DENTAL WEAR SURFACE
USING 3D PROFILOMETRY

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INTRODUCTION

Tooth wear, the loss of tooth material due to reasons other than cavities and sudden dental trauma over the course of a lifetime, is a normal process in all adults. The topmost layer of a tooth is enamel, which is the hardest substance in the human body, and cannot be naturally restored. Enamel can wear away from tooth-to-tooth, tooth-to-foreign body, or tooth-to-dental crown wear, as well as a result of exposure to acidic environments. It is important to be able to precisely measure the wear rate, volume loss, and change in topography of a tooth or dental crown in order to be able to effectively slow down tooth wear. All these calculations can be made using a surface subtraction study.

Surface subtraction studies are critical in any application looking at the topographic change in a relatively small area in relation to the entire sample. Such studies can effectively quantify surface wear, corrosion, or the degree of similarity between two parts or molds. Being able to precisely measure the surface area and volume loss of an area of interest is vital in order to properly design wear or corrosion resistant coatings, films, and substrates

IMPORTANCE OF 3D NON CONTACT PROFILOMETER FOR WEAR STUDY

Unlike other techniques such as touch probes or interferometry, the 3D Non Contact Profilometer, using axial chromatism, can measure nearly any surface, sample sizes can vary widely due to open staging, and there is no sample preparation needed. Nano through macro range is obtained during Volume and/or Area measurement, among many others, with zero influence from sample reflectivity or absorption. The system has advanced ability to measure high surface angles and there is no software manipulation of results. Easily measure any material: transparent, opaque, specular, diffusive, polished, rough etc. The technique of the 3D Non Contact Profilometer provides an ideal, broad and user friendly capability to maximize surface studies of wear or corroded surfaces in both 2D/3D with bench top & portable options.

MEASUREMENT OBJECTIVE

The surface topography of a human tooth before and after wear with sandpaper is measured using the Nanovea ST400 Profilometer. Four total measurements are made, with varying degrees of wear. The first and last measurements will be combined and compared using the software surface subtraction operator to visualize the material lost and calculate the surface area and volume of tooth wear in areas of interest

Fig. 1: Optical line sensor scanning on the tooth sample

RESULTS AND DISCUSSION

The tooth was mounted in a polymer resin, and fixed in place using a vice, as shown in Fig. 1. Using the optical line sensor, a high resolution 15 x 15 mm scan was made of the entire top surface of the tooth in under 2 minutes. The 3D view of the tooth before any wear is shown in Fig. 2a, and different amounts of wear are shown in Fig 2b-d

