Application Report

Wetting Behavior of Dental Implants

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Method:

Drop Shape Analyzer – DSA100M

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Characterization of microscopically small surfaces on dental implants by using contact angle measurements on picoliter drops

Abstract

With tooth implants the wettability determines the degree of contact with the physiological surroundings and can therefore – together with other influencing factors – be a measure of the biocompatibility of the implant material. In the article presented here the wetting behavior of titanium dental implants with respect to water was studied by measuring the contact angle with water. The particular challenge in this task lay in positioning small drops in the implant screw thread and measuring their contact angles. Such measurements are possible with the DSA100M optical contact angle measuring system, which can dose out very small drops down to a few picoliters exactly and then analyze them – even in depressions.

Background

Dental implants used today are normally rotationally symmetrical pegs provided with a screw thread; these are screwed directly into the jawbone (see Fig.1).

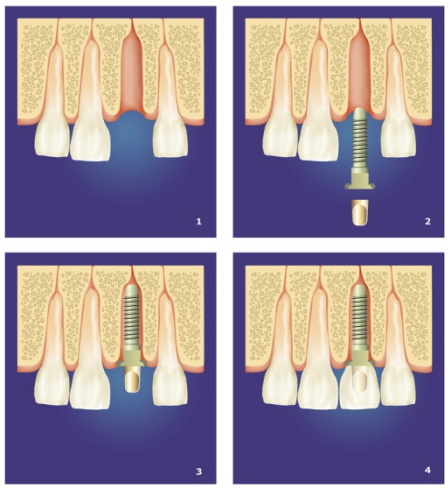

Fig. 1: Inserting a dental implant

The material used should enter into as firm a connection as possible with the jawbone as quickly as possible. This is why titanium is frequently used as the implant material because of its high degree of biocompatibility.

The surface topography of the titanium and the chemical structure of the surface influence both the hydrophilicity of the implant surface and the bone deposition on the implant. Initially the microstructured titanium surfaces (sand-blasted or acid-etched) used for the implants were hydrophobic as a result of the passivation occurring in an atmosphere containing oxygen [1], [2]. Studies have shown that hydrophilic surfaces improve the interaction of proteins and cells with the implant surface – they make bone cell growth on the implant easier and accelerate their firm adhesion (osseo-integration) [3]. In order to improve the wettability, manufacturer-specific surface modifications are usually carried out.

The success of the hydrophilizing process can be checked by using water contact angle, which quantifies the wettability of the implant by water and therefore the degree of contact with the hydrophilic surroundings. The threads of that part of the implant intended for contact with the bone require a measuring technique that can measure the contact angle of microscopically small drops in depressions.

Experimental part

The DSA100M instrument is used for contact angle measurements on drops in the picoliter range on microscopically small surfaces.

Five differently pretreated implant samples were removed from their packaging immediately before the measurement and attached to the instrument using a sample holder. Drops of about 100 pl pure water at a temperature of 26±1°C were first deposited on the cylindrical part and then in the thread depressions (see Fig. 2).

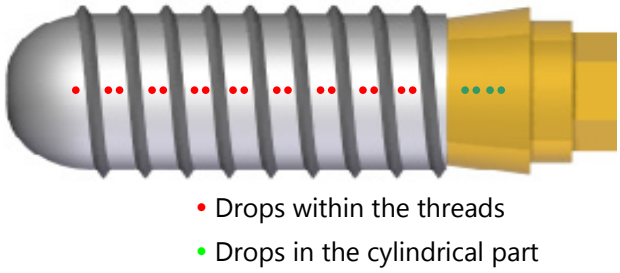

Fig. 2: Diagram showing drop placement on an implant sample

Immediately after deposition the behavior of the drop was filmed with the camera of the instrument. In order to be able to record the initial wetting process to the best possible extent a camera speed of 260 fps was used. The contact angles of the drops were determined from the video sequence. Figures 3 and 4 show the surface of the threads and a drop placed within a screw thread.

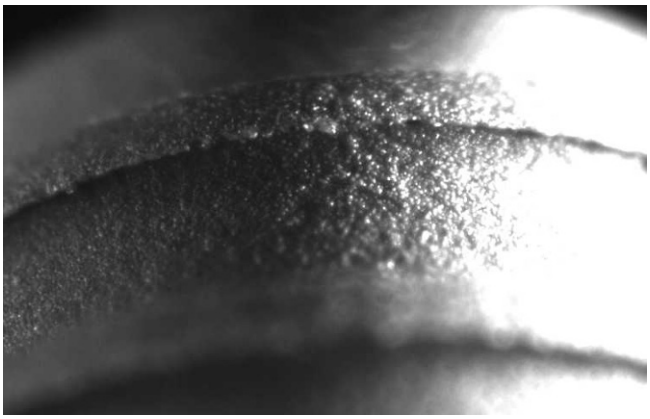

Fig. 3: Surface of the thread of an implant

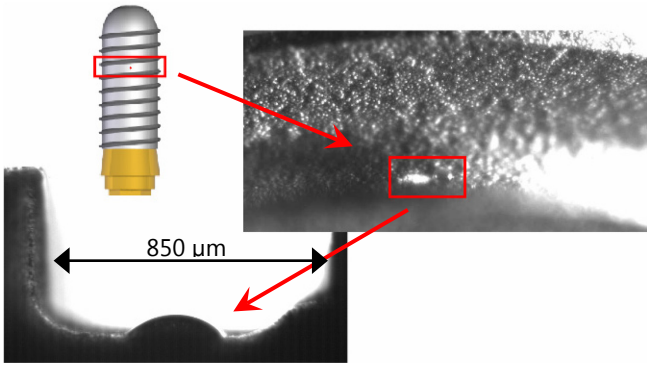

Fig. 4: Water drops within a thread

Results

The contact angle measurement demonstrated the different wetting behaviors of the various implant samples. Figures 5 - 8 show examples of the water drop images of various samples placed in the microscopically small depressions of the implant screw thread (width about 850 µm, depth about 450 µm); contact angles of different values are formed.

