Dynamic Contact Angle Measuring Device and Tensiometer (DCAT)

Effectiveness of Surface Treatment Techniques for Dental Implants using Imaginary Dynamic Contact Angle measurements

dataphysics
Understanding Interfaces

The "in dentist's room" surface treatment of dental implants has attracted increasing attention since it allows an optimisation of the implant's wetting behaviour that significantly increases the biocompatibility. Studies have shown that the initial attachment of osteoblasts is improved by increasing the surface energy or charging the surface positively, which subsequently leads to increased formation of new bone after implantation. To guarantee a high surface energy, the surfaces of most dental implants are treated to be ultra-hydrophilic which gives them a water contact angle of 0° or below. To study these ultra-hydrophilic surfaces, ***imaginary contact angle measurements*** *have evolved into a powerful technique [1,2].* ***Tensiometers of the DCAT series from DataPhysics Instruments*** *are the only measuring systems so far which feature a* ***reliable and reproducible imaginary contact angle determination*** *in their software. In the following the application of this method will be presented on samples of UV and plasma treated dental implants.*

– In collaboration with De Kliniek voor Tandheelkunde, Netherlands –

Fig. 1: Plasma treatment of dental implant

Keywords: DCAT ▪ Dynamic Contact Angle Measurement ▪ Imaginary Contact Angles ▪ Dental Implant ▪ UV ▪ Plasma

Technique and Method

A tensiometer of the DCAT series from DataPhysics Instruments is a universal measuring system for the force-based study of interfacial parameters and phenomena. With the software module DCATS 32 and suitable sample holders it can be used to measure dynamic contact angles on various solids, like implants, plates, films, powders, fibre bundles and even single fibres. This is particularly useful for studying hydrophilic samples: When optical contour analysis reaches its limits, one still obtains reliable and accurate results measuring dynamic contact angles with a DCAT due to its precise weighing system.

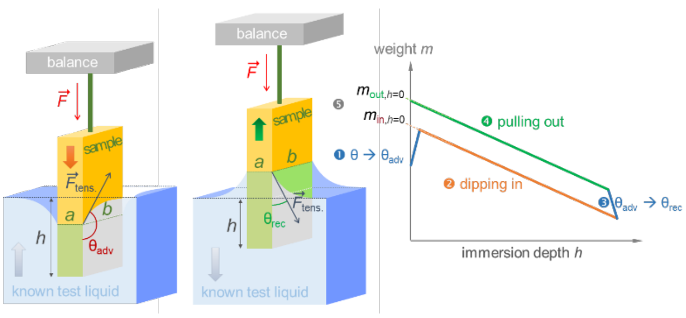

Fig. 2: Dynamic contact angles can be measured when the solid sample is dipped in or pulled out of the test liquid with known surface tension σ

For measuring dynamic contact angles the solid sample is attached to the instrument's balance via a holder and then dipped into and pulled out off a test liquid with a known surface tension σ (see Fig. 2 left). The measured weight m of the liquid lamella that links the sample at the contact line of length L is related to the contact angle Θ as:

$$\cos\Theta = \frac{m_{(h=0)}g}{L\sigma} \qquad \text{Eq. 1}$$

where g is Earth's gravity. In order to eliminate the buoyancy effect of the sample the measured weight is extrapolated to zero immersion height h before calculating the advancing contact angle Θ_{adv} or the receding contact angle Θ_{rec} for dipping in and pulling out, respectively (Fig. 2 right).

The fraction in equation (1) should theoretically not be larger than 1 (for which Θ is 0°). However, in practice, measurements of very hydrophilic surfaces do yield values greater than 1, in particular for rough surfaces where an additional force is generated during wetting by the capillarity of a porous surface [3].

Instead of assigning a contact angle of 0° in all those cases, the DataPhysics Instruments tensiometer software **calculates the imaginary contact angle**, *i.e.*, the complex number fulfilling Eq 1. This opens the possibility to still **distinguish between very hydrophilic** materials and study surface treatment techniques such as the UV, or plasma treatment of e.g., dental implants.

Experiment

In this application note the advancing and receding contact angles of two kinds of untreated dental implants and dental implants that had their surfaces UV or plasma treated were determined with a DCAT 25.