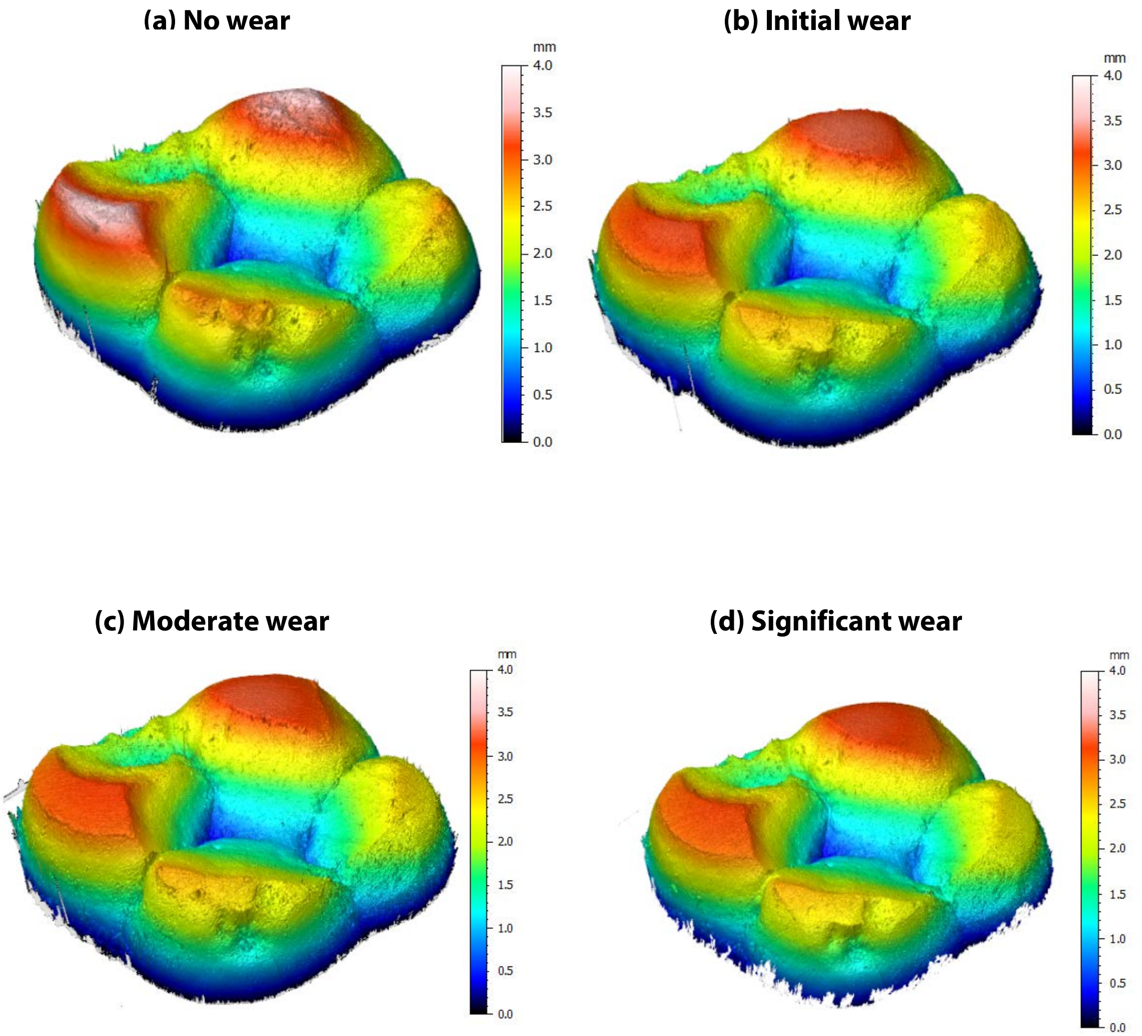


Fig. 2: 3D view of tooth with different amounts of wear, normalized in x, y, and z

The surface subtraction of the 'no wear' and significant wear' scans can be seen in Fig. 3. Each peak corresponds to material lost between the two scans. Most of the materials worn away was on the peaks in each corner of the tooth.

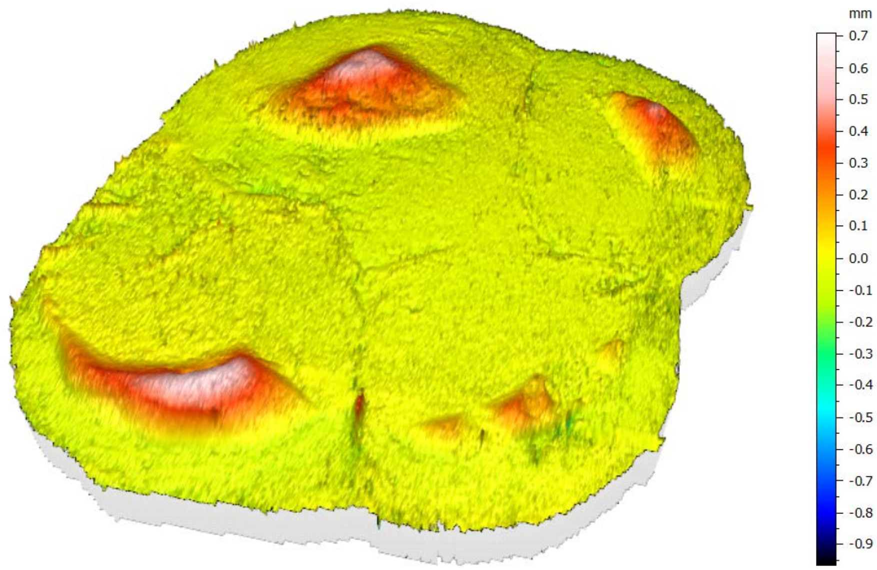
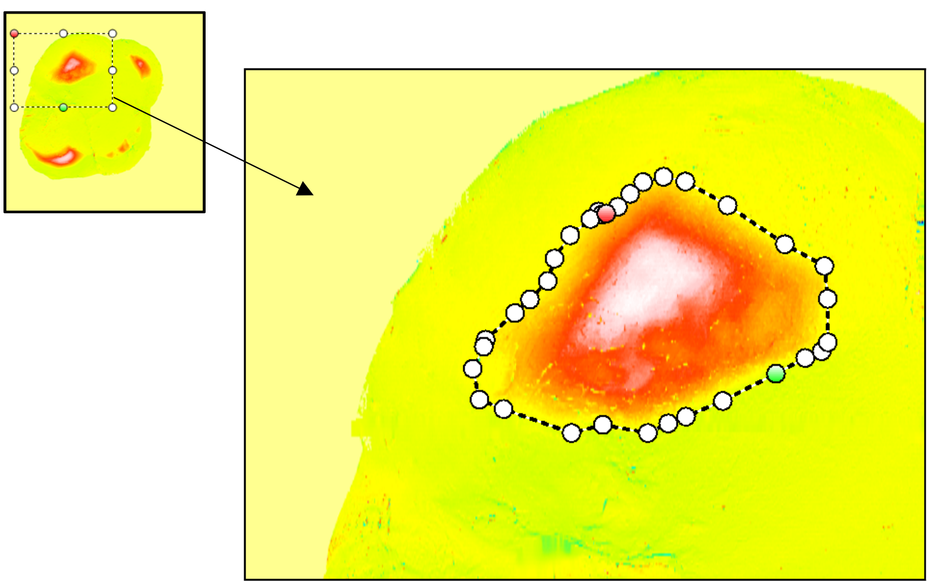


