Efeects of Low Level Laser Irradiation with 904 nm Pulsed Diode Laser on the Extraction Wound

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CONTENTS

I. INTRODUCTION

Various studies on low reactive level laser (LLL) have been performed to investigate the therapeutic benifits of laser irradiation on wounds or lesions. Mester et al.[1] reported that the healing of total skin defects that artificially created on the back of white mice was significantly accelerated by the irradiation of ruby laser.

Chavrier et al.[2] and Kim et al.[3] stated that the infra-red GaAs laser has biostimulation effect. They proposed that the LLL irradiation may stimulate the protein and DNA synthesis to accelerate the proliferation of gingival fibroblast. The interest for laser therapy applied in healing of post-traumatic lesions and myopathies has recently increased for the investigation of the molecular basis for explaining therapeutic effects of LLL[4-7].

In 1987, Lee and Kim[8] reported that LLLI was effective in reducing gingival inflammation. They compared the irradiated and non-irradiated gingiva microscopically and microbiologically and concluded that the irradiated gingiva and the ratio of motile rods and spirochetes in the gingival sulcus were significantly decreased. They also suggested that LLLI have biostimulation effects on the growth of bacterial cells as well as tissue cells. Kim et al. supported that LLLI also have the biostimulation effect on the growth of *Streptococcus mutans*[9], *Candida albicans*[10], in the specific irradiation dose and time.

Lee et al.[11] reported animal studies in which LLLI is applied onto an infected wound. They suggested that the acceleration of healing in an infected wound following LLLI indicates that the cellular activity due to the biostimulation effect of LLLI in the surrounding normal tissue predominates over the tissue irritation due to the bacterial growth in the infected wound. The purpose of this study, therefore, was to evaluate clinically the effect of LLLT for the extracted wound and to suggest LLLT as an additional modality in the treatment of intraoral wound.

* The Present research was conducted by the research fund of Dankook University in 1995.

II. MATERIALS AND METHODS

Laser Apparatus

The laser used in this work was the BIOLASER (Dong Yang Medical, Seoul, Korea) employing GaAs semiconductor diode. It is a pulsed infrared laser apparatus with a wavelength of 904 nm and a peak output power is 27 W. The pulsing frequency used in this study was P13(6000Hz, 14mW average output power), investigated as the most proliferative pulse for Staphylococcus aureus in the previous study.(12) LLL was irradiated in the extracted wound for 1 minute immediately after extraction of tooth. The energy fluence of LLLT was 840 mJ.

Subjects

Nineteen patients (5 females, 14 males, age range 28-69 years, average age 52 years) visited to Dept. of Dentistry at Asan City Health Center between May and July 1995, were invited to take part in the study. After a complete oral examination, patients with a problem tooth to be extracted due to severe dental caries or periodontal disease were randomly allocated to one of two groups; (1) LLLT group or (2) sham irradiation group (table 1). For all patients antibiotics was prescribed for 3 day to control an infection, but analgesics was prescribed only when untolerable pain occurred.

LLL was irradiated at the extracted wound immediately after extraction of tooth in the LLLT group, but LLL was irradiated at the opposite tooth in the sham irradiation group.

Measures

A blinded dentist evaluated the degree of pain clinically using a 10 cm visual analogue scale (VAS) every day for 1 week after extraction of tooth. In VAS, scores were from zero to ten in horizontal axis. Zero meant no pain and ten meant the strongest pain to be imagined. The question accompanied the pain scale was What is your average pain level for today? Each time, paitents marked the appropriate score to quantify the pain they felt.

The numbers and duration of analgesic use were also assessed for 1 week after extraction of tooth.

Statistical Analysis

All measurements in each group were averaged. Statistical comparisons were then made to determine the significance of the differences between the groups. Repeated measures ANOVA was used to compare the difference of VAS between LLLT and sham irradiation groups and unpaired t-test was used to determine a significance of difference in the number and duration of analgesic use between LLLT and sham irradiation groups.

III. RESULTS

The means of VAS measured in two groups, LLLT and sham irradiation groups, every day for 1 week are given in Table 2. The results of repeated measures ANOVA test according to the groups and the elapsed time are also given in Table 2 and Figure 1. The between-group effect for LLLT is significant. This means that there is a significant difference in the effectiveness of LLLT as measured by the VAS. From Figure 1, it is seen that the LLLT-by-time interaction arose from the fact that the scores of VAS in the LLLT group were decreased significantly at the day of extraction and at day 1 and day 3 after extraction of tooth.

