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Haemostasis in Oral Surgery with Blue-Violet Light

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Abstract

BACKGROUND: The invasive dental procedures usually result in wounds accompanied by physiological bleeding. Even though the bleeding is easily manageable, it is still one of the major concerns of the patients and a reason for their subjective discomfort. Recently, a novel approach with light-emitting diode (LED) was introduced to control the bleeding. This study aims to examine the effectiveness of the irradiation with blue-violet light LEDs on the haemostasis.

MATERIAL AND METHODS: The study included 40 patients with an indication for tooth extraction, divided into two groups: examination group (n = 30) and a control group (n = 10). The site of the extraction socket in the examination group was irradiated with LED (410 nm) until the bleeding stopped. The patients from the control group were treated by conventional gauze pressure to stop the bleeding (control group). The duration of irradiation and gauze pressure was measured and compared. The statistical analysis was performed with Student T-test.

RESULTS: The examination group showed the shorter duration of bleeding compared to the control group for 13.67 seconds and 156 seconds, respectively. The most of the cases in the examination group were irradiated in 10 seconds (70%), followed by irradiation of 20 seconds (23.3%) and 30 seconds (6.6%). In the control group, the average time to stop the bleeding by the conventional method was 156 second.

CONCLUSION: The blue-violet LED light shortens the bleeding time from the extraction socket after tooth extraction and may be a promising method for achieving haemostasis.

Introduction

Light presents a spectrum of electromagnetic particles that travel in waves. The shorter the wavelength is, the higher the energy. On one end of the visible light spectrum, there are the blue light rays with the shortest wavelengths (and highest energy) and this area of light is called blue-violet or violet light. This is why the invisible electromagnetic rays just beyond the visible light spectrum are called ultraviolet (UV) radiation (Figure 1). The blue light has a wavelength of approximately 380nm to 500nm; making it one of the shortest and highest-energy wavelengths.

The blue light heightens the reaction times, elevates moods, boosts awareness and increases the feeling of well-being. Artificial sources of blue light include electronic devices (cell phones, laptop computers) as well as energy-efficient fluorescent bulbs and light-emitting diode (LED) lights [1]**.** A LED is a two-lead semiconductor light source (p-n junction diode) which emits light when activated [2]. The "p" (positive) side contains an excess of holes, while the "n" (negative) side contains an excess of electrons.

When a suitable voltage is applied to the leads, electrons can recombine with electron holes within the device and energy is released in the form of photons. This effect is called electroluminescence, and the colour of the light corresponds to the energy of the photon [3].

Blue LEDs were first developed by Herbert Paul Maruska in 1972 using gallium nitride (GaN) on a sapphire substrate [4] [5]. Nakamura, Hiroshi Amano and Isamu Akasaki were awarded the Nobel Prize in Physics in 2014 for the invention of the blue LED [6]

[7].

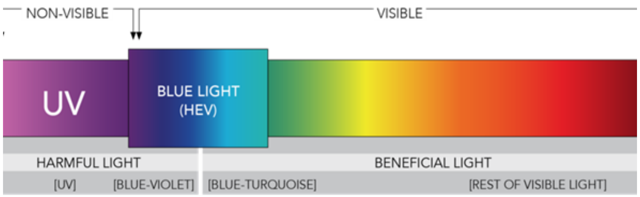

Figure 1: Location of blue light wavelengths in the spectrum

The invasive dental procedures usually result in bone and soft tissue wounds accompanied with physiological bleeding during the first few minutes. The most common technique to stop the postoperative bleeding is the superficial tamponade, i.e. placing gauze and applying pressure on it in the duration of 10-15 minutes. In patients without systemic diseases, disorders of the bleeding, coagulation or blood vessels and those who do not take any medications for altering the bleeding, this approach is appropriate enough to control the bleeding. However, even though the bleeding is easily manageable, it is still one of the major concerns of the patients and a reason for their subjective discomfort. Post-extraction dental sockets are filled with blood immediately after tooth extraction. The haemoglobin from the red blood cells has the strong light-absorbing capacity [10]. The absorbing haemoglobin can transform the light from the LED irradiation into heat energy on the bleeding surface (photocoagulation).

