Available online at www.sciencedirect.com
ScienceDirect
Journal of the Chinese Medical Association xx (2018) 1−6
www.jcma-online.com

Original Article

Effects of non-thermal plasma on sandblasted titanium dental implants in beagle dogs

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Received October 23, 2017; accepted March 5, 2018

Abstract

Background: In this study, we investigated the effects of treating dental implants made from titanium with argon based non-thermal plasma, immediately before insertion on implant stability and bone formation. Biodegradable sandblasting and acid etching had been previously used to modify the surface of the implants.
Methods: To obtain data for 4-time points in triplicate with references, a total of 36 dental implants were divided into 2 groups; 18 implants served as the experimental group and received a spray containing non-thermal plasma, while the other 18 implants served as controls. Two treated and two untreated implants were each inserted in the jaws of 9 beagle dogs. After periods of 4, 8, and 12 weeks, the Implant Stability Quotient scores were determined and histometric values obtained.
Results: Plasma spray treatment increased the healing time slightly during the early recovery period (4th to 8th week, $p = 0.1595$ and 0.1041, respectively), but was not profoundly effective in the later recovery stage (12th week, $p = 0.4942$). Both non-decalcified histometric measurements and bone growth analysis showed no statistically significant differences between the plasma spray group and the controls at 4, 8, and 12 weeks.
Conclusion: Non-thermal plasma did not enhance the stability of the implants nor did it increase bone formation in our animal models.

Keywords: Biodegradable sandblasting; Bone formation; Dental implant; Etching; Non-thermal plasma

1. Introduction

Titanium has been widely used in dental implants for decades due to its exceptional properties. The material is known for its outstanding strength, chemical stability and resistance, along with having excellent biocompatibility.[1] However, because of its poor bonding with bone cells, implant failure

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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https://doi.org/10.1016/j.jcma.2018.03.004
1726-4901/

has been found during clinical practice.[2] Therefore, the enhancement of osseointegration is highly desired. This may be achieved through modifications in the surface texture.[3]

The implants used in this study were surface treated using both biodegradable sandblasting and acid etching. The porosities are sequentially produced by hydroxyapatite, and beta-tricalcium phosphate grit blasted and double acid etched in stages, so as to increase the contacting area and activate osteoblasts. The blasting utilizes the biocompatible and bio-absorbable media rather than traditional aluminum grits, on account of safety issues in the long term. The perfect topographic surface resulting from a superior cleaning process, allows for an excellent performance during the initial osseointegration. The surface treatment possesses the following features: blasting material with no residual risk, inorganic acid etching which can be easily cleaned using a superior process, a macro pore size with a diameter of approximately 20–40 μm, a micro pore size with a diameter of around 1.5 μm, a surface roughness around Sa 1.5–2.5 μm, and the surface element analysis using SEM–EDS of 97–100% Ti. The biodegradable sandblasting and acid etching technique was modifying from the sandblasted (large grit) and acid-etched (SLA) treatment. The blasting utilizes biocompatible and bio-absorbable media, rather than traditional alumina grit. This results in surface roughness and excellent bone integration,[4,5] while providing higher long-term patient safety. It has been proven that a moderately rough surface outperforms a turned surface. This data is provided by the Royal Dental Implant Company.

Plasma treatment has shown promising results with regards to tissue regeneration around the implant.[6] We sought to discover if subjecting titanium implants to a spray containing an argon-based non-thermal plasma would generate synergetic effects, while improving the stability and the osseointegration of the implants which have been pre-treated through biodegradable sandblasting acid etching.

Recent biomaterial and bio-methodological research has focused on additional modifications which could possibly increase the bioactivity of the implant.[7,8] Furthermore, the surface energy of the implant has been found to be a critical factor involved in the regulation of osteogenesis. In particular, depending upon the surface energy, the surface may be either hydrophilic or hydrophobic.[9] The energy state of the implant depends on the type of biomaterial, the method of handling during manufacturing, the mode of cleaning, sterilization, and the handling of the implant during the surgical procedure.[10] In general, when the surface is positively charged it becomes hydrophilic, and some of the plasma proteins that are essential for the initial osteogenic interactions are adsorbed onto the hydrophilic surfaces.[6,9,11] It has been suggested that the charge of the implant surface may be altered through oxidization, chemical and topographical modification,[12] and plasma treatment.[13]

The enhancement of osteogenic responses[14] has been shown to be beneficial, as surface treatment with atmospheric plasma significantly enhances wettability and improves the initial cellular interaction.[15] Plasma treatment has been shown to provide a positive effect on the host-to-implant response, when the implants are plasma-treated immediately prior to their placement at the surgical site.[16] Valuable information would be provided if it was determined whether such a surface modification is effective over longer periods of time, since the surface may be contaminated when the implant is re-exposed to air. This however, remains unknown. The surface modification through plasma treatment remains effective over a longer time, although the surface may be exposed to air upon storage and become contaminated. It has been reported that it may be possible to maintain the high surface energy state of the titanium implant for at least 30 days, depending on storage conditions. This was shown in a 30 day study where a commercially large scale production of implants was simulated.[14]

2. Methods

2.1. Approach strategy

Two-year-old beagle dogs were used for the experiments. The lower right large and small molars were extracted from each animal. After a 12 week period of healing the mandibular cortex bone, the implants were inserted in the areas where the molars had been extracted. At the 4th, 8th, and 12th week periods, the Implant Stability Quotient (ISQ) was measured. The ISQ is a value which indicates the level of stability and osseointegration in the dental implant.[17] Furthermore, after the ISQ measurements were taken, thin ground sections were obtained from each implant using a 10 mm trephine. The soft tissue was then analyzed, while tissue morphometrics were performed during the healing period primarily to assess the implants' effect on both the surrounding tissue and bone parameters. A more detailed description of the procedure is provided below.

2.2. Animal experiments and ethical approval

Nine 2-year-old beagle dogs weighing approximately 10–11 kg were used in the study. The dogs were housed in individual cages and fed a standard laboratory diet. The experiments were approved by the Institutional Experimentation Committee of Taichung Veterans General Hospital (La-1021065) under the government's supervision. All feeding procedures followed both national and international guidelines.

2.3. Anesthesia and removal of the bicuspid teeth

The dogs were anaesthetized with an intramuscular injection of ketamine (1 ml/kg), along with 4% isofluorane for induction, followed later by a maintenance dose (1–2%). On both sides of the jaw, the lower bicuspid teeth were removed using dental forceps and elevators. After the procedure, the mucosa was sutured.

2.4. Implants

Titanium screws (implants) measuring 3.5 mm in diameter and 8 mm in length were inserted into the jawbone while the