

# Efficacy of Multiwavelength Light Therapy in the Treatment of Pressure Ulcers in Subjects With Disorders of the Spinal Cord: A Randomized Double-Blind Controlled Trial

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**ABSTRACT.** Taly AB, Sivaraman Nair KP, Murali T, John A. Efficacy of multiwavelength light therapy in the treatment of pressure ulcers in subjects with disorders of the spinal cord: a randomized double-blind controlled trial. *Arch Phys Med Rehabil* 2004;85:1657-61.

**Objective:** To study the efficacy of multiwavelength light therapy in the treatment of pressure ulcers in subjects with spinal cord disorders.

**Design:** Randomized controlled trial.

**Setting:** Neurologic rehabilitation ward of a referral center in India.

**Participants:** Thirty-five subjects with spinal cord injury, with 64 pressure ulcers (stage 2, n=55; stage 3, n=8; stage 4, n=1), were randomized into treatment and control groups. One subject refused consent. Mean duration of ulcers in the treatment group was 34.2±45.5 days and in the control group, 57.1±43.5 days.

**Interventions:** Treatment group received 14 sessions of multiwavelength light therapy, with 46 probes of different wavelengths from a gallium-aluminum-arsenide laser source, 3 times a week. Energy used was 4.5J/cm<sup>2</sup>. Ulcers in the control group received sham treatment.

**Main Outcome Measures:** Healing of the ulcer, defined as the complete closure of the wound with healthy scar tissue, time taken for the ulcer to heal, and stage of the ulcer and Pressure Sore Status Tool score 14 days after last treatment.

**Results:** There was no significant difference in healing between the treatment and control groups. Eighteen ulcers in treatment group and 14 in control group healed completely ( $P=.802$ ). Mean time taken by the ulcers to heal was 2.45±2.06 weeks in the treatment group and 1.78±2.13 weeks in the control group ( $P=.330$ ). Time taken for stage 3 and 4 ulcers to reach stage 2 was 2.25±0.5 weeks in treatment group and 4.33±1.53 weeks in control group ( $P=.047$ ).

**Conclusions:** Multiwavelength light therapy from a gallium-aluminum-arsenide laser source did not influence overall healing pressure ulcers. Limited evidence suggested that it improved healing of stage 3 and 4 pressure ulcers.

**Key Words:** Laser therapy; Lasers; Pressure ulcers; Rehabilitation; Spinal cord injuries

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**O**VERALL, 85% OF SUBJECTS with spinal cord disorders develop a pressure ulcer during their lifetime, and around 8% die from them.<sup>1</sup> Pressure ulcers result in loss of therapy time, increase the duration of hospital stay, escalate the cost of treatment, aggravate spasticity, delay neuronal recovery, and impair quality of life. Various pharmacologic, physical, and surgical methods have been tried in the treatment of pressure ulcers. However, with currently available techniques, healing of a pressure ulcer takes several weeks to several months.

Since the 1960s, lasers have been used for surgery, relief of pain, treatment of soft-tissue injuries, and control of inflammation. Lasers promote fibroblast proliferation, collagen production, and epithelialization.<sup>2</sup> At the cellular level, lasers enhance succinic dehydrogenase activity and alter prostaglandin levels. These changes favor wound healing.<sup>3</sup> Lasers such as gallium aluminum arsenide and helium neon are commonly used for wound healing. A few studies<sup>2-5</sup> in both experimental animals and human subjects report that lasers assist in wound healing. After searching 19 electronic databases, including MEDLINE, CINAHL, EMBASE, and the Cochrane Controlled Trials Register (CENTRAL), Flemming and Cullum<sup>6</sup> concluded that currently evidence was insufficient to draw conclusions about the contribution of laser therapy to wound healing. The aim of our study was to assess the efficacy and safety of multiwavelength light therapy from a gallium-aluminum-arsenide laser source as a treatment for pressure ulcers in subjects with spinal cord disorders.