Some devices that are used in everyday dental practice for photopolymerisation of the composite fillings (LEDs) emit blue-violet light with a wavelength of 380-515 nm with two peaks (410 nm and 470 nm). These wavelengths can cover most of the absorption ranges of haemoglobin (430 nm). Control of bleeding is a major problem during oral-surgical interventions.

The study aims to examine the effectiveness of the new revolutionary method of irradiation with blue-violet light (LEDs) in achieving rapid and effective haemostasis.

Material and Methods

The study included overall 40 patients at the Clinic for Oral Surgery and Implantology at University Dental Clinical Centre "St. Pantelejmon" in Skopje, scheduled in appropriate time periods for oral surgical interventions. The written informed consent (Declaration of Helsinki**)** was obtained from all patients with their signature before starting with the treatment protocol.

In the questionnaire, appropriate data were noted, such as age and sex of the patient, type of intervention, localisation of intervention, duration of intervention and postoperative condition. The age of the patients varied from 20 to 80 years. The reasons for extraction were gangrenous dental radices, periodontitis, chronic apical periodontitis (HAP) and prosthodontic reasons for extraction (teeth that were not included in the prosthodontic treatment). Exclusion criteria were as follow: patients with the compromised general medical condition, patients under 18 years, pregnant women, patients who received anticoagulation medication and patients with systemic bleeding disorders.

Dental extractions were performed under local anaesthesia Scandonest 2% (Septodont, United Kingdom), consisting of mepivacaine hydrochloride 2% with epinephrine 1:100.000. After the tooth extraction, the surgical debridement (granulation tissue curettage) was done. The LED irradiation was performed on 30 patients over the extraction socket for 10 seconds and an additional 10 seconds in those clinical cases where bleeding continued. The same operator irradiated the bleeding socket with LED light from a distance of 1 cm from the surgical site (Figure 2a, b). Another 10 patients were treated by conventional gauze pressure to stop the bleeding (control group).

Figure 2: A) Extraction socket just after extraction of the maxillary right second premolar with obvious bleeding B) Extraction socket after LED irradiation

The study used LED device (Ivoclar Vivadent-Bluephase C5) with wavelengths of 380-515 nm and two peaks (410 nm and 470 nm) according to the protocol of Prof. Isao Ishikawa (Tokyo Women's Medical University, Tokyo, Japan) [11].

Protocol for blue-violet LED (380-515 nm) irradiation (Prof. Isao Ishikawa) includes:

- Light guide aperture: 1 cm in diameter (0.785 cm^2).

- 750 mW/cm^2 at a distance of 1 cm from light emitter aperture.

- Irradiation area: approximately 1.25 cm^2.

- The irradiation time of 10 sec equals energy 50 joules and an energy density of 7.5 J/cm2.

- The irradiation time of 20 sec equals energy 100 joules and an energy density of 15 J/cm^2.

Bleeding time for both procedures was measured. Bleeding time was defined as the length of needed time to stop the bleeding from the extraction socket after a gentle wipe with a piece of gauze. After seven days the extraction sockets were reexamined to confirm the healing process.

The obtained data and values of the duration of bleeding were collected and statistically analysed using the statistical software SPSS Statistics, v. 20. Student t-test was used to compare the means of the values. The significance for p-value was set to 0.05.

Results

The mean age of the patients in the experimental group was 51, while in the control group it was 53 years. In the examination group, most of the teeth were indicated for extraction due to periodontal disease and prosthodontic needs. In the control group, the most frequent reason was the periodontal disease (Table 1).

Table 1: Distribution of the indications for tooth extractions in both groups

Indication for extraction	*Examination group (n=30)*		*Control group (n=10)*	
	Count	Percentage	Count	percentage
Periodontal disease	9	30%	4	40%
Proshtodontic needs	9	30%	2	20%
Remained necrotic root	5	16.6%	3	30%
Chronic periapical disease	7	23.3%	1	10%

The examination groups showed the shorter duration of bleeding compared to the control group for 13.67 seconds vs 156 seconds, respectively. The statistical difference was very strong (p = 0.000), (Tables 2 and 3).

