

Assessing Gloss of Tooth using Digital Imaging

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Gloss plays an important role in the appearance of teeth. In dentistry, gloss is usually evaluated visually by experienced examiners who evaluate teeth according to a subjective scale. In order to get more reliable and accurate assessment, instrumental measurement is necessary. The aim of this study is to assess gloss of tooth by digital photography. A gonio-imaging system (gonio - being Greek for angle) was developed to measure the gloss of human teeth in a laboratory stage. Polarized and non-polarized images were acquired around the specular angle. The gloss component was extracted and normalised to a theoretical standard. A BRDF curve was built to describe the gloss profile of the subject. Porcelain teeth were used to test the repeatability of the system and several human lateral teeth were etched to check the system's capability to detect gloss changes. In addition to the BRDF, the area under the curve was calculated to give a quantitative value of gloss. The comparison result between the original and etched teeth can prove the validation of the gonio-imaging system for measuring tooth-gloss changes.

Gonio-imaging system

The gonio-imaging system consisted of three main parts, light source, digital camera and the subject. A halogen cold light source was used to provide a spot light. A focusing lens was fixed on the output light guide of the KL1500 to generate a narrow beam. The light source was 28cm away from the subject to provide approximate parallel light, and was mounted in an arc so that human teeth are considered to be similar to highly glossy porcelain materials, the measuring specular angle was set to be 20°. A Jai SCCD camera was mounted at a distance of 15cm from the subject, with the angle of detection θ' equal to 20°.

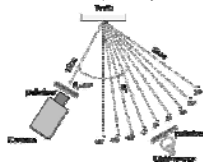


Figure 1: The experimental set-up for the digital camera to measure specular distributions of teeth.

The aim of the imaging system is to generate the gloss profile of the subject. In order to extract the gloss information of an image, two polarizers were placed in front of the camera lens and the light source to exclude or include the specular light by rotation. The specular angle (20° to the normal) was rotated as 0° position. In this rotation, 9 positions (corresponding to -20°, -15°, -10°, -5°, 0°, 5°, 10°, 15°, 20°) were measured. Two images, polarized and non-polarized, were captured at each of the 9 positions and the difference between these two images was used as an indication of gloss.

The camera gamma of the Jai camera was manually set close to 1.0, a further linearisation was applied to the grabbed camera RGB. A grey scale chart made from a Ditzinger/Leith Colour Checker DC was used to build the linearisation model. The green channel value was used for measurement of gloss because it correlates well with the luminance channel of CIE XYZ space. The difference of the linearised G values between the polarized and non-polarized images was calculated. Generalized gloss measurement is made relative to a theoretical standard, which is specified to be a highly polished plane black glass with an index of refraction $n=1.567$ at the wavelength of 589.3 nm. In theory, this standard gives $G=255$ for the non-polarized image, and $G=0$ for the polarized image. If this glass is assigned a gloss value of 100, the measured gloss value can be calculated and normalised by Equation (1).

$$G_{\text{tooth}} = \frac{G_{\text{tooth}} - G_{\text{p}}}{255} \times 100 \quad (1)$$

where G_{tooth} is the gloss value of angle θ , G_{p} is the gloss channel value of the non-polarized image on angle θ , G_{p} is the green channel value of the polarized images on angle θ .

Tooth Etching Experiments

In order to test the system performance of measuring the gloss changes for real tooth, two experiments (I and II) of tooth etching were conducted. In the Experiment I, an extracted human molar (tooth 0) was used as the test sample, which was initially polished to be highly glossy to represent high tooth gloss both after bleaching. After measuring the original BRDF of the tooth, a 37% phosphoric acid solution was used to etch the right side of the tooth for 20 seconds leaving the left side unetched. The purpose of Experiment II was to compare the gloss profiles of the etched and the non-etched sides of the tooth. The maximum BRDF curves before and after etching were compared.



Figure 2: Captured images of the human molar in Experiment I, notated as Tooth 0, before and after etching. Note that only the right was etched.

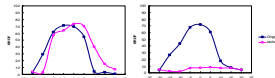


Figure 3: BRDF of the left (non-etched) and the right side (etched) of Tooth 0.

In Experiment II, three lateral human teeth exhibiting different levels of gloss were measured (notated as Tooth 1, 2 and 3). As the teeth were natural human teeth without being polished, a mild 20% phosphoric acid was applied for 20 seconds. The BRDF of each tooth was generated and compared.

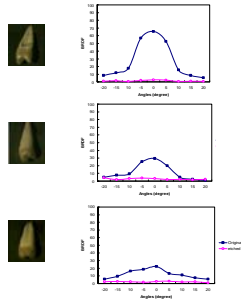


Figure 4: BRDF of the three teeth before and after etching (Tooth 1, Tooth 2 and Tooth 3)

Table 1 summarizes the area under the BRDF curves for the four human teeth before and after etching (for Tooth 0, only the data of the etched right side is shown). From the differences between the value of the original and the etched teeth, it was evident that the gloss component decreased a large amount. Combined with the BRDF curves, the area can be a quantitative index for assessing-gloss of surfaces in addition.

Table 1: Area under the BRDF curves for the four human teeth before and after etching

Area Under BRDF	Tooth 0		Tooth 1		Tooth 2		Tooth 3	
	Original	Etched	Original	Etched	Original	Etched	Original	Etched
	1528.9	236.3	1201.6	64.7	624.7	110.2	623.8	96.6

CONCLUSIONS

In conclusion, from the stability test and human-teeth etching experiment, the gonio-imaging system can be considered to be suitable to build the gloss profile of tooth and to be sensitive to measure the changes of gloss. These findings have implications in the use of digital camera in the assessment of gloss related to dental practices, such as tooth surface enhancement and tooth bleaching. In addition, the system could be used to evaluate gloss of human teeth in a laboratory level but the system could be modified for further measurement of patient teeth in a clinical environment.