Biomedical Research 2017; 28 (9): 4228-4232

ISSN 0970-938X
www.biomedres.info

Assessment of bone vascularity in the posterior maxilla during dental implant insertion by laser Doppler flowmetry.

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Abstract

Bone quality is an important factor that may determine implant success. In addition to the other parameters that define bone quality, vascularity plays a vital role in the process of osseointegration of dental implants. Laser Doppler flowmetry (LDF) is an appropriate method for assessment of tissue vascularity at the level of microcirculation. It is non-invasive, painless and well accepted by the patients. The results are expressed in Perfusion Units (PU). The aim of this study was to estimate bone vascularity in the human posterior maxilla during implant insertion using LDF. Nine patients, three females and six males, mean age 57.56 ± 8.83 years, consecutively treated with 54 implants were enrolled in this study. Implants were inserted in the posterior maxilla, in positions of first premolar, second premolar and first molar bilaterally in each patient. After implant site preparation with a drill of diameter 2.8 mm, bone vascularity was measured using LDF. Mean LDF value for 54 osteotomy sites was 43.39 ± 14.65 PU. Results of the present study showed there wasn't statistically significant difference in LDF values between implant site positions and genders. It was also revealed that the proximity from the apical part of the implant site to the maxillary sinus floor had no influence on LDF values. Therefore, bone vascularity in the posterior maxilla could be measured by LDF during implant insertion, and those results might be considered as a standard data for this part of the upper jaw.

Keywords: Bone vascularity, Posterior maxilla, Dental implants, Laser Doppler flowmetry.

Accepted on March 6, 2017

Introduction

The success of implant therapy depends on many patient- and procedure-related factors. These factors include patient health condition, implant material biocompatibility, implant design and chemistry of the surface, the surgical procedure as well as quality and quantity of local bone at the surgical site [1,2]. Clinical reports suggest that dental implants have lower survival rates in maxilla than in mandible, especially in posterior maxilla [3-5]. The basic cause of this difference is poor quantity and quality of maxillary bone. Assessment of bone quality prior to implant insertion can help dental practitioners to make adequate treatment plan.

Bone quality is often considered as equal as bone density, but in the definition of bone quality many factors are important: bone vascularity, bone metabolism, cells turn over, mineralization, maturization, intercellular matrix, and others which may affect implant outcome [6]. During the process of osseointegration, bone vascularity and formation of new vascular tissue is crucial for bone tissue differentiation and ossification [7]. Development of a vascular system is the most important factor after implant insertion for the delivery of oxygen and nutrients and removal of cell debris. This also allows the cytokine signals to reach the osteocytes and osteoblasts [8,9]. The healing process after implant insertion begins from hematoma to woven bone formation, bone remodeling and the formation of new bone, leading to the osseointegration [10,11]. The first tissue that implant surface will contact after insertion is blood. This contact will initiate a series of biological processes that lead to tissue formation. So, good level of osseointegration of dental implants depends on development of vascular system of peri-implant bone [11].

Tissue vascularity at the level of microcirculation can be assessed by Laser Doppler Flowmetry (LDF). This method is non-invasive and painless, and the results are objective and reproducible [12]. It has been used for detection of blood flow in oral mucosal, pulpal, muscular, gingival and bone tissues

[13-19]. In a recent clinical studies LDF was used for assessment of bone vascularity during implants insertion [20,21], and it has been shown that the obtained results can predict future osseointegration [21]. Previous experimental studies have shown that LDF is an adequate method for assessment of bone vascularity and, as derivation bone quality [19,22]. This is especially important when considering implant insertion in irradiated bone where the main problem for successful osseointegration represents decreased bone vascularity [19,23].

This method is based on a phenomenon known as the Doppler Effect which means a change in frequency of light after reflecting from blood cells in motion. The first LDF techniques used laser light with wavelength of 632.8 nm [24] and later it was increased to 780-820 nm [19,20]. Helium-neon laser light is directed through the optical fiber probe to the surface of tissue where the flow is examined. Reflected light returns to the photo detector, which is located in the probe, where converts into an electric impulse which is expressed in Perfusion Units (PU) by laser Doppler device software. PU represents the blood velocity in the tissue [12].

The objective of the present study was to estimate bone vascularity in human posterior maxilla during implant insertion using LDF, in order to provide a standard data for bone vascularity in this region.