## METHODS

Our double-blind, randomized controlled trial (RCT) was conducted at a neurologic rehabilitation ward, the National Institute of Mental Health and Neurosciences (NIMHANS), in Bangalore, India. The study was approved by the institutional ethics committee of NIMHANS. None of the authors have any financial interest with manufacturers of laser equipment.

Patients with spinal cord disorders and admitted to the rehabilitation ward with pressure ulcers or who developed ulcers during their stay in the ward were eligible for the study. Pressure ulcers were divided into the conventional 4 stages: stage 1, nonblanching erythema of intact skin; stage 2, partial-thickness skin loss; stage 3, full-thickness skin loss; and stage 4, extension into muscle and bone.<sup>7</sup> Pressure ulcers of the conventional stages 2, 3, and 4 were included in the study. Subjects with photosensitivity, ulcers from other causes, necrotic tissue in ulcers that would interfere with the application of laser, flask-shaped ulcers that cannot be adequately exposed to laser, pressure ulcers with underlying osteomyelitis, or pressure ulcers requiring surgical intervention at the time of first assessment were excluded.

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**Table 1: Characteristics of Multiwavelength Light Source**

Power (mW)	Wavelength (nm)	Frequency (Hz)	No. of Sources
15	660*	20	10
15	950*	20	10
25	870*	20	10
25	880*	20	10
25	940*	20	5
15	820 <sup>†</sup>	20	1

\*Supraluminous light-emitting diode.

<sup>†</sup>Laser.

Informed consent was obtained from all the subjects. Socio-demographic and clinical information was obtained in a pre-designed format. A clinical examination was done according to the guidelines of the International Standards for Neurological Examination and Functional Classification of Spinal Cord Injury.<sup>8</sup>

The wound was assessed by using the Pressure Sore Status Tool<sup>9</sup> (PSST), which scores pressure ulcers from 0 to 60; lower scores indicate a better status. This tool includes the following parameters: size, depth, edges, undermining, necrotic tissue type, necrotic tissue amount (1, not visible; 2, covering <25% of total wound bed; 3, covering 25%–50% of total wound bed; 4, covering >50% to <75% of total wound bed; 5, covering ≥75% of total wound bed), exudate type, exudate amount, skin color surrounding wound, peripheral tissue edema, peripheral tissue indurations, granulation tissue, and epithelialization. The PSST has a content validity of .91. Its interrater reliability varies from .91 to .92 and its intrarater reliability from .96 to .99.<sup>10</sup> This tool is widely used in different populations with pressure ulcers.<sup>11</sup> Photographs of all ulcers were taken at the beginning of treatment, end of treatment, and 14 days after last treatment session. Ulcer stage and PSST scores were also repeated on these days. All evaluations were done by an investigator who was blind to the type of intervention.

Laboratory investigations, including hemogram, serum total protein, albumin, and culture and sensitivity from the pressure ulcers, were done at study entry and were repeated thereafter at weekly intervals.

### Interventions

Each ulcer was given a unique identification number and then was randomized into 1 of 2 groups—the treatment group or the control group—by using a random number table. Different ulcers in the same patient could be randomized into either group. Pressure ulcers in both groups received daily dressing with sterile gauze soaked in normal saline and pressure relief with either a water mattress or a split mattress. The dressings were given by the neurologic rehabilitation ward nursing staff, who were blind to the treatment status. Ulcers were débrided if thought necessary by the nurse during dressing. Eschars, if any, were removed. Education regarding care of the ulcer was given to all patients.

