mRNA. Histological studies [8] also confirmed intense new bone formation surrounded by highly vascularized connective tissue indicative of increased osteogenic activity on LLLT exposure. Lastly, other authors [9] 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 healing in the upper and lower extremities with a view not only in enhancing bony healing but also in enhancing fracture re-modelling.

Conclusion

The current prospective study of a clinical case series of patients presenting with delayed consolidation of fractures involving the upper and lower extremities in the pediatric population indicated that low-level laser therapy if administered correctly can on the one hand initiate the bone healing process thereby shortening the time for fracture union, but also LLLT can in fact promote fracture re-modelling as well. All patients tolerated very well this non-invasive form of conservative management at an affordable costs comparable to conventional physical therapy.

Conflict of Interest Statement

The author is not in receipt of any funds from any party during the whole clinical study

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