Table 2: Means of the duration of bleeding in both groups

	Group	*N*	*Mean*	*Std. Deviation*	*Std. Error Mean*
Duration of bleeding	Examination group	30	13.67	6.149	1.123
	Control group	10	156.00	57.966	18.330

The most of the cases in the examination group were irradiated in 10 seconds (70%), followed by irradiation of 20 seconds (23.3%) and 30 seconds (6.6%). In the control group, the average time to stop the bleeding by the conventional method was 156 second.

Table 3: Significance of the values of bleeding between the groups (Student T-test)

		t	*df*	*Sig. (2-tailed)*
Duration of bleeding	Equal variances assumed	(13.574)	38	0.000
	Equal variances not assumed	(7.750)	9.068	0.000

The means of the duration of surgical procedure and significance of the difference of the values of duration of surgical procedures are presented in the Tables 4 and 5.

Table 4: Means of the duration of surgical procedure between the 10 seconds and > 10 seconds LED irradiated patients from the examination group

	Duration of irradiation	*N*	*Mean*	*Std. Deviation*	*Std. Error Mean*
Duration of surgical procedure	10 seconds	21	15.3571	1.63663	0.35714
	>10 seconds	7	19.2857	4.00892	1.51523

Discussion

The haemostasis is a complex process consisting of different steps, involving some cells and factors. The main purpose of this process is to stop bleeding by mechanical mechanisms of reparation of the injured blood vessels and clotting of the leaked blood. The first step is the vascular spasm as a first response to the injury.

Table 5: Significance of the difference of the values of duration of surgical procedures between the cases irradiated for 10 seconds and those irradiated for longer than 10 seconds, in the examination group

		t-test for Equality of Means			
		T	*df*	*Sig. (2-tailed)*	*Mean Difference*
Duration of surgical procedure	Equal variances assumed	(3.748)	26	0.001	(3.92857)
	Equal variances not assumed	(2.524)	6.679	0.041	(3.92857)

The vessels get constricted, and the blood flow decreases. Then, the platelets aggregate and release factors which further improve the vasoconstriction. The second step consists of the formation of the platelet plug, which depends on some factors from the plasma. The third step is the process of coagulation, which can be enhanced by the intrinsic or extrinsic pathway. Some coagulation factors are involved, and the final result is the formation of fibrin around the platelet plug, representing the blood clot.

The process of haemostasis after tooth extraction is enhanced by applying dressing pressure with gauze, for the duration of 10 minutes. The normal ranges of bleeding time by Duke are from 2-5 minutes [12]. In this time frame, it is expected the bleeding to stop. However, because the wound that is caused by such invasive procedure is sometimes bigger than just a simple blood vessel injury, the gauze is left in place for extended period of time. The other methods to control the bleeding are used usually when extensive bleeding is present.

The electrocoagulation is an effective way to stop the bleeding [13]. This is a physical method which includes heat and causes almost immediate bleeding stop. However, the risk of damaging the surrounding soft and bone tissues make this approach only acceptable where very extensive and uncontrolled bleeding is present.

Various materials, such as hemostatic agents, gelatin sponges, hemostatic gauze and collagen have been used to help stop bleeding [14]. Also, various lasers are used in oral surgery because of their excellent cutting and hemostatic effects. The laser's effects are due to three phases included in the mechanism of photocoagulation. The first phase consists of heating effects, followed by formation of spherocytes and met-haemoglobin. Finally, extended coagulum formation happens due to spherocyte rupture [11]. Thermal damage and carbonisation of the underlying soft and hard tissues could be possible complications after laser irradiation [15]. The high financial cost of the laser apparatus could be a barrier for its wide application in dentistry.

LEDs are used for the photopolymerization of composite resin fillings. The device Ivoclar Vivadent-Bluephase C5 was used in our study because it emits a wide range of blue-violet specific wavelengths (380-515 nm) and two peaks (410 nm and 470 nm). These wavelengths can cover most of the absorption ranges of haemoglobin (430 nm).