The laser device<sup>a</sup> was calibrated before each treatment session. During treatment, the eyes of all subjects and of the therapist were covered with protective goggles. These precautions were carried out for both treatment and control groups. The treatment group received multiwavelength light therapy in addition to the above, whereas for the control group, the multiwavelength light therapy source was held over the ulcer after switching off the beam. Fourteen treatments were given, 1 every alternate day, 3 times a week, until the ulcer healed or the ulcer received 14 exposures. Each ulcer was divided into

10cm<sup>2</sup> squares. During every session, each square was exposed for 60 seconds. The details of the multiwavelength light therapy source are given in table 1. The central 820nm laser source was surrounded by 45 supraluminous diodes of different wavelengths. Energy applied to the ulcer was calculated by using the formula: energy delivered = (power/spot size) × time. Energy given was 4.5J/cm<sup>2</sup>. Ulcers were examined after each treatment for complications like burns, excessive granulation or cicatrization, infection, necrosis, dermatitis, or erythema of surrounding tissues. All adverse events during the study period were recorded and analyzed.

The end points of the study were healing of the ulcer, time taken for the ulcer to heal, and, for ulcers that did not heal, the PSST score and ulcer stage 2 weeks after completion of the treatment protocol. Ulcer healing was defined as the complete closure of the wound with healthy scar tissue. Eschar was removed before application of intervention. Ulcers with eschar at the end of the study period were considered not healed.

Analysis of data was done by using SPSS, version 11.0,<sup>b</sup> for Windows.

The number of ulcers that healed in each group was compared by using the chi-square test. When the cell size was less than 5, the Fisher exact coefficient was used. The significance level was set at *P* less than .05. Time taken by the ulcers to heal was compared using an independent sample *t* test, with the significance level set at *P* less than .05. The PSST score and the pressure ulcer stage are ordinal scales. Hence, the differences in the PSST scores and the pressure ulcer stage between the 2 groups were analyzed with the Mann-Whitney *U* test, with the significance level at *P* less than .05. Intention-to-treat analysis was used, and in patients who did not complete the study after entry, the last available observations or measurements were considered for analysis.

### RESULTS

Of 129 persons with spinal cord disorders admitted to the rehabilitation ward during the study period, 40 had pressure ulcers at the time of transfer to the rehabilitation ward. Thirty-five subjects (27 men, 8 women) satisfied all entry criteria for the study. Age ranged from 8 to 65 years (mean, 31.71 ± 1.23y). The etiology of spinal cord lesions is given in table 2. Sixty-four ulcers in 35 subjects were randomized into the 2 groups: 35 in the treatment group and 29 in the control group. The number and location of these ulcers were: 21 (32.8%) on the sacrum, 18 (28.1%) on the greater trochanter, 9 (14.1%) on the gluteal region, 2 (3.1%) on the lateral malleolus, 2 (3.1%) on the elbow, 1 (1.6%) on the ischial tuberosity, 1 (1.6%) on the heel, and 10 (15.6%) on other sites. The number of ulcers by stage at the beginning of the study were: 55 at stage 2, 8 at stage 3, and at stage 4. Most ulcers evolved after hospitalization: 33 ulcers (51.6%) developed in an acute care facility, 13

**Table 2: Etiology of Spinal Cord Disorders**

Acute transverse myelitis	14
Trauma	6
Tuberculosis	4
Lumbar meningomyelocele	3
Epidural abscess	2
Cervical spondylosis	2
Intervertebral disk prolapse	1
Spinal cord infarction	1
Neurofibroma	1
Vitamin B <sub>12</sub> deficiency	1

Table 3: Comparison of Pressure Ulcers in the Treatment and Control Groups

	Treatment (n=35)	Control (n=29)	Significance
PSST score*			.570
Mean $\pm$ SD	21.9 $\pm$ 5	22.7 $\pm$ 4.4	
Median (range)	22 (14–32)	23 (14–31)	
Mean rank	31.30	33.95	
Pressure ulcer stage <sup>†</sup>			
2	31	24	.38
3	3	4	.50
4	1	1	.70
Duration of ulcer (d) <sup>‡</sup>			.374
Mean $\pm$ SD	34.2 $\pm$ 45.5	57.1 $\pm$ 43.5	

Abbreviation: SD, standard deviation.

\*Mann-Whitney *U* test.

<sup>†</sup>Fisher probability test.

<sup>‡</sup>Student *t* test.