The means of numbers and durations of

Table 1. Demographic data of the LLLT and control groups

group	number of patients		cause of extractions		averaged age
	male	female	dental	periodontal	
LLLT(n=11)	7	4	9	2	51.4
Control(n=8)	7	1	7	1	51.0
Total(n=17)	14	5	16	3	51.2

Table 2. Means and standard deviations of visual analogue scales measured with time in the LLLT and control groups and results of repeated measures ANOVA test

group	n	Day0	Day1	Day2	Day3	Day4	Day5	Day6	p value
LLLT(n=11)	11	2.5±2.1	1.6±2.1	1.0±1.9	0.2±0.6	0±0	0±0	0±0	<0.0001
Control(n=8)	8	5.0±3.7	4.2±4.3	2.5±3.6	2.9±3.7	1.2±2.2	0.9±1.7	0.5±1.1	
p value					0.591				

Table 3. Means and standard deviations of the numbers of analgesic use measured after extraction of tooth in the LLLT and control groups and results of unpaired t-test

group	n	number of analgesic use	p value
LLLT	11	1.3±2.1	<0.0223
Control	8	6.5±6.5	

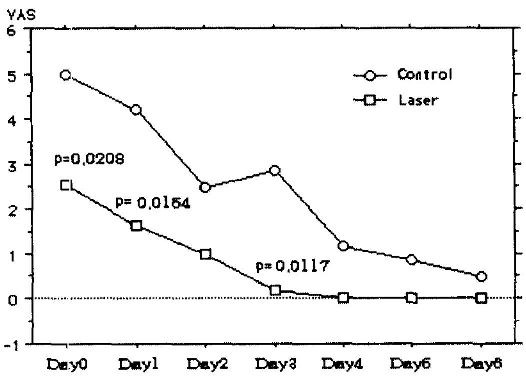

Figure 1. Linear graph showing the change of VAS with time in the LLLT and control groups

Table 4. Means and standard deviations of the duration of analgesic use measured after extraction of tooth in the LLLT and control groups and results of unpaired t-test

gruop	n	duration of analgesic use (hour)	p value
LLLT	11	12.4±21.3	<0.0177
Control	8	62.7±59.1	

analgesic use for the LLLT and sham irradiation groups and the results of unpaired t-test are given in Table 3 and 4. The number and the duration of analgesic use in the LLLT group were both decreased significantly compared with that in the sham irradiation groups. This means that LLLT had a significant effect on the control of pain in the extraction wound as measured by the number and the duration of analgesic use.

IV. DISCUSSION

Recently, there has been an increasing amount of interest in the application of low reactive level laser therapy (LLLT) for wound healing[11,13-16] and pain attenuation or pain removal in different acute and chronic pathological illness[17,18]. However, the mechanisms by which LLLT works are not yet full understood.

Lee et al.[11] and Kim et al.[16] also suggested a hypothesis on the acceleration of healing in the infected lesion following GaAs LLLI. They postulated that the biostimulation of LLLI in the surrounding normal tissue predominated over the destructive irritation due to the bacterial growth in the infected lesion. They showed that the healing of wounds infected with S. aureus was accelerated by LLL irradiation regardless of the irradiation type and the pulse type[16].

In this study Pulse 13(6000Hz, 14mW average output power) was used, although it was proved to stimulate the growth of S. aureus[12]. It is, however, not believed that the pulse type used may be effective on the results of this study, because the normal cells of vital tissues were stimulated unlimitedly by LLLI in vivo compared with microorganisms of a confined petridish in vitro and therefore, some inhibitory doses of LLLI in the cell culture level might be a stimulatory doses in the tissue or organ level[16].

It is certainly said that, in order to interact with tissue, light has to be absorbed by chromophores in the cell. Lubart et al.[19] found that singlet oxygen is generated in the cells during HeNe (630 nm) irradiation. Porphyrins have an intense absorption band in the 360 nm region, and four additional bands with decreasing intensity at 502 nm, 540 nm, 560 nm and 630 nm. Porphyrins are known to be excellent photosensitizers through generation of the lowest excited singlet state of the oxygen.

In this study, GaAs semiconductor laser, of which wavelength is 904 nm, was used instead of HeNe laser(630nm). As mentioned above, porphyrins do not have absorption bands in the 904 nm region. Nontheless, GaAs laser irradiation increased the growth of S. aureus in a specific range of energy density significantly. Therefore, Singlet oxygen generation theory failed to explain this result, although it can be partially acceptable in the region of visible light, and a different mechanism should be considered.