The two kinds of untreated dental implants are from the same brand with same size, but produced in 2015 and 2021, respectively. The implants produced in 2021 were used for the surface treatment test. The treatment technique and treatment time are shown in table 1.

Table 1: Treatment technique and treatment time.

Technique	Treatment time (min)
UV	5
UV	12
Plasma	1 (3 cycles of 20s)
Plasma	2 (6 cycles of 20s)

The measurements were done on three identical samples per implant, which were taken out of the packaging with as little contact as possible and then analysed without further cleaning.

In a preliminary test the surface tension of the water, which was later used as the known test liquid, was measured using a Wilhelmy plate, ensuring its purity (σ = 72.8 mN/m).

For the dynamic contact angle measurement an implant sample was attached to the sample holder. The dynamic contact angle method was selected in the software and the sample diameter was entered (4.7 mm). As the implants are slightly tapered, with the tip being a little smaller than the given diameter, the immersion depth was set to 8 mm. Then the measurement was started, and the instrument automatically dipped the sample into the water and pulled it out again, whereafter the software calculated the dynamic contact angles.

Results

Fig. 3 shows the advancing (green) and the receding (red) contact angles (CAs) determined for the dental implants. For all implants, only a small deviation between the repetition measurements with same surface properties was found, which results in small error bars.

As can be seen in Fig. 3, both advancing contact angle and receding contact angle of UV treated implants and plasma treated implants are showing imaginary contact angles, indicating that these two surface treatments result in hyperhydrophilic surfaces and possess extremely high wetting behaviour. The data in Fig. 3 shows that the imaginary contact angles on surfaces that have been UV treated for 5 min and the ones that were treated for 12 min ("the gold standard" of implant treatment) are similar, indicating that the treatment time of 5 min is sufficient in regards of wettability. In contrast, the advancing contact angles on the implants that are plasma treated for 60 s with is smaller than the one that has been treated for 120 s, suggesting that the treatment time of 60 s is too short to achieve the best wetting possible.

Interestingly, as shown in Fig. 3, the advancing contact angles of all untreated implants are real contact angles higher than 90°, which indicates that the original surface is not hydrophilic, and the wetting rate is extremely low. Additionally, the advancing contact angle of the implant from 2021 was smaller than that of the implant from 2015. This suggests that a long storage time will decrease the hydrophilicity to some extent.

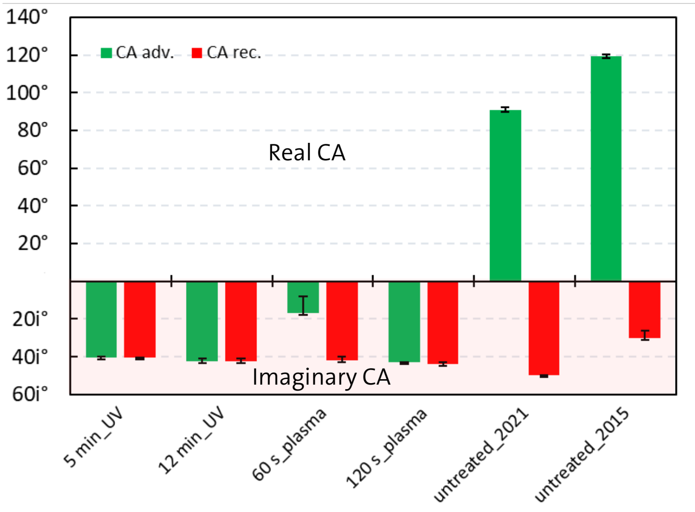

Fig. 3: Dynamic contact angles (green: advancing, red: receding) for differently treated and untreated implants.

Hence, both UV and plasma treatment techniques are capable of improving the wettability of dental implants and making them hyperhydrophilic. Additionally, an UV treatment of 5 min exhibited the same wettability as the gold standard of 12 min treatment. Overall, it is likely that a 120 s plasma treatment is a promising candidate to replace the more time-consuming UV technique.

Summary

The tensiometers of the DCAT series with their dedicated software from DataPhysics Instruments can be used to research surface treatment techniques and treatment times of dental implants reliably and reproducibly. Imaginary contact angles make it possible to easily study hyperhydrophilic materials and notably to quantitatively distinguish the results even in cases where conventional methods would simply yield a contact angle of 0°. Hence, it is an ideal technique for developing and improving surface treatments for hyperhydrophilicity.

Literature

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