(20.3%) in a rehabilitation ward, and 18 (28.1%) at home. These ulcers could be attributed to prolonged lying in bed, 49 (76.6%); improper transfers, 10 (15.6%); and prolonged sitting, 5 (6.3%).

Thirty-five ulcers received multiwavelength light therapy and 29 received the sham treatment. There were no significant differences between the 2 groups (table 3). The number of treatments given varied from 1 to 14 sessions (mean, 9.89 $\pm$ 4.87; median, 12.50). Therapy sessions could not be completed for 10 ulcers (treatment group, 8; control group, 2) in 5 subjects because 2 subjects (7 ulcers) died, 1 subject opted out of the study, and 2 subjects developed ulcer infection. Both deaths occurred in the treatment group and were attributed to septicemia in 1 subject and pulmonary embolism in the other. By the end of the study period, 32 ulcers had healed completely (treatment, 18; control, 14). The PSST score was lower in 23 ulcers (treatment, 11; control, 12), and 9 ulcers did not show any improvement. One patient in the control group developed excessive granulation tissue. None of the patients had burns or scarring. Figure 1 shows the flow chart for the study.

Of the 32 ulcers that healed completely, 18 received multiwavelength light therapy and 14 the sham treatment. This difference was not significant ( $\chi^2$  test=.063,  $P$ =.802). The mean time taken for the ulcers to heal from the day of randomization was 2.45 $\pm$ 2.06 weeks in the treatment group and 1.78 $\pm$ 2.13 weeks in the control group. This difference was not statistically significant ( $t$ =.987,  $P$ =.330). The PSST score and the stage of the 32 ulcers that did not heal during the study period are shown in table 4. There were no significant differences between the treatment and control groups.

Of the 9 ulcers that were at stages 3 and 4 at the time of randomization, the PSST score and the ulcer stage were significantly lower in the treatment group ( $n$ =4) than in the control group ( $n$ =5) at the end of the study (table 5). Three of the 4 ulcers in the treatment group reached stage 2 by 2 weeks after starting treatment and stage 1 by 3 weeks. In the control group, none of the ulcers reached stage 2 at the end of the second week, and only 1 ulcer reached stage 2 by 3 weeks. The mean time for ulcers in the treatment group to reach stage 2 was 2.25 $\pm$ 0.5 weeks; in the control group, it took 4.33 $\pm$ 1.53 weeks ( $t$ =-2.621,  $P$ =.047).

## DISCUSSION

Several studies<sup>2,4,5</sup> have shown that lasers may assist in wound healing. The proposed mechanisms for this action include an increase in aerobic energy production, prevention of cellular necrosis, enhancement of cell proliferation and colla-

gen synthesis, and stimulation of fibroblast and macrophage proliferation.<sup>2,3,12</sup> However, many studies contradict this claim. Longo,<sup>13</sup> de Braeck,<sup>14</sup> Hall,<sup>15</sup> and Petersen,<sup>16</sup> and colleagues did not find any significant effect of low-level energy laser on the process of wound healing in experimental animals.

Santoianini et al<sup>17</sup> compared the helium neon laser, with a 632.8-nm wavelength, and energy of 1J/cm<sup>2</sup> or 4J/cm<sup>2</sup>, with antiseptic compresses in the treatment of venous ulcers. They concluded that the laser did not influence healing. In a randomized, placebo-controlled trial, Lundberg and Malm<sup>18</sup> did not find any significant difference in wound healing among subjects treated with the gallium-aluminum-arsenide laser. A recent Cochrane review<sup>6</sup> also did not find sufficient evidence to support the efficacy of lasers treatment of venous ulcers. Culum et al,<sup>19</sup> after an exhaustive review, did not find sufficient evidence to draw conclusions about the efficacy of lasers in chronic wound healing. In our study, we also did not find significant differences in the number of ulcers healed and the

