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Transected sciatic nerve repair by diode laser protein soldering

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ABSTRACT

Background and Objective: Despite advances in microsurgical techniques, repair of peripheral nerve injuries (PNI) is still a major challenge in regenerative medicine. The standard treatment for PNI includes suturing and anastomosis of the transected nerve. The objective of this study was to compare neurorraphy (nerve repair) using standard suturingto diode laser protein soldering on the functional recovery of transected sciatic nerves.

Study Design/Materials and Methods: Thirty adult male Fischer-344 Wistar rats were randomly assigned to 3 groups: 1. The control group, no repair, 2. the standard of care suture group, and 3. The laser/protein solder group. For all three groups, the sciatic nerve was transected and the repair was done immediately. For the suture repair group, 10.0 prolene suture was used and for the laser/protein solder group a diode laser (500 mW output power) in combination with bovine serum albumen and indocyanine green dye was used. Behavioral assessment by sciatic functional index was done on all rats biweekly. At 12 weeks post-surgery, EMG recordings were done on all the rats and the rats were euthanized for histological evaluation of the sciatic nerves. The one-way ANOVA test was used for statistical analysis.

Results: The average time required to perform the surgery was significantly shorter for the laser-assisted nerve repair group compared to the suture group. The EMG evaluation revealed no difference between the two groups. Based on the sciatic function index the laser group was significantly better than the suture group after 12 weeks ($p < 0.05$). Histopathologic evaluation indicated that the epineurium recovery was better in the laser group ($p < 0.05$). There was no difference in the inflammation between the suture and laser groups.

Conclusion: Based on this evidence, laser/protein nerve soldering is a more efficient and efficacious method for repair of nerve injury compared to neurorraphy using standard suturing methods.

1. Introduction

Traumatic neuropathies are a consequence of traffic accidents as well as injuries at the workplace and home [1]. PNI may result in demyelination, axonal degeneration, or both. Clinically, demyelination or axonal degeneration result in disruption of sensory function, motor function, or both in the injured nerve. The damage induced from PNI often leads to permanent loss of function and disabilities. In many cases full functional nerve recovery is not achieved even after repair [2–6]. Depending on the severity and degree of nerve injury, recovery of function occurs with remyelination, axonal regeneration, and reinnervation of the sensory receptors, motor end plates, or both [7–9].

Classification of nerve injury was described by Seddon in 1943 as neurapraxia (temporary blockage of nervous conduction caused by a segmental demyelinization(, axonotmesis (axonal interruption with the connective sheath intact), and neurotmesis (complete transection disrupting the whole nerve trunk) [10],the latter was used as the experimentally induced injury in this study. Babcock and Bunnell proposed standardized techniques for peripheral nerve repair including management of injured nerve tissue, surgical techniques for repair of the

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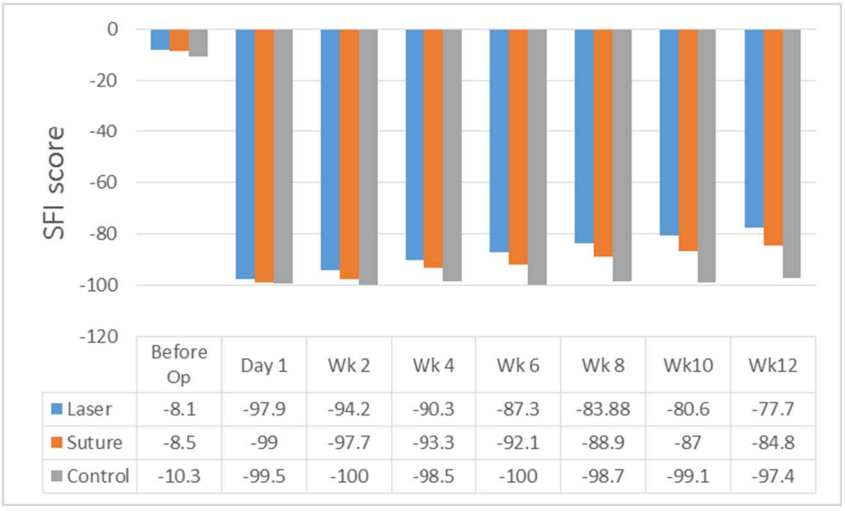

Diagram 1. SFI score of laser/protein solder, suture and control groups over a 12 weeks post-operation period.

