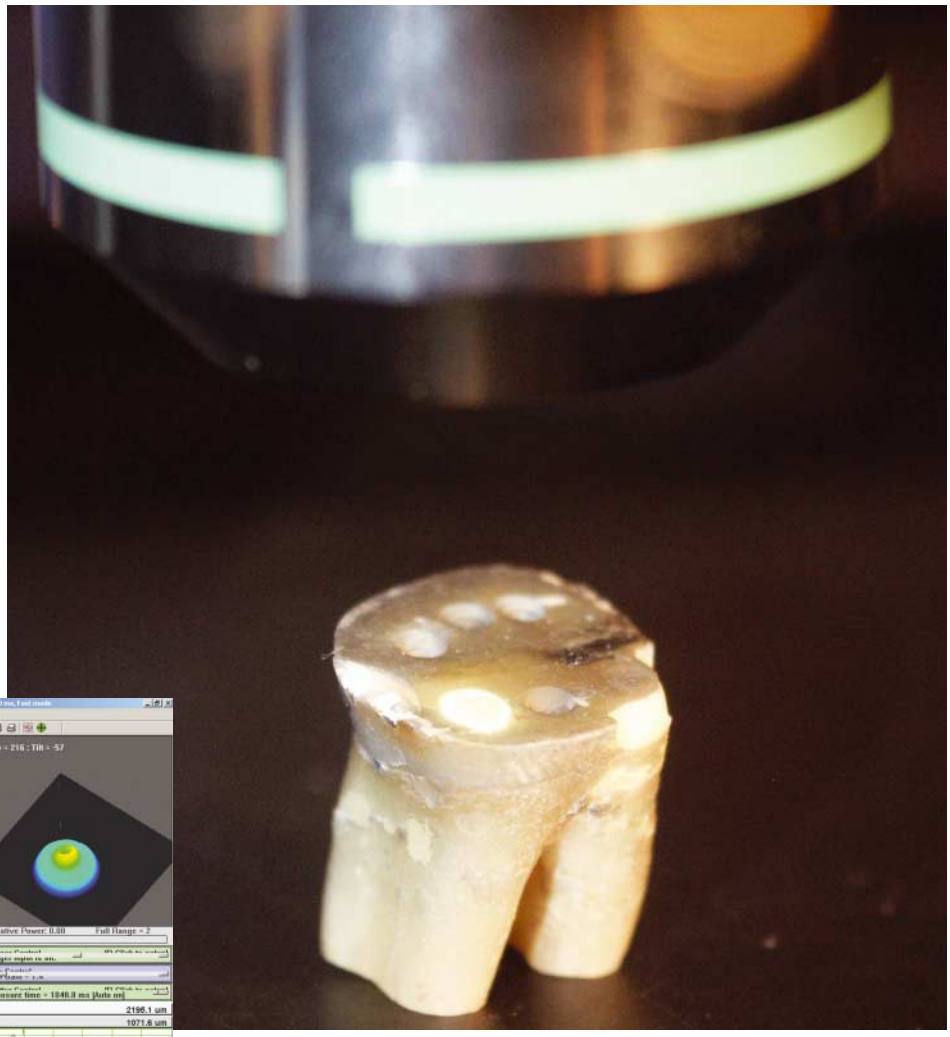
3D Imaging and Measurement Capabilities for Laser Dental Drilling Applications

Currently technology to utilize laser pulses for the treatment of hard tooth structure is in well underway. Research and development efforts by the Dental Sciences and equipment manufacturers have placed great emphasis on the need to develop accurate methods to characterize and guide the development of this new method of dental treatment. Infinitefocus microscopy is a method of imaging and quantifying microscopic three- dimensional features. This unique optical reconstruction technique is referred to as "Topomicroscopy". It is ideally suited to the evaluation of laser (and conventional) dental drilling procedures because of its ability to produce geometrically-accurate, 3D color images and the corresponding volumetric data sets of drilled dental surfaces.



Infinitefocus Microscope (IFM) examining holes drilled in the test specimen. True-color images and volumetric measurements of the drilled holes assist researchers to understand the ideal energy distribution for an optimized laser drilling system.

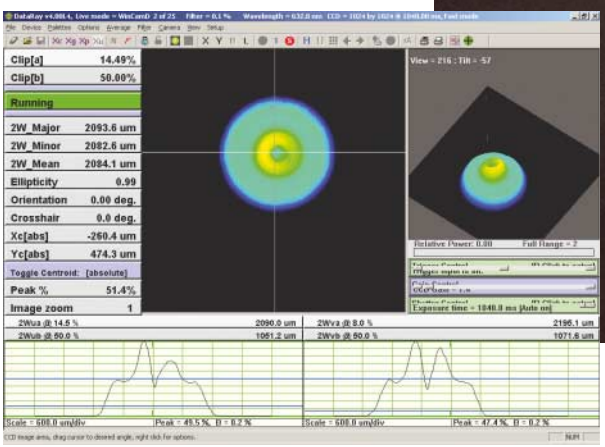


Fig. 1: Laser intensity displayed in combination with the InfiniteFocus Microscope's 3D results permit a correlation between laser intensity and 3D measurement results to be established.