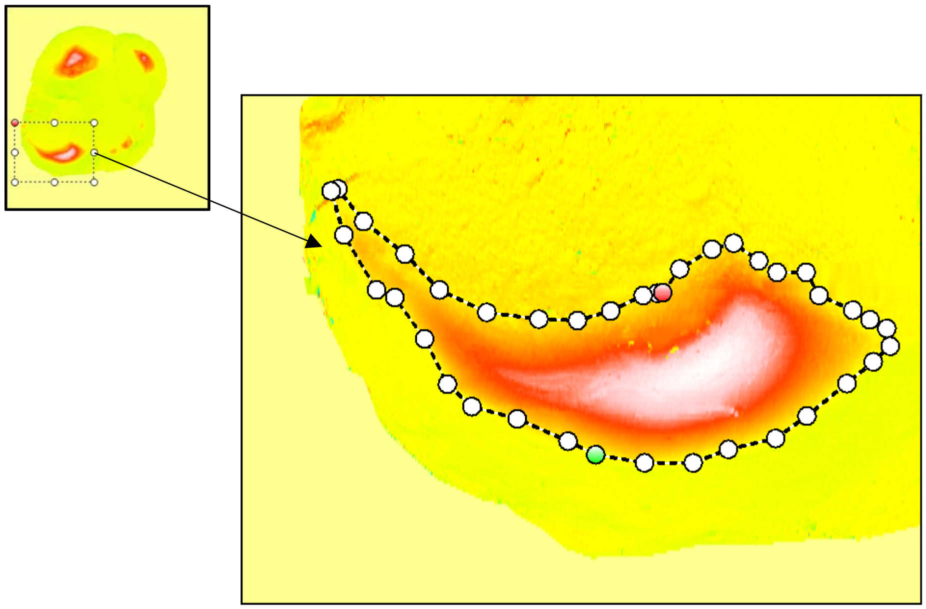
Fig. 3: 3D view of surface subtraction of tooth before and after wear

The surface area and volume loss of the top left and bottom left areas of the tooth are calculated in Fig. 4 and Fig. 5. A similar analysis could be done for holes on the surface subtraction study. Thus, differences between two scans in both the positive and negative z-directions, as well as resulting surface area and volume differences, can be compared simultaneously if needed.



Parameters	Unit	Peak
Surface	mm²	6.932
Volume	mm³	1.577
Max. depth/height	mm	0.5866
Mean depth/height	mm	0.2275

