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Three-dimensional tooth occlusal surface imaging using optical sectioning method

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The paper presents a system of three-dimensional tooth occlusal surface imaging. This system is composed of a conventional microscope and Image-Pro Plus software with programmable motorized *X*, *Y* and *Z* stages. The optical sectioning method is applied to determine the location of each point on the occlusal surface of the tooth. Having a three-dimensional image of the occlusal surface of the tooth, we can simulate and study the mastication process and take into account all the forces acting on the tooth during mastication.

Keywords: conventional microscope, optical sectioning, programmable motorized stage, tooth occlusal surface, digital image, focal plane, step of discretization

1. Introduction

The goal of orthopedic treatment is to make the patient feel comfortable while he is using his partial denture. The three-dimensional image of a tooth occlusal surface allows us to simulate and to study the mastication process and take into account all the forces acting during it. This knowledge is necessary for the elimination of the undesirable forces and for the design of the better construction of a partial denture. The optical sectioning method is used in order to obtain the location of each point on the occlusal surface of the tooth.

2. Three-dimensional imaging system

2.1. Optical sectioning method

The system is composed of an optical microscope and Image-Pro Plus software with programmable motorized *X*, *Y* and *Z* stages.

A conventional microscope analyses the three-dimensional occlusal surface of the tooth. First, only some points on the occlusal surface of the tooth in or near the plane

of focus are visible. Furthermore, points just outside the focal plane are visible, but they appear blurred. Points of the occlusal surface of the tooth farther away from the local plane are not visible, but they contribute to the recorded image as well.

The phenomenon of three-dimensionality can be overcome by serial sectioning, a technique that involves slicing of the occlusal surface of the tooth to produce a series of thin sections that may be studied individually to develop the three-dimensional structure of the occlusal surface of the tooth.

2.2. Imaging of the occlusal surface of the tooth

The optical system of a microscope imaging occlusal surface of the tooth of the thickness T is shown in Fig. 1. The three-dimensional coordinate system has its origin at the bottom of the tooth occlusal surface, and the z-axis coincides with the optical axis of the microscope. The lens-to-image-plane distance d_i is fixed, and the in-focus plane falls at $z = z'$. The distance d_f is below the centre of the lens. The image plane has its own coordinate system (x', y') with its origin on the z-axis.

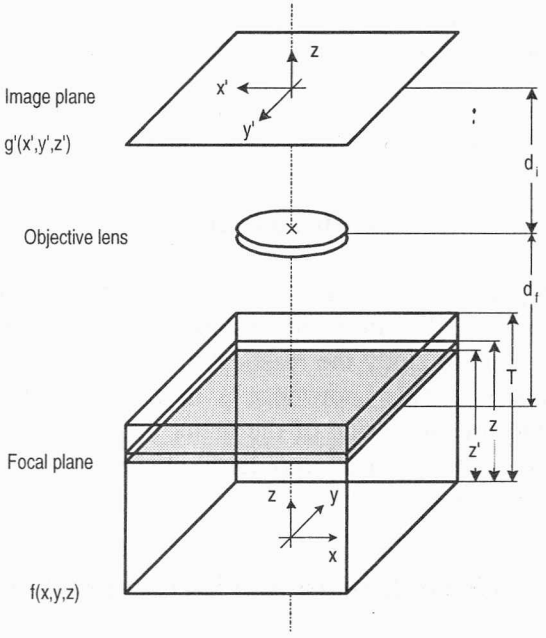

Fig. 1. Optical system of a microscope imaging of the occlusal surface of the tooth of the thickness T

Since the image distance d_i and the length f are fixed, the focal plane may be placed anywhere within the occlusal surface of the tooth by moving it up and down. Thus, we can place the focal plane at any desired level z'.

The digital image is processed and all scale factors are referred to the coordinate system related to the occlusal surface of the tooth.