Dental Laser Drilling - The Technology of Laser Pulses: Pros & Cons

Due to its thermic properties, the use of laser pulses is an appropriate technology for the treatment of biological tissue. Among a wide spectrum of applications is its use in the controlled removal of hard tooth structure. The benefits associated with this new technology make it very desirable in modern dentistry. However, there are certain aspects of this treatment that have to be taken into account. Foremost, the tooth must not be heated more than 5°C; which if exceeded could cause irreversible tooth damage. A second concern is that the laser pulses need to be well-focused to assure precise, controlled, dental structure removal.

Several dental equipment manufacturers have successfully developed products utilizing pulsed-laser technology. Among this group is the Austrian-based company W&H Dentalwerk Bürmoos GmbH, a leading global developer of precision dental equipment. In order to better understand the laser's behaviour during the removal process, their R&D staff utilizes the topomicroscopy (3D) measurement system InfiniteFocus Microscope, developed by fellow-countrymen Alicona Imaging GmbH of Graz, Austria. Topomicroscopy is a technique that combines the functions of metrology and microscopy in a single optical instrument. In the dental application it is used to image and characterize (in 3D) the drilled opening. This non-contact inspection method yields brilliant, true-color images that can be analyzed with respect to surface profile (including surface roughness), surface area, and volume.

The Application: Measurement of the Decayed Region to Determine the Ideal Energy Distribution for Laser Drilling

The dental drill's laser beam is automatically steered across the subject area of the tooth surface with a beam diameter between 0,5–2 mm. This scanning method is similar to the television's elec-

Fig. 2a: 3D true-color image of laser-drilled hole

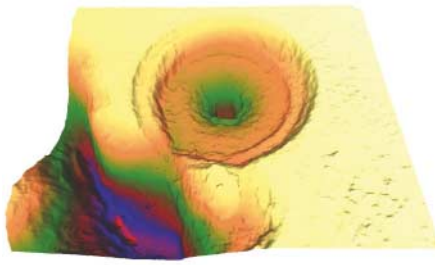


Fig. 2b: 3D pseudo coloring to visualize depth

tron beam path. Next, the scanned-results algorithm calculates the ideal energy distribution curve for the affected area. During this process the cavity, its correlation with the laser drill's proper energy distribution curve as well as the extracted volume has to be determined. Consequently, robust 3D measurement of the laser drilling system's ablation performance is critical to the development and application of this dental treatment method.

The Solution: 3D Color Image Reconstruction and Volumetric Measurements of Laser Drilled Dental Surfaces with the InfiniteFocus Microscope

Because cavities consist of free-form surfaces, a robust (mega-point, non-contact) measurement system is necessary to provide adequate resolution of the measured volume throughout the cavity's entire depth. The Infinitefocus Microscope (IFM) is able to satisfy all these imaging and measurement requirements. Once the drilled feature of the test specimen is captured with the IFM, its software generates a 3D reconstruction.

The following figures illustrate the IFM's non-contact, mega-point, true-color image (Fig. 2a) and the corresponding height gradient map (Fig. 2b). Measurement of the holes´ volume can be carried out on either of these two images because they are both based on virtually the same 3D data file. With an excess of a million data points comprising the surface, measurements are simple and powerful. Since the IFM combines a digital microscope image with the XYZ data point coordinates, surface profile (and roughness), surface area, and volumetric information are all readily at hand.

Summary

In order to develop an optimized laser scanning technology to treat hard tooth structure, robust measurement techniques are critical. Conventional profilometry does not provide full spatial data sets. Further, it is a tactile device which lacks the important link between the 3D true color digital image and the 3D data sets. This unique combination provided in the Infinitefocus Microscope permits 3D measurements directly on the reconstructed image. As a result, the IFM has provided invaluable information

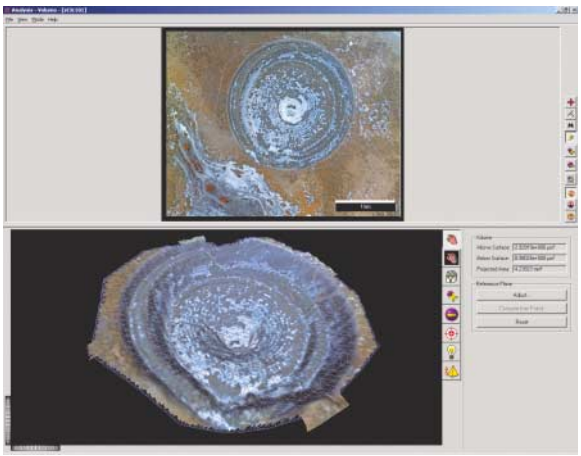


Fig.3: 3D volume measurement of the hole directly in the 2D texture image. The results lead to the development of an optimized laser scanning system since the ideal energy distribution can be determined.

for the development of accurate laser scanning and dental drilling systems. With the reliable correlation between the laser intensity and the topometrically-mapped surface, the advantages of Infinitefocus technology have directly contributed to an optimized treatment of hard tooth structures.

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