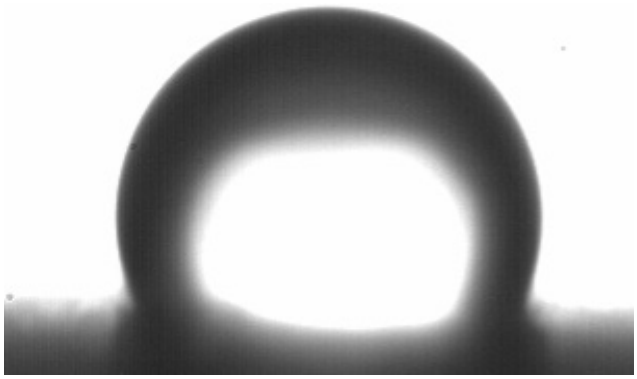

Fig. 5: Drop in thread depression of sample A

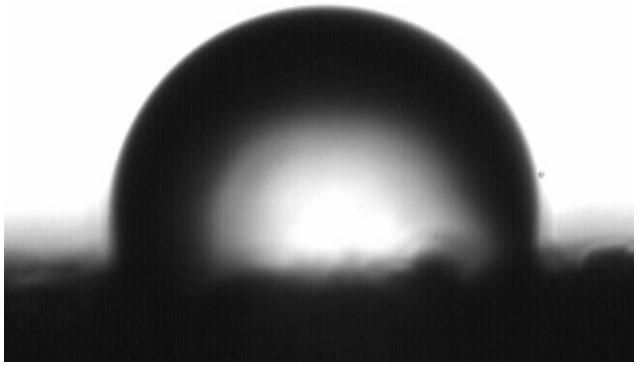

Fig. 6: Drop in thread depression of sample B

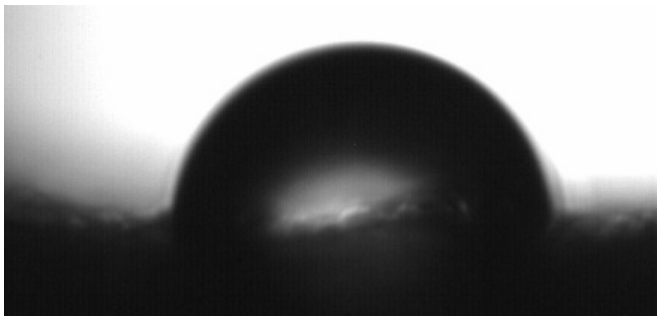

Fig. 7: Drop in thread depression of sample D

Fig. 8: Drop in thread depression of sample E

Table 1 contains the mean values of the contact angles CA_{mean} for the depressions and cylindrical areas for the five samples identified by the letters A to E.

Sample	CA_{mean} / Depression	CA_{mean} / Cylindrical area
A	116.5°	116.2°
B	103.0°	103.7°
C	99.5°	105.9°
D	77.2°	84.5°
E	19.3°	37.6°

Tab. 1: Contact angles (mean values) of water drops on implant samples

The limiting value for wettability is represented by a contact angle of 90°; water contact angles above 90° indicate a hydrophobic solid surface; from 90° down to 0° the surfaces are increasingly hydrophilic. The limiting value of 90° was exceeded for three of the five samples studied; both on the cylindrical part and in the thread depressions. In contrast, samples D and E exhibit increasingly hydrophilic behavior. According to the Baier model [4], which was developed for contact with blood and biomaterials, there is a relationship between biocompatibility, bioadhesion and the contact angle. According to this, a hydrophilic surface with a contact angle from 0 – 30° exhibits very strong bioadhesion. In accordance with this model, the high hydrophilicity of sample E means that it is to be expected that it will have the highest degree of biocompatibility of all the analyzed samples.

The data in Tab. 1 also indicates that at lower wettabilities the results for the cylindrical part will agree with those for the threads, whereas with hydrophilic samples increasingly larger differences between these two areas will occur. From this result it can be seen that the measurement of the easier-to-characterize cylindrical part alone is not sufficient, but that the thread surface intended for intensive tissue contact must be studied separately.

Summary

Micro-drop measurements with suitable dosing, optics, camera techniques and drop shape analysis software permit wettability studies on microscopically small surfaces and in depressions. With the contact angle measuring system DSA100M the hydrophilic and hydrophobic properties of the cylindrical part of dental implants can be determined. In addition, it has been possible to make measurements in the depressions of the threads of the implant that are to be screwed into the jawbone. In this way it was not only possible to determine the wetting behavior of five implant samples qualitatively (wetting or non-wetting), but also quantitatively by using the measured contact angles. In accordance with [4], such measurements provide valuable information about the expected biocompatibility of the material.

Literature

[1] H.P. Boehm, "Acidic and basic properties of hydroxylated metal oxide surfaces", Discussions Faraday Society, 1971, 52, 264-275.

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