Fig. 4: Volume of wear loss for top left corner of tooth

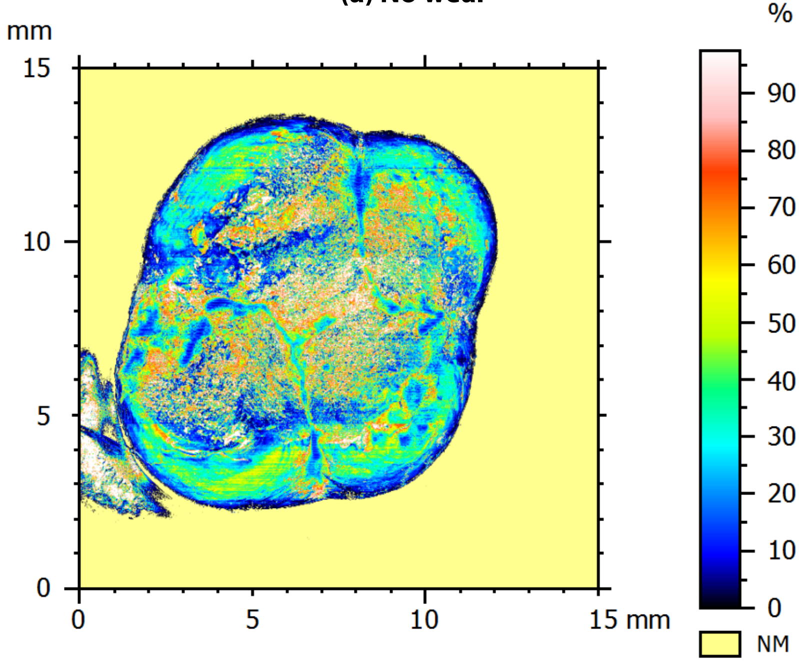


Parameters	Unit	Peak
Surface	mm²	4.679
Volume	mm³	1.107
Max. depth/height	mm	0.6740
Mean depth/height	mm	0.2366

Fig. 5: Volume of wear loss for bottom left corner of tooth

In many cases, viewing the intensity measurements of the scan, in addition to the height data, can reveal important information. As seen in Fig. 6, in this application, the intensity measurement of the post-wear scans can reveal where the enamel has completely worn away and revealed the tooth's dentin, due to the differing reflectivity of the two layers.

