Optical Contact Angle Measuring and Contour Analysis (OCA)

Surface Energy Analysis of Dental Implants after Plasma Activation with the piezobrush® PZ3, using the picolitre dosing system PDDS

dataphysics
Understanding Interfaces

The surface treatment of dental implants has attracted increasing attention due to its important utilisation in the optimisation of the implants wetting behavior. Studies have shown that the initial attachment of osteoblasts is improved by increasing the surface energy, which subsequently leads to increased new bone formation after implantation. Thus, various surface treatment devices have appeared and the plasma handheld device piezobrush® PZ3 is widely used in dental laboratories. The surface energy is a vital parameter to verify a successful pretreatment or cleaning process of the implant surface. Furthermore, the knowledge of the surface energy facilitates an estimation of the wetting behaviour and adhesive properties of the implants for further processing. However, the surface energy analysis of micro-structured samples (Fig. 1) is still a big challenge, because the available test areas are very small and a reliable analysis requires small enough dropletts that don't touch or wet beyond the edge of the test surface. To meet this issue, DataPhysics Instruments developed the picolitre dosing system (PDDS) for dosing extra-small droplets (down to 30 pl). In combination with the contact angle measuring system OCA 200, a fast and reliable surface energy analysis of implants is guaranteed.

Fig. 1. Droplet between the screw threads of a dental implant.

Keywords: OCA ▪ Picolitre Dosing System PDDS ▪ Dental Implants ▪ Surface Energy Analysis ▪ Plasma ▪ piezobrush® PZ3

Technique and Method

The optical contact angle measuring and contour analysis system OCA 200 (Fig. 2) is designed to analyse both macroscopic and micro-structured samples. With the trendsetting 10-fold zoom lens, a reliable auto focus and the high-performance camera system even smallest drops of highly volatile liquids can be monitored. In addition, the electrically driven sample table ensures a quick and precise positioning of micro-structured samples for fast automated measuring procedures.

In combination with the picolitre dosing system PDDS (Fig. 3), contact angle measurement on the smallest structures becomes feasable, such as the mesh structure of a coronary stent or on single fibres.

Fig. 2. The optical contact angle measuring and contour analysis systems OCA 200, DataPhysics Instruments.

Hence, utilising the OCA 200 with PDDS, the contact angle of an individual drop that can easily fit between the screw threads of a dental implant can be measured.

Futhermore, the surface energy (SFE) of a solid is evaluated by contact angle measurements with at least two different test liquids, whose surface tensions including their dispersive and polar parts are known. These dispersive and polar parts are used to calculate the interfacial tension σ_{SL} between the solid and a liquid based on a suitable model. In this application note the Owens, Wendt, Rabel and Kaelble model (OWRK-model) is used, which considers the geometric mean of the dispersive and polar parts of the liquid's surface tension σ_L and of the solid's surface energy σ_s (EQ 1):

$$\sigma_{SL} = \sigma_S + \sigma_L - 2\sqrt{\sigma_S^d \sigma_L^d} - 2\sqrt{\sigma_S^p \sigma_L^p} \qquad \text{EQ 1}$$

Substituting this expression in the Young equation, the polar and the dispersive part of the solid's surface energy can then be determined from a regression line in a suitable plot.

For the plasma activation the piezobrush® PZ3 (relyon plasma GmbH, Regensburg, Germany) is used. This handheld device uses a piezoelectric element to transform the low input voltage to a high voltage output to create cold atmospheric plasma. A plasma treatment has the effect of surface activation and fine cleaning, which typically both impact the surface energy and its partition in polar and dispersive parts.

Experiment

In this note, one ceramic dental implant and two metallic dental implants were analysed. The packaging was carefully removed from the dental implants to not disturb its initial surface energy.

First the surface energy of the samples was measured without any cleaning or treatment. In a second step the dental implants were treated with the piezobrush® PZ3, using the Standard Module for the ceramic implant and the Nearfield Module for the titanium dental implant. Cold atmospheric pressure plasma with a temperature of less than 50°C is used for surface pre-treatment of the dental implants to increase the surface energy and thus the osseointegration.