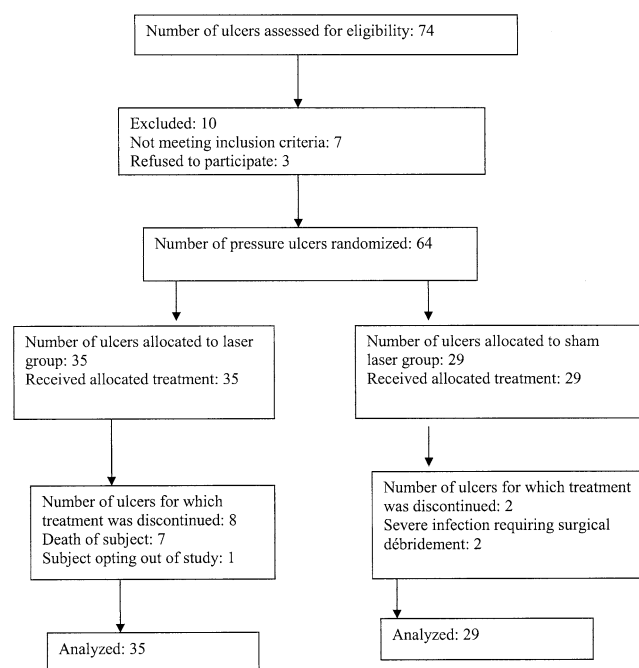


Fig 1. Flow chart of the RCT of laser treatment of pressure ulcers.

Table 4: PSST Score and Stage of Ulcers That Did Not Heal During the Study

	Treatment (n=17)		Control (n=15)		Mann-Whitney <i>U</i>	<i>P</i>
	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median		
PSST score at start of treatment	24.2 $\pm$ 3.3	23.0	24.5 $\pm$ 3.5	24.0	119.5	.761
Stage at start of treatment	2.2 $\pm$ 0.4	2.0	2.3 $\pm$ 0.7	2.0	113.0	.486
PSST score at end of treatment	21.1 $\pm$ 4.6	21.0	20.7 $\pm$ 4.6	21.0	126.0	.955
Stage at end of treatment	2.0 $\pm$ 0.0	2.0	2.2 $\pm$ 0.6	2.0	102.0	.057
PSST score at end of study	19.9 $\pm$ 6.4	18.0	19.00 $\pm$ 4.9	18.5	73.5	.806
Stage at end of study	2.0 $\pm$ 0.4	2.0	2.1 $\pm$ 0.8	2.0	77.5	.971

time for the ulcers to heal, between the treatment group and the control group.

Two trials do report that light therapy is useful in treatment of ulcers. Schindl et al<sup>5</sup> reported that the helium neon laser was useful in the treatment of chronic nonhealing ulcers. This open-labeled study, without a control group, included 20 ulcers of different etiologies. Differences in ulcer etiology, study design, and source of light may account for differences in results between our study and that trial. In a placebo-controlled, double-blind study, Gupta et al<sup>4</sup> concluded that low-energy photon therapy assists in healing venous ulcers. Gupta used light sources of 2 wavelengths, 660 and 880nm. Our study included only pressure ulcers in patients with spinal cord disorders and used multiwavelength light therapy. Hence, it is not possible to compare these 2 trials.

Ulcer healing is influenced by many different host factors, for example, age, nutritional status, continence of bowel and bladder, mobility, sensations and concomitant illness, care, and medications.<sup>1</sup> The effect of lasers on wound healing was influenced by etiology: ulcers caused by radio damage healed faster with lasers than those caused by diabetes and vasculitis.<sup>5</sup> Hence, there is a need to study the effect of various interventions for pressure ulcers on specific diagnostic categories. Spinal cord injury (SCI) per se alters the cardiovascular responses, interfering with blood flow to the skin and wound healing.<sup>1</sup> Before our study, there was only 1 study on the effect of laser on wound healing in patients with SCI. In that study, Nussbaum et al<sup>20</sup> compared nursing care alone with nursing care combined with laser or ultrasound and ultraviolet-C. Although the combination of ultrasound and ultraviolet treatment decreased wound healing time, lasers did not have any significant effect.