To explain the biostimulation effect of low level irradiation at 633 nm, Karu[20] proposed a chain of molecular events starting with the absorption of light by a photoreceptor, which leads to signal transduction and amplification, and finally results in the photoresponse. This model also suggests an explanation for why radiation at 904 nm can produce biological effects similar to those produced by radiation at 633 nm. In this model, radiation at 633 nm triggers, probably by photoactivating enzymes in the mitochondria, a cascade of molecular events leading to the photoresponse. Smith[21] suggested that radiation at 904 nm produces the same final response, but initiates the response at the membrane level (probably through photophysical effects on Ca^{++} channels) at about halfway through the total cascade of molecular events that leads to biostimulation. It can be summarized that if the biological effect of low level visible light therapy is through photochemistry (probably the photoactivation of enzymes), the biological effect of infrared radiation is through molecular rotations and vibrations. Abergel et al.[22,23] reported that the irradiation of fibroblasts in culture either at 633 nm or at 904 nm increased the synthesis of collagen. Kim et al.[3,9,10] reported that GaAs laser (904 nm) enhenced the protein and DNA synthesis and accelerated the proliferation of the gingival fibroblast.

Halevy et al. reported that 780 nm low power diode laser irradiation promotes wound healing, presumably by enhancing porliferation of fibroblasts and keratinocytes[24]. This study also suggests that 904 nm GaAs diode laser irradiation promotes wound healing, inhibiting complications such as infection and pain. On the basis of these studies, it is reasonable to accept Smith theory that different wavelengths of LLLT have identical biologic effects at cell level through molecular rotations and vibrations.

It was reported that the HeNe laser irradiation over the mouse liver or spleen area may enhance the ability to clear carbon particles from mouse blood and this means HeNe laser irradiation may activate the macrophages to engulf and remove foregin materials with greater efficiency, a very important aspect of the body resistance to pathogenic microorganisms. In addition, it was suggested that irradiation with HeNe laser at appropriate energy densities may increase the lysozyme amounts and the acid phosphatase activity. It thus indicates that the HeNe laser may exert photobioactivating effects on mouse macrophages. This may be one of the mechanisms of the antiinfection action of the HeNe laser[25].

The changes in the redox status of both the mitochondria and the cytoplasm after LLLT exert an effect on membrane permeability and transport, with changes in Na^+/H^+ ratio and an increase in Na^+K^+ATPase activity which in turn has an effect on the Ca^{++} flux. The Ca^{++} flux affects the level of cyclic nucleotides, which modulate DNA and RNA synthesis, which in turn modulate cell proliferation. It is also said that the magnitude of the photobioactivative effect of lasers depends on the physiological state of the cell at the moment of irradiation. In other words, the incident cells are growing poorly at the time of irradiation or are otherwise compromised. Thus if a cell is fully functional, there is nothing for laser irradiation to stimulate and therefore no therapeutic benefit will be observed[26].

It seems from the Osanai in vitro study that, for shorter irradiation times and weaker output powers, the phagocytic action of neurtophils is higher, the time to reach maximum action shorter, and neutrophil chemotaxic action stronger[27].

In this study only one irradiation of LLLT was performed immediately after extraction and the time of irradiation was short, and the physiological state of irradiation area was very poor. It is, thus, thought that LLLT in this study stimulated the cells around wound and had a therapeutic benefit on the wound healing.

The results in this study provide a clear indication that LLLI with the 904 nm GaAs laser porvides beneficial effects in the healing of extracted wounds, and that LLLI would be a beneficial supportive modality for the treatment of oral wounds. Although the mechanisms of both pain attenuation and wound healing remain as yet unclear, it is believed that the pain control of extracted wound in this study should be obtained from anti-infection action[25] as well as analgesic effect[17,18] of LLLT.

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국문초록

904 nm의 펄스형 다이오드 저수준레이저광조사가 발치창에 미치는 효과

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본 연구에서는 904 nm의 다이오드 레이저를 발치창에 조사하여 효과를 분석하고, 동물실험에서 제시된 가설 즉 레이저 광조사가 주위정상조직을 자극하여 창상치유를 촉진하고 진통, 항염증효과가 있는지를 간접적으로 확인하고저 하였다. 먼저 19명의 발치환자에게 발치후 즉시 1분간 평균 14mW의 저수준레이저를 조사하였다. 이들중 8명은 대조군으로서 위조사(sham-irradiation)하였다. 일주일동안 시간경과에 따른 동통의 정도, 진통제의 사용횟수, 진통제 사용기간등을 각각 조사하였다. visual analogue scale로 두군에서 동통의 정도를 비교한 결과 대조군 보다 레이저조사군에서 동통이 유의하게 감소하였으며, 진통제의 사용횟수와 기간도 레이저조사군에서 유의하게 감소하였다. 이러한 결과로 보아 비록 1분간의 적은 량의 레이저 조사라도 발치후 합병증을 억제하여 동통을 억제하고 치유를 촉진한다고 사료된다.

Key words: LLLT, wound healing, GaAs diode laser, pulsed laser, extraction wound