The surface energies for untreated and plasma treated implats were determined indirectly via contact angle measurements by using two test liquids with known properties. Water and diiodomethane were chosen in this note.

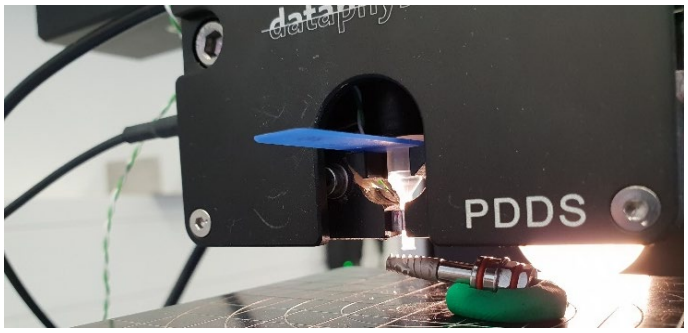

Fig. 3. Picolitre dosing system PDDS

The samples were fixed and orientated horizontally with plasticine on the sample stage of the OCA 200 (Fig. 3). To ensure a reliable contact angle measurement with unhindered wetting, the PDDS was set up to generate test liquid drops with wetting areas smaller than the screw threads of the dental implants. One single droplet was disposed between the screw threads of the dental implants each time. To ensure the accuracy and reproducibility of the result, each liquid was tested three times. After automatic evaluation with the SCA software module, average contact angles and the surface energy of the three samples were obtained.

Results

The contact angle values of the treated implants are lower than of the untreated ones, indicating the surfaces become more hydrophilic after surface treatment. Using the contact angle values, the surface energy of all implants has been calculated according to the OWRK method (EQ. 1). Fig. 4 shows the respective results together with the polar and dispersive components of the surface energy.

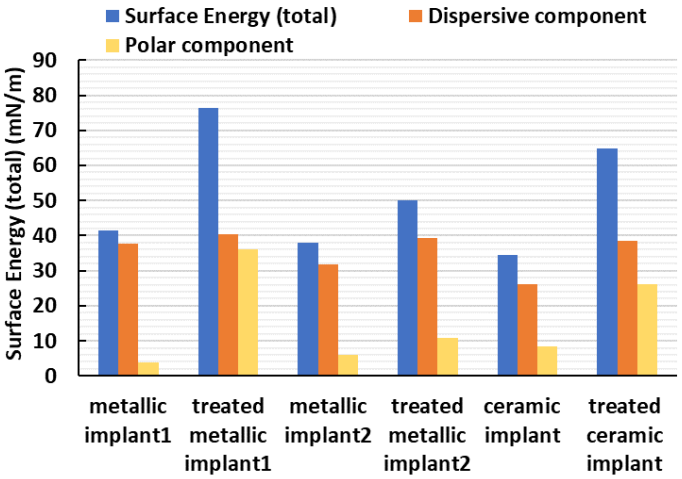

Fig. 4. Surface energy of the untreated and treated implant surfaces with the polar and dispersive components

The total and polar components of the surface enegy of all treated implant surfaces increased compared to their untreated surfaces, especially, that of the treated metallic implant 1 and the ceramic implant increased significantly. As known, higher surface energies implicate more polar as well as cleaner surfaces. Therefore, the finest organic impurities that are invisible to the naked eye, could be simultaneously removed from the dental implants after activating the surface, which are benefcial for further processing.

Summary

Wettability is of major importance for all kinds of surface treatments. To gain a deeper understanding of the wettability difference between the original and treated dental implant surfaces, contact angle measurements and a surface energy analysis were done using water and diiodomethane as the test liquids.

The optical contact angle measuring and contour analysis system OCA 200 in combination with the picolitre dosing system PDDS from DataPhysics Instruments provides a simple and reliable method to determine the surface energy of dental implants before and after surface treatment with a piezobrush® PZ3.

The used measuring system can be employed to study the surface energy of all kinds of micro-structured samples, which is of increasing importance for improving industrial treatments like painting, cleaning, coating or conglutination.

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