Materials and Methods

The study was performed at the Clinic of Oral Surgery, School of Dentistry, University of Belgrade, Serbia. Ethical approval was obtained from the local Ethics Committee (No. 36/48). Nine patients were enrolled in the study. Three females and six males consecutively treated with 54 implants (Straumann Tapered Effect (TE) SlActive, Ø 4.1/4.8 mm, 8 mm length). Implants were inserted in the posterior maxilla, in the positions of first premolar, second premolar and first molar bilaterally in each patient. Patients were given a detailed explanation of the forthcoming surgery and possible complications, and all signed an informed consent form.

The patients were included in the study following the next criteria:

a) Patients of American Society of Anesthesiology (ASA) I patient classification (i.e. normal, healthy patients);

b) Patients with bilateral terminal edentulous spaces distal to the canine in the maxilla.

c) Adequate oral hygiene.

d) Non-smokers.

e) Patients without oral para-functions (bruxism).

Preoperative planning was based on clinical and radiographic examinations. Computerized tomography scans (Somatom sensation 16, Siemens, Erlangen, Germany) were used for determination of available bone volume. Distance from the apical part of the implant site to the maxillary sinus floor was measured at the cross-sectional images. To avoid the influence of vasoconstrictor on the blood flow, local anesthesia was achieved using 0.75% ropivacaine without vasoconstrictor (0.75% Naropine, AstraZeneca, Sweden).

After application of local anesthetic, middle crest incisions were performed in both edentulous sides of maxilla, and mucoperiostal flap was elevated. Surgical guide was used for determination of implant positions. Three pilot osteotomy sites were prepared at the positions of first premolar, second premolar and first molar bilaterally with a drill of a diameter 2.8 mm. The LDF device with laser light of 780nm (PeriFlux System 5000, Perimed, Sweden) was used for blood flow recordings. Before the recording sessions flowmeter was calibrated with a colloidal suspension of latex particles (Perimed Motility Standard, Jarfalla, Sweden). The special optical fiber probe with a diameter of 2.8 mm (PF 415, PeriFlux System, Perimed, Sweden) was used for laser light transmission to the implant site. The probe was inserted in the pilot osteotomy site at a standard depth of 8 mm. The diameter of the probe was the same as the pilot osteotomy site and additional holders or handholding of the probe was not needed. Before each measurement implant sites were rinsed with saline solution and patients were in a semi-reclined position in dental chair to avoid disturbing movements [19]. The flowmeter was connected to a personal computer for calculating the recordings. Four recordings were performed for 20 seconds in each implant site with the probe directed to the mesial, distal, buccal and lingual wall. The average LDF value of four recordings was considered as bone vascularity at implant site. The results were expressed in Perfusion Units (PU) [19,20]. After vascularity measurement, the preparation of implants sites was finished, and implants were inserted according to manufacturer recommendation.

Statistical analysis

Data were analysed by SPSS statistical software (SPSS Inc., Chicago, IL, USA). Shapiro-wilk test was used for data distribution analysis. For the comparisons between the different implant site positions, Kruskal Wallis test was used. Mann Whitney U test was used to verify possible differences between genders. A correlation between LDF values, age and distance from the maxillary sinus floor was evaluated by Spearman's rho test. Statistically significance was determined as $p<0.05$.

Results

Nine patients (six males, and three females, mean age 57.56 ± 8.83) were enrolled in this study. Mean value of LDF for 54 pilot osteotomy sites was 43.39 ± 14.65 PU.

Comparing the values for LDF between the different implant site positions, i.e. first premolar, second premolar and first molar, no statistically significant differences were found (Table 1).

Table 1. *Bone vascularity at different implant site positions.*

Implant site position/PU (mean ± SD)						
Right			**Left**			**p value (Kruskal Wallis Test)**
1st premolar	**2nd premolar**	**1st molar**	**1st premolar**	**2nd premolar**	**1st molar**	
41.20 ± 17.06	36.43 ± 11.69	45.41 ± 12.40	40.32 ± 12.40	38.73 ± 20.69	45.77 ± 21.43	0.618
Total 43.39 ± 14.65						

Mean LDF value of the 30 pilot osteotomy sites of the 5 men was 45.31 PU, and standard deviation 12.51. Mean LDF value of the18 pilot osteotomy sites of the 3 women was 40.20 PU, and standard deviation 20.34 PU (Table 2). Mann-Whitney U test showed that there is no statistically significant difference in LDF values between genders (p=0.571). The proximity from the apical part of the implant site to the maxillary sinus floor is presented in the Table 3. There is statistically significant difference in mean distance comparing different implant sites positions (p<0.05).