Blue-violet LED irradiation immediately controlled postextraction bleeding in our study. The photothermal interaction caused superheating of the blood, absorption and scattering of the energy, surface condensation of proteins, and vaporisation of blood fluid followed by coagulation.

In the statistical analysis of the results, we obtained a significant association of the analysed parameters. Irradiation with blue-violet LEDs causes immediate haemostasis of extraction socket after 10 sec; some cases still needed additional 10 sec. A double length of irradiation was needed in 23.3% of the cases, while the triple length in only 6.6% of the cases. The examination group showed almost immediate bleeding stop after applying LED light, compared to the control group. These findings are very similar to the findings from author Isao Ishikawa et al., which tested the effects of LED on postoperative bleeding in oral surgery [11]. The duration of the irradiation needed to stop the bleeding in our study was also similar to his results.

A conventional method stops the bleeding for 2-5 min (mean interval 180 sec). LED irradiation of the extraction alveoli caused the immediate formation of a blood clot and achieved stable haemostasis. The LED application provided rapid haemostasis and better coagulum filling than conventional pressure dressing.

- Postoperative side effects were not noted

- The healing of the extraction site was uneventful

The transmission electron microscopy of the blue-violet LED irradiated blood clot found out a unique structure of the clot (photothermal interaction with the blue-violet LED). On the surface of the LED irradiated clot, there was a thin amorphous layer of denatured plasma proteins (about 50-1500 nm) [11]. This amorphous layer is clinically presented as a shiny surface of the LED irradiated blood clot. Beneath the layer, many agglutinated platelets and other cellular elements (red blood cells, leukocytes) supported the layer and formed a blood clot. Red blood cells seemed to keep their normal morphologies. In laser irradiation, the spherocytes and their rupturing are present extensively, and it crosses the phase of absorption of the wavelength from the haemoglobin. In our study only wavelength that is enough to cause photocoagulation was used. Therefore, the LED light has considerably slighter effects on the wound healing, compared to the laser light [11]. The LED application is less harmful to the eyes than lasers and is less expensive. However, it is known that the light is often unable to penetrate more than 2-3mm into the composite [16]. LED irradiation never causes adverse effects on the surrounding tissues.

LED photocoagulation may produce not only rapid haemostasis but also the acceleration of periodontal tissue healing. The LED application has the potential to benefit periodontal photo-engineering and bone repair processes. This better coagulum formation may result in early tissue repair with minimal alveolar bone resorption. Pinheiro and Gerbi [17] reviewed the recent studies of photo-engineering of accelerated bone repair processes by low-level laser irradiation and mentioned that fibrin on a coagulum would act as a framework for cell migration during bone healing. Based on these findings, it seems possible that the role of photomedicine, including photo engineering, will be recognised and applied in oral treatment shortly.

The results of a study where LED irradiation was implemented in combination with gelatin sponge in patients taking warfarin showed effects of enhanced haemostasis in 30 seconds [18]. This finding is of particular importance because no sutures and further invasive measures were undertaken in this group of patients, who usually need additional measures of bleeding control due to the changed coagulation process. The study supports the photocoagulation effects on the platelet aggregation and further improved blood clotting, which is the late phase of the haemostasis process. However, these statements should be further examined in more details.

Another study showed that LED light enhances the cell and immune response to some of the bacteria specimens involved in the developing of the periodontal disease [19]. It is well known that the stable and appropriate coagulation is a first and a very important step in the process of wound healing. Favourable healing means no postoperative complications and less bone defect and resorption. When all these factors are combined, it becomes clear that the LED irradiation may positively affect both the immediate and later wound healing.

In conclusion, the blue-violet LED light with a wavelength of 410 nm significantly shortens the bleeding time from the extraction socket after a tooth extraction. It may be a promising method for controlling the bleeding in healthy patients. There is a need for future research in this field, and the possible effects in patients with bleeding disorders should be evaluated, as well.

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