2.3. Deblurring optical section images

A special algorithm is used to remove the defocused information from optical section images of the occlusal surface of the tooth. In other words, the three-dimensional function of the occlusal surface of the tooth is recovered from a series of images taken at different focal plane levels.

Image-ProPlus software with the programmable motorized X, Y and Z stages is used in this setup. The minimal step in the x, y and z directions is 2 μm.

As mentioned above, the occlusal surface of a tooth is sliced to get a series of thin sections, each of which can be studied individually. The step of discretization in X direction was 1.04200191 μm, in Y direction – 1.01804785 μm and in Z direction – 20 μm.

3. Generation of three-dimensional graphics

Two programs were used for generation of digital images of the occlusal surface of the investigated tooth. First, the MATLAB (High-Performance Numeric Computation and Visualization Software) program and, second, the Imaging for Windows 95 program.

The MATLAB program gives the opportunity to revise mathematically the digital data arrays and portray them in a graphical format. Using this program, it is possible to convert easily the digital data array of the points of the occlusal surface of the tooth, obtained by using the optical sectioning method, into the real three-dimensional image. The results of optical sectioning of the occlusal surface of the tooth are as shown in Fig. 2.

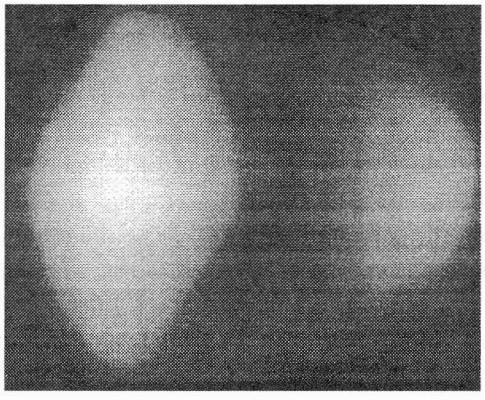

Fig. 2. The results of optical sectioning of the occlusal surface of the tooth

It was necessary to confirm that the difference between the image of the occlusal surface of the tooth obtained by the optical sectioning method and the real one is very insignificant. Also it was necessary to ensure that steps of discretization in three perpendicular directions were chosen correctly.

The Imaging for Windows'95 program was used to convert the digital photo images of the occlusal surface of the tooth (Fig. 3) into the real ones. It gave a possibility of revising digital photo images and images received by scanning and a possibility of confirming that the steps of the discretization in three perpendicular directions (X, Y and Z) were chosen correctly.

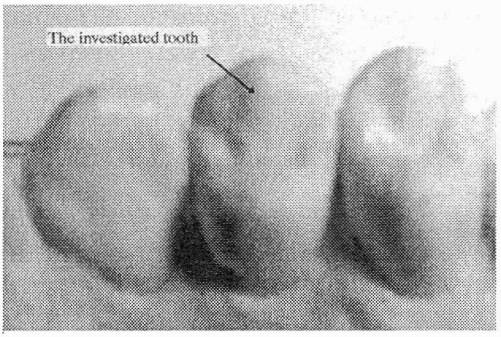

Fig. 3. The digital photograph of the occlusal surface of the investigated tooth

The results obtained prove that the digital data of the occlusal surface of the investigated tooth can be used in the simulation and study of the mastication process and determination of all forces acting upon the tooth during this process and also in determining the distribution of the stresses and strains within the periodontal ligament and the surrounding bones during the mastication process.

4. Conclusion

The system for obtaining three-dimensional images of the tooth is developed on the basis of the programmable motorized X, Y and Z stages and a conventional microscope. The optical sectioning method is used in order to obtain the location of each point on the occlusal surface of the tooth.

The future research will focus on: (1) the study of the reaction of the dentoalveolar structure to forces acting during mastication process, (2) the impact of the partial denture on the abutment tooth during mastication, (3) the simulation and study of the mastication process and determination of all forces acting upon the tooth during this process and (4) determination of the distribution of stresses and strains within the periodontal ligament and the surrounding bones.

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