In our study, we noted a significant reduction in the time for stage 3 and 4 ulcers to improve to stage 2 in the treatment group compared with the control group. Hence, multiwavelength light therapy may be useful in promoting wound healing in large ulcers. One major limitation of our study is that there were only 9 stages 3 and 4 ulcers in the treatment group. Because of sample size limitations, these findings need to be validated further.

Overall, 32 of 64 ulcers healed in 28 days. Most of the ulcers were in stage 2 when subject entered the study. Even though ward nursing staff was blind to the type of intervention, they were aware that a trial on healing of pressure ulcers was in progress. It is possible that this resulted in overall improvement in wound care practices. This may be a reason for relatively rapid healing of ulcers in this trial. Another study limitation was that it was done at a single center using a specific device. A study with a larger number of ulcers in stages 3 and 4, with participation of multiple centers, might help expand our understanding of the efficacy of lasers in the treatment of large pressure ulcers.

Total healing of the ulcer is the most desirable outcome of any intervention for pressure ulcers. We used healing of the ulcer, time taken for the ulcer to heal, the conventional stage, and the PSST score as the end points of the study. Total healing of the ulcers in a relatively short period may not be a sensitive measure. The PSST is comparable to other assessment methods of wound healing.<sup>21</sup> Another limitation is that we had no previous experience using the PSST.

Treatment could not be completed in 10 ulcers because of concomitant medical complications, which resulted in the death of 2 subjects, 1 subject withdrawing from study, and 2 ulcer infections. Subjects with spinal cord disorders are prone to develop several medical complications, which will interfere with the healing of pressure ulcers and the selection of treatment. None of the subjects in our study had any complications directly attributable to treatment. None of the previous studies<sup>4,5,16,19</sup> reported any significant complications because of laser therapy for wound healing.

## CONCLUSIONS

Overall, there were no significant differences in healing of the ulcers between the treatment group and the control group. Multiwavelength light therapy reduced the time taken by a small subgroup of stage 3 and stage 4 pressure ulcers to reach stage 2. Because there were only 9 of these ulcers in our study and because this was a single-center study, the findings cannot be generalized. Further double-blind, controlled trials with

Table 5: Effect of Lasers on Stage 3 and 4 Ulcers: Comparison of the Treatment and Control Groups

	Treatment Group (n=4)		Control Group (n=5)		Mann-Whitney <i>U</i>	<i>P</i>
	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median		
PSST score at start of treatment	27.0 $\pm$ 3.4	28.5	27.8 $\pm$ 2.6	28.0	9.5	.900
Stage at start of treatment	2.8 $\pm$ 0.5	3.0	3.2 $\pm$ 0.5	3.0	8.0	.371
PSST score at end of treatment	18.3 $\pm$ 2.9	17.5	24.2 $\pm$ 4.0	24.0	2.0	.047
Stage at end of treatment	2.3 $\pm$ 0.5	2.0	2.8 $\pm$ 0.8	3.0	6.0	.273
PSST at end of study	16.8 $\pm$ 3.5	16.5	22.4 $\pm$ 3.9	22.0	2.0	.049
Stage at end of study	1.8 $\pm$ 0.5	2.0	2.4 $\pm$ 1.1	2.0	6.5	.345

multiple participating centers and a larger number of stage 3 and 4 ulcers are required.