(a) No wear



(b) Significant wear

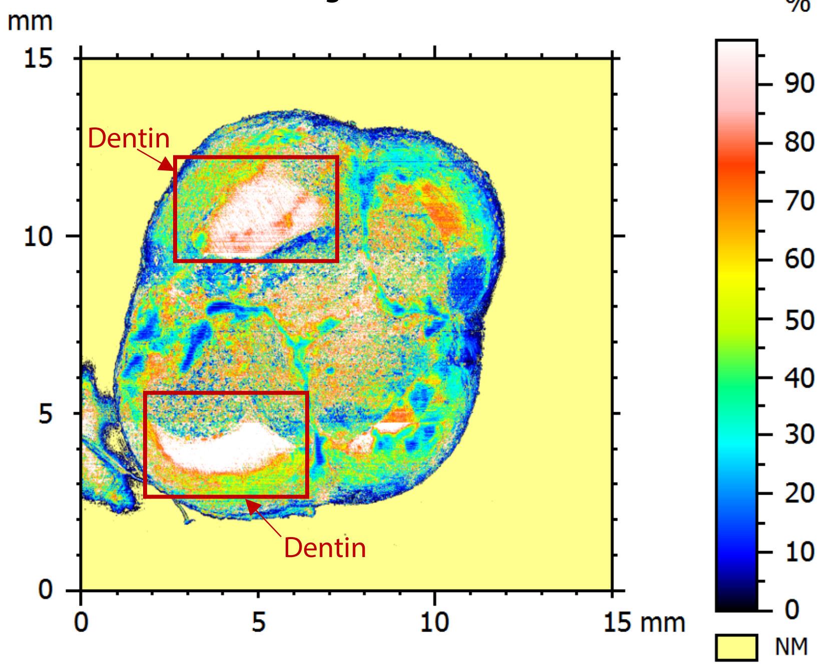


Fig. 6: Intensity measurement of tooth before and after wear

CONCLUSION

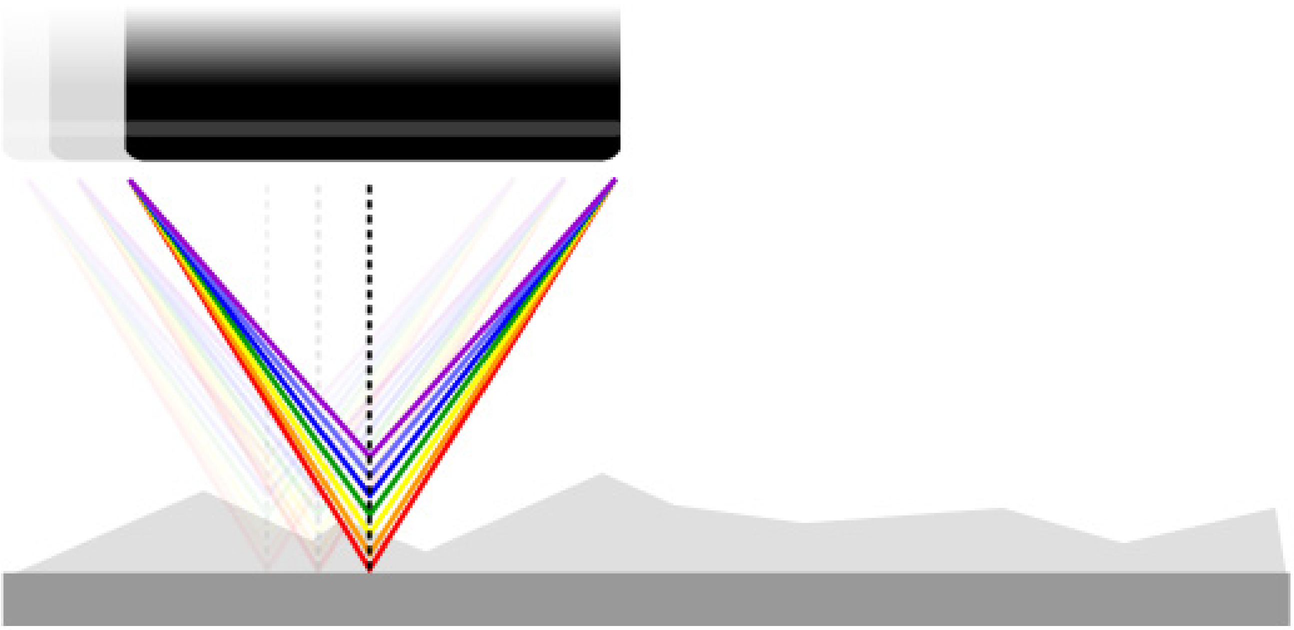
The unknown features of a wear area were precisely characterized using the Nanovea ST400 non-contact profilometer. The optical line sensor allowed a high resolution scan of a large area at a fast speed. By comparing the pre and post surfaces, it has been clearly shown how the surface subtraction can provide for the precise volume loss measurement over the area of wear. From the 3D surface measurements, areas of interest can quickly be identified and then analyzed for desired measurements (Dimension, Roughness Finish Texture, Shape Form Topography, Flatness Warpage Planarity, Volume Area, Step-Height Depth Thickness and others). With this information wear and corroded surfaces can be broadly investigated with a complete set of surface measurement resources

The data shown here represents only a portion of the calculations available in the analysis software. Nanovea Profilometers measure virtually any surface in fields including Semiconductor, Microelectronics, Solar, Fiber Optics, Automotive, Aerospace, Metallurgy, Machining, Coatings, Pharmaceutical, Biomedical, Environmental and many others.

Learn more about the Nanovea Profilometer or Lab Services

MEASUREMENT PRINCIPLE:

The Chromatic Confocal technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



Unlike the errors caused by probe contact or the manipulative Interferometry technique, Chromatic Confocal technology measures height directly from the detection of the wavelength that hits the surface of the sample in focus. It is a direct measurement with no mathematical software manipulation. This provides unmatched accuracy on the surface measured because a data point is either measured accurately without software interpretation or not at all. The software completes the unmeasured point but the user is fully aware of it and can have confidence that there are no hidden artifacts created by software guessing.

Nanovea optical pens have zero influence from sample reflectivity or absorption. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent or opaque, specular or diffusive, polished or rough. Measurement includes: Profile Dimension, Roughness Finish Texture, Shape Form Topography, Flatness Warpage Planarity, Volume Area, Step-Height Depth Thickness and many others.

DEFINITION OF HEIGHT PARAMETERS

	Height Parameter	Definition
Sa	Arithmetical Mean Height	Mean surface roughness. $$Sa = \frac{1}{A}\iint_A \lvert z(x,y)\rvert dxdy$$
Sq	Root Mean Square Height	Standard deviation of the height distribution, or RMS surface roughness. $$Sq = \sqrt{\frac{1}{A}\iint_A z^2(x,y)dxdy}$$ Computes the standard deviation for the amplitudes of the surface (RMS).
Sp	Maximum Peak Height	Height between the highest peak and the mean plane.
Sv	Maximum Pit Height	Depth between the mean plane and the deepest valley.
Sz	Maximum Height	Height between the highest peak and the deepest valley.
Ssk	Skewness	Skewness of the height distribution. $$Ssk = \frac{1}{Sq^3}\left[\frac{1}{A}\iint_A z^3(x,y)dxdy\right]$$ Skewness qualifies the symmetry of the height distribution. A negative Ssk indicates that the surface is composed of mainly one plateau and deep and fine valleys. In this case, the distribution is sloping to the top. A positive Ssk indicates a surface with a lot of peaks on a plane. Therefore, the distribution is sloping to the bottom. Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.
Sku	Kurtosis	Kurtosis of the height distribution. $$Sku = \frac{1}{Sq^4}\left[\frac{1}{A}\iint_A z^4(x,y)dxdy\right]$$ Kurtosis qualifies the flatness of the height distribution. Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.
Spar	Projected Area	Projected surface area.
Sdar	Developed Area	Developed surface area.