Table 2. *Distribution of LDF values between genders.*

Gender	No. of patients	No. of Implants	PU/Mean ± SD	p value (Mann-Whitney U test)
Women	3	18	40.20 ± 20.34	0.571
Men	6	36	45.31 ± 12.51	
Total	9	54	43.39 ± 14.65	

Table 3. *Distance from the apical part of implant site to the maxillary sinus floor.*

Implant site position/PU (mean ± SD)						**p value (Kruskal Wallis Test)**
Right			**Left**			
1st premolar	**2nd premolar**	**1st molar**	**1st premolar**	**2nd premolar**	**1st molar**	
6.73 ± 2.21	4.13 ± 2.80	2.56 ± 2.92	5.90 ± 1.77	3.15 ± 2.42	1.79 ± 1.30	0.001
Total 43.39 ± 14.65						

Spearman's correlation coefficient showed statistically insignificant correlation between age and LDF values (p=0.82), and also there was no correlation found between LDF values and distance from the sinus floor (p=0.5).

Discussion

Bone quality at implant recipient sites is one of the most important factors that will determine future osseointegration. Accurate assessment of implant recipient sites prior to implant insertion is crucial for proper treatment planning. There are different radiographic modalities suggested for assessment of bone quality [6], but recently LDF has been introduced as a valid method of determining bone vascularity as an important parameter of bone quality [20].

There are only two clinical studies that investigated bone vascularity in humans during implant insertion [20,21]. To the best of authors' knowledge this is the first study considering bone vascularity in posterior maxilla measured by LDF.

Having in mind the importance of bone vascularity in the process of osseointegration, the aim of this study was to assess the vascularity in posterior maxilla in patients receiving dental implants, using LDF.

In the present study, for recording bone vascularity six pilot osteotomy sites at the position of first premolar, second premolar and first molar bilaterally were drilled in each patient. There were 54 implant sites assessed in this study. The mean value of bone vascularity measured by LDF was 43.39 PU. The first study that investigated jaw bone vascularity during implant insertion was conducted by Verdnock et al. [20]. They found that mean LDF value at 41 pilot osteotomy sites in anterior mandible of 23 patients, was 25.80 PU. These results much differ from the results of our study. This difference can be explained by bone density variations of upper and lower jaw, due to the predominance of trabecular bone in the upper jaw, considering the fact that trabecular bone is ten times more vascularized compared to the cortical bone [9]. In the study of Kokovic at al. [21], that investigated bone vascularity in posterior mandible, mean bone vascularity at 36 implant sites of 6 patients was 53.05 PU. Result of this study was not in correlation with our results since it would be expected that bone vascularity is greater in the posterior maxilla than in the posterior mandible due to difference in bone structure. This disparity may be explained with differences in data collection, since the probe used in the study by Kokovic was different diameter. For the reproducibility of the results, LDF measurements have to be standardized, and future studies are needed to compare present methodology.

The results showed, there was no statistically significant difference between different implant site positions (Kruskal-Wallis test, p=0.618). Considering the influence of gender on the results, there was no found significant difference between males and females (Mann-Whitney U-test, p=0.571), which is similar to results of previous studies [20,21].

This study confirmed observations of the previous studies, that jaw bone vascularity can be measured by LDF during implant insertion, and those results can be considered as a standard data for bone vascularity in posterior maxilla. Edentulous posterior maxilla often requires bone augmentation before implant insertion, due to deficient alveolar ridge after tooth loss and sinus pneumatization. Revascularization of nonvascular bone grafts is very important in healing process [25]. It has been shown in earlier investigations that LDF can be used for measurement of maxillary sinus bone grafts vitality [26,27].

As a valid method for determination of bone vacularity LDF might be used as an alternative or complement to the other methods for determination of bone quality at implant recipient sites. Future studies have to confirm is there influence of LDF values on implant stability during osseointegration or crestal bone loss after implant loading in posterior maxilla. Also it would be interesting to investigate the correlation between LDF and radiographic methods for bone quality assessment.

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