Laser-assisted nerve repair. An experimental study
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Surgical repair of injured peripheral nerves has considerably advanced during the last decades. The introduction of the operating microscope, microsutures, and microsurgical instruments has helped to improve the functional regeneration of repaired nerves. Since the first repair of nerves in the 16th century, more than one hundred different repair techniques have been described in the literature. However, despite the progress made, results from surgical repair remain limited mainly by a sequence of events that occurs at the repair site. The presence of suture material at the repair site results in a foreign body reaction and connective tissue proliferation which is detrimental to nerve regeneration. Currently, the results of peripheral nerve repair techniques seem to have reached a plateau where functional recovery is still unsatisfactory, but where the microsurgical suture techniques hardly can be further refined.

Sutureless repair of peripheral nerves, e.g. by using lasers, has stimulated the interest of several researchers for years (FISCHER, 1985; ALMQUIST, 1988; HUANG, 1992; DORT, 1994; HAPPAK, 1998). Lasers are used widely in surgery and medicine for coagulation, incision, and vaporisation of various tissues. The ability of tissues to absorb laser light and to convert light energy into heat is the basis of these laser-tissue interactions. By applying a low total light dose (low power and short exposure time) temperatures below 100°C can be maintained in irradiated tissues. Under these conditions thermal fusion of tissues can be accomplished (SCHOBER, 1986), that, although generally weaker than suturing, have sufficient tensile strength to allow uncomplicated wound healing. This photothermal bonding of tissues, known as laser tissue welding, has opened the way to use lasers for reconstructive purposes. Due to the shallow tissue penetration at 10,600 nm, the CO₂ milliwatt laser is one of the most frequently used lasers for laser-assisted nerve repair. During the past years, a number of experimental techniques have been investigated in an attempt to define the role of the CO₂ and other lasers in nerve repair. These experiments have produced both promising and conflicting results and were often performed on an empirical basis only.

Purpose and outline of the study

The purpose of the studies reported in this thesis is to develop, improve, and refine laser-assisted nerve repair (LANR) techniques and to finally compare the technique with the current repair methods.

In the first part of the thesis (Chapters II and III), an overview is given of
the literature on surgical nerve repair and laser tissue welding. Chapter II describes the normal anatomy and histology of peripheral nerves, the historical sequence of nerve injury, and the surgical techniques employed to perform nerve repair. In chapter III, an introduction is given in basic laser surgery and a review is given of laser tissue welding with emphasis on LANR.

In the second part of the thesis (Chapters IV to IX) several experimental studies are described designed to gain more insight into the value of the CO2 laser as an surgical tool for nerve repair. In chapter IV, optimal laser parameters to obtain the strongest bond between the nerves are determined in an in vitro study using rabbit tibial nerves. Furthermore, several protein solders were examined for their ability to reinforce the repair site. The aim of chapter V is to elucidate the mechanism of CO2 laser tissue welding of dura mater and peripheral nerves, with emphasis on the alterations in tissue morphology and ultrastructure which occur during laser welding. Both tissues have been investigated using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). In chapter VI, the thermal damage of rat sciatic nerves irradiated by a CO2 milliwatt laser at different powers and exposure times is described. The results were evaluated up to 12 weeks after surgery using a toe-spreading test, light, and transmission electron microscopy. Chapter VII is designed to investigate early peripheral nerve regeneration after CO2 laser welding using three different suture materials (nylon, polyglycolic acid, and stainless steel) and a protein solder as an adjunct to the welding process. Evaluation was performed at one and six weeks after surgery and included light microscopy. In the final in vivo study, chapter VIII, compares LANR in rat sciatic nerves with two established techniques of nerve repair, i.e. suture and fibrin glue nerve repair (FGNR). Evaluation was performed 16 weeks after surgery and included toe-spreading test, light microscopy, and morphometric assessment. Because no data were available on the effect of CO2 laser irradiation on microsurgical suture material, chapter IX is designed to investigate the tensile strength of 10-0 nylon and 25 μm stainless steel threads irradiated by a CO2 laser at different power densities and exposure times. Finally, chapter X provides the discussion and the conclusions of this thesis and describes future perspectives of LANR.