Table 1
Histological data of laser/protein solder group.

N	inflammation	replaced tissue	Epineurium
1	0	> 75% muscular tissue	Replaced by muscular tissue and mild bleeding
2	0	25% fibrovascular tissue	–
3	0	25% fibrotic tissue	
4	1	–	–
5	1	50% fibrotic and muscular tissue	Mild bleeding
6	0	–	Mild thickening (fibrovascular tissue)
7	0	–	–
8	0	–	
9	0	–	–
10	0	–	–

Table 2
Histological data of suture group.

N	inflammation	replaced tissue	Epineurium
1	0	–	Thickened by fat and fibrovascular tissue
2	0	Replaced by muscular tissue	Replaced by muscular tissue
3	0	–	
4	0	75% fat tissue	Mild thickening
5	1	25% inflammation	Mild thickening and inflammation
6	0	25% muscular and fibrotic tissue	Thickened
7	0	50% fibrous tissue	Inflammation and bleeding
8	0	–	–
9	0	–	Bleeding and destruction in perineurium

injury, and postoperative management. Much of the information presented in these reports form the basis of operative management of PNI today [11,12].

The primary surgical techniques used for PNI repair include external neurolysis, end-to-end repair, nerve grafting and nerve transfer [13]. The most common technique of nerve repair (neurorraphy) involves placement of a series of simple interrupted sutures through the epineurium. For neurorraphy repair, sutures should pass through only the epineurium and precise realignment of peripheral nerve stumps is essential. Unfortunately, the biggest disadvantage of suture technique is additional trauma to axons as the needle is passed, penetrating deeper than the epineurium unintentionally. Also this technique has disadvantages such as scar tissue formation, foreign body reaction to the suture material, axon escapement and neuroma formation [14–16]. These problems have underscored the need for alternative techniques for PNI repair.

Laser-nerve soldering is an alternative method for nerve repair by which nerve ends are co-apted and united without injury to the nerve itself. In laser tissue soldering, the laser light is absorbed and heats the tissue, causing coagulation of proteins to form a bond. In most cases, the laser technique is also simpler and faster to perform than the standard suture technique [17]. The application of a protein solder to the tissue being welded overcomes the complication of high dehiscence rate and provides additional strength to the bond [17,18]. Indocyanine green (ICG) is the most common chromophore used in laser soldering research and has a peak absorption at a wavelength of 805 nm [32].

The purpose of this study was to investigate the feasibility of laser nerve protein soldering as an alternative to conventional suture repair using a rat model of experimentally induced sciatic nerve injury.

2. Material and Methods

2.1. Animals

The animal study was conducted in accordance with the internationally accepted principles for laboratory animal use and care (IASP, 1983) which is also documented in our national community guidelines and the Institutional Animal Welfare Law. All study protocols were approved by the internal deputy for animal research and an independent ethics committee in our university with permission number 68849.

Thirty adult male Fischer-344 Wistar rats, 350–400 g, were housed at a room temperature of 21 ± 0.5 °C with a 12-h light/dark cycle and free access to water and food. Rats were allocated into 3 groups: 1. The control group, no repair (n = 2), 2. The standard of care suture group (n = 14) and 3. The laser/protein solder group (n = 14). During the course of the experiment, 4 rats in laser solder group and five rats in suture group died and were excluded from the reported data. The final number of rats on which the data presented here was based included: 10 rats in the laser solder group, 9 rats in suture group and 2 rats in control group.

2.2. The Protein Solder

The protocol used to make protein solder was that of Lauto et al. [18]. ICG (25% by weight) was dissolved with distilled water. Bovine serum albumin (BSA) was added to the water + ICG solution until a concentration of 62% by weight was achieved. The resulting solution