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#### References

1. Byrne DW, Salzberg CA. Major risk factors for pressure ulcers in the spinal cord disabled: a literature review. *Spinal Cord* 1996; 34:255-63.
2. Reddy GK, Stehno-Bittel L, Enwemeka CS. Laser photostimulation of collagen production in healing rabbits Achilles tendons. *Lasers Surg Med* 1998;22:281-7.
3. Conlan MJ, Rapley JW, Cobb CM. Biostimulation of wound healing by low energy laser irradiation. A review. *J Clin Periodontol* 1996;23:492-6.
4. Gupta AK, Filonenko N, Salansky N, Sauder DN. The use of low energy photon therapy (LEPT) in venous leg ulcers: a double-blind, placebo-controlled study. *Dermatol Surg* 1998;24:1383-6.
5. Schindl M, Kerschman K, Schindl A, Schon H, Heinzl H, Schindl L. Induction of complete wound healing in recalcitrant ulcers by low intensity laser irradiation depends on ulcer cause and size. *Photodermat Photoimmun Photomed* 1999;15:18-21.
6. Flemming K, Cullum N. Laser therapy for venous leg ulcers. *Cochrane Database Syst Rev* 2000;(2):CD001182.
7. Pressure ulcers prevalence, cost and risk assessment: consensus development conference statement—The National Pressure Ulcer Advisory Panel. *Decubitus* 1989;2:24-8.
8. Ditunno JF, Young W, Donovan WH, Creasey G. The international standards booklet for neurological and functional classification of spinal cord injury. American Spinal Injury Association. *Paraplegia* 1994;32:70-80.
9. Bates-Jensen BM. Tools to measure wound healing. In: Sussmann C, Bates-Jensen BM. *Wound care: a collaborative practice manual for physical therapists and nurses*. Gaithersburg: Aspen; 1998. p 115-6.
10. Bates-Jensen BM, Vredevoe DL, Brecht ML. Validity and reliability of the Pressure Sore Status Tool. *Decubitus* 1992;5:20-8.
11. Bates-Jensen BM. The Pressure Sore Status Tool: a few thousand assessments later. *Adv Wound Care* 1997;10:65-73.
12. Saperia D, Glassberg E, Lyons RF, et al. Demonstration of elevated type I and type II procollagen mRNA levels in cutaneous wounds treated with helium-neon laser. Proposed mechanism for enhanced wound healing. *Biochem Biophys Res Commun* 1986; 138:1123-8.
13. Longo L, Evangelista S, Tinacci G, Sesti AG. Effect of diode laser silver arsenide aluminium 904 nm on healing of experimental wounds. *Lasers Surg Med* 1987;7:444-7.
14. de Braekt MM, van Alphen, FA, Kuijpers-Jagtman AM, Maltha JC. Effects of low level laser therapy on wound healing after palatal surgery in beagle dogs. *Lasers Surg Med* 1991;11:462-70.
15. Hall G, Anneroth G, Schennings T, Zetterquist L, Ryden H. Effect of low energy laser irradiation on wound healing. An experimental study in rats. *Swedish Dental J* 1994;18:29-34.
16. Petersen SL, Botes C, Olivier A, Guthrie AJ. The effect of low level laser therapy (LLL) on wound healing in horses. *Equine Vet J* 1999;31:228-31.
17. Santoianni P, Monfrecola G, Martellotta D, Ayala F. Inadequate effect of helium-neon laser on venous leg ulcers. *Photodermatol* 1984;1:245-9.
18. Lundberg T, Malm M. Low power HeNe laser treatment of venous leg ulcers. *Ann Plastic Surg* 1991;27:537-9.
19. Cullum N, Nelson EA, Flemming K, Sheldon T. Systematic reviews of wound care management: (5) beds; (6) compression; (7) laser therapy, therapeutic ultrasound, electrotherapy and electromagnetic therapy. *Health Technol Assess* 2001;5(9):1-221.
20. Nussbaum EL, Beimann I, Mustard B. Comparison of ultrasound/ultraviolet-C and laser for treatment of pressure ulcers in patients with spinal cord injury. *Phys Ther* 1994;74:812-23; discussion 824-5.
21. Woodbury MG, Houghton PE, Campbell KE, Keast DH. Pressure ulcer assessment instruments: a critical appraisal. *Ostomy Wound Manage* 1999;45:42-55.

#### Suppliers

- a. Biotherapy 2001; Omega Laser Systems, Omega House, 211 New North Rd, London, NI 6UT, UK.
- b. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.