ARTICLE IN PRESS

Measurement xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Measurement of temperature change during the implant site preparation to determine influence of tool characteristics

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ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Temperature measurement
Bone drilling
Drill tip angle
Osteonecrosis

ABSTRACT

Implant site preparation procedure is the most important factor that affects early osseointegration performance of a dental implant. During the side preparation procedure increase in the bone temperature above critic limit causes irreversible osteonecrosis. This heat rise compromises implant area around implants thus ending with unsuccessful osseointegration outcomes.

In this experimental study drill tip geometry, drill tip angle and drill sharpness affects on procedure temperature were investigated. Experiments were carried on fresh bovine bones and implant sites were prepared individually for each experimental set.

1. Introduction

Today different kind of dental implant surfaces, geometries and materials are being developed to overcome early implant failures and to lengthen implant duration in the mandible. Bone is an anisotropic material with organic and inorganic components. Also, its microarchitecture and density is changeable according to mechanical and physical affect such as loading conditions and hormonal affects [1–3]. There are numerous works focused on implant osseointegration performance to prevent implant failures. The following reports investigated effective factors for osseointegration performance by various authors: implant surface modification [4–8], implant materials [9,10], implant geometry [11,13], dental drills [12,14] and surgical technique [15,16]. All of these factors influence loosening of dental implant-bone interface, consequently osseointegration performance. Among these, dental drills and surgical technique has crucial effect on early osseointegration period. Determining optimum procedure parameters enables to decrease procedure temperature, prevent osteonecrosis and implant failures as well.

Implant site preparation procedure is a drilling procedure which causes friction and heat rise in the bone [17,18]. This friction and heat rise conduce osteonecrosis which result in problem during osseointegration and consequently mechanical misfits of dental implant [17]. During implant site preparation bone temperature must be below 47 °C to prevent necrosis [19,20]. Thermal damage to the cells in this area may cause failure and miss fixation of the implant. Implant success is strongly correlated with the quantity and quality of bone in the implant recipient site. From this point of view minimization of the heat rise in bone-implant interface increases osseointegration performance and decreases failure risks. In the literature there are studies for understanding the effect of factors to the implantation success by identifying favorable drilling conditions, bone behavior and drill geometries [14,21–26].

The aim of this experimental study is to obtain the relation between factors that will contribute to the

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http://dx.doi.org/10.1016/j.measurement.2015.05.046
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temperature attained include drill tip angle, drill coating, usage duration of drill (drill sharpness and tip degenerations) and the application of coolant. The experimental design was made by means of Taguchi Method. Data were analyzed using descriptive statistics. Statistical analyses were conducted with ANOVA. The quality characteristics for analysis considered as lowest temperature during the procedure. After experimental study the optimum parameters are determined according to these analyze results.

2. Material and method

The experimental set up was built as close as real dental drill conditions as seen in Fig. 1. For this purpose a medical slow hand piece (NSK, Nakanishi Inc., Tokyo, Japan) and irrigation system were used. The drilling parameters were controlled by the slow hand piece. The constant movement of slow hand piece in the *y* direction was controlled by the computer with 5 mm/sn velocity. Cutting speed was 800 Rpm under constant torque automated by the slow hand piece. The irrigation system was provided from slow hand piece system with 20 ml/d. Sterile saline sodium chloride 0.9% solution (Eczacıbası Company, Istanbul, Turkey) was used. To observe precisely the effect of tool characteristics same cutting parameters were used. Furthermore *x*, *z* axes were fixed in the experimental set up (Fig. 1).

In the present study, three procedure parameters (coating, drill tip angle and usage of drill) with two and three different levels were used and are shown in Table 1.

Before every implant site preparation all of the thermo-couples were calibrated by a certificated company (TESTO Company, Istanbul, Turkey) according to the related standard *ISO*/IEC 17025 [27]. Linearity of the calibration curve was confirmed with a regression curve fit and used as calibration equation. Afterwards room temperature and bone temperature were recorded. 0.5 mm diameter holes with 1 mm depths from the surface were drilled on fresh bovine bone for the placement of thermo-couples. The drills were inserted into the bone with 6 mm intervals. The thermo-couple places were prepared by means of 2 mm diameter burs (Fig. 2a and b).

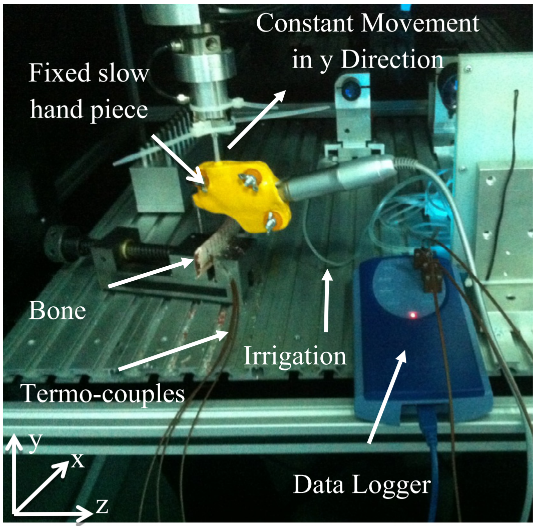

Fig. 1. Experimental set-up.

Table 1
Milling parameters and their levels.

Parameters	Parameter designation	Level 1	Level 2	Level 3
Coating	A	Coated	Uncoated	–
Drill tip angle (°C)	B	120	110	90
Usage	C	New	45 Times	90 Times

The three thermo-couples were located parallel to the drill area vertically with 6 mm intervals (Figs. 2(a and b) and 3). During the drilling procedure temperature was measured from these three different points. Afterwards mean value of these three points was used as the output value. The holes and number of location for each thermo-couple can be seen in the cross-sectional view of the sample in Fig. 2(b).

Temperature rise of the bovine bone during the drilling was recorded with embedded t-type thermo-couples by a data logger (PicoTC-08 with the accuracy of the unit; sum of ±0.2% and 0.51 °C) which was connected to computer program. The rise of heat during the drilling procedures was recorded every 0.01 s time intervals. This facilitated the continuous monitoring of the temperature changes with small intervals that were produced within the bone at the interface. Maximum and minimum difference was taken as Δt, and used as the output value for the analyses that represents the heat change in the bone. Temperature measurements were recorded by the program with three digits after the decimal point.

Taguchi method is a widely used technique for determining parameters effect on selected quality characteristic and optimizing industrial/production processes. This method can be divided three stages; (1) Orthogonal array selection, (2) Parameters and their levels selection, (3) Experiments and statistical analysis according to experimental results. By mean of these analyses optimum conditions are identified. First two steps are crucial for accurately optimization of the procedure [28]. Using a specific orthogonal array decreases number of experiments compared to classical design approach. With the increase of the process parameters the number of experiments also increases with the combination of these parameters. Taguchi method proposed various combinations which decreases the number experimental sets and provides a proper parameter combination [28]. A loss function is defined by this method to calculate deviation between the experimental results and the expected quality. With statistical analyses this loss function is digitized into signal/noise (S/N) ratio by means of the determined quality characteristics i.e. the lower-the-better (LB), the higher-the-better (HB) and the nominal-the-better (NB) [28]. For our experiments, quality characteristic selected as the lowest process temperature for lowest temperature rise in the bone. In accordance with this purpose lower the better function was used for the analysis of the results. After determining the optimal levels of factors a statistical

Please cite this article in press as: A.G. Bulutsuz et al., Measurement of temperature change during the implant site preparation to determine influence of tool characteristics, Measurement (2015), http://dx.doi.org/10.1016/j.measurement.2015.05.046