Identification of defect in the surface of the dental enamel

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Abstract: In the present work is a methodology for the detection of defects in the surface of dental enamel, this one is based on the method of reflectometry, the prototype is made up of: tracto emitting - receiving, which consists of a laser beams with infrared length near and photodiode, which is placed on an automatic device to make a sweeping of the surface and to obtain an optimal angle that allows to collect the data in a computer. The collected data are stored of matrix form, to this matrix a processing is applied to him to make the conversion to an image RGB on gray scale. From these data a representation is made in three dimensions using metric topological to make the reconstruction in three dimensions of the roughness of material, with which it will be possible to be observed the defects that are in the roughness of the dental enamel with their characteristics of starting point, final position.

Key Words: Reflectometry, Topological Metrics, Interpolation, Detection of Defects, Dental enamel

1 Introduction

Even with the modernization of the devices with invasive technology used in dentistry diagnosis, it does not allow a more exact analysis in the determination of defects such as fissures, fractures, zones of demineralization, etc. Said devices are X-rays with digital plates, in which the images appear on a computer and the diagnosis process is quicker and more clear [1], although the dosage of radiation absorbed by the organs continues to be high; the disadvantage is that the zones of demineralization less than 100 micras are not observable. The dental laser uses the transillumination method and allows for the diagnosis of cavities and fissures, but there is no clear information about the wave length and size of the zone of demineralization that can be detected [2,3]. The non-invasive methods are revealing tablets, chemical methods, intra-oral cameras, inspection method, the digitalization of the figure help to determine where and to what extent the computerized model and the real object differ. These differences may serve as a guide to modify the development process until the model and real object are acceptable [3,4]. The optoelectronic system developed in the “Non-Invasive Methods for Dental Diagnosis” Laboratory is based on the reflectometer method [5,7,8,9.10]; it is used to acquire the data (voltage) of the dental enamel surface, this is found to be within the active range acquisition, non-contact, reflected and optic models [5].

2 Methodology

The main objective of this work is to determine micrometric defects in the tooth enamel surface, for which the reconstruction of the surface topography should be developed using digital image processing techniques.

2.1 Transmitter-Receiver Tract

This device is based on the reflectometer method, which consists of shining a ray of light on a surface and through the reflection intensity measure the rugosity of the sample surface; the tract consists of a laser beam as transmitter and a photodiode as receiver. This transmitter-receiver tract is placed in an automatic mechanism which makes a sweep over an X-Y Cartesian grid; the sweep is made at different distances 25, 50, 100, 150 micras, which allows an exact analysis of the rugosity of the surface of dental pieces.
The angles which are implemented for the analysis of rugosity are carried out experimentally, which

consists of a sweep over a surface and for each point analyzed, the angle of the transmitter and receptor changes and the distance between the T-R tract and the dental piece, since the rugosity of a dental piece is anisotropic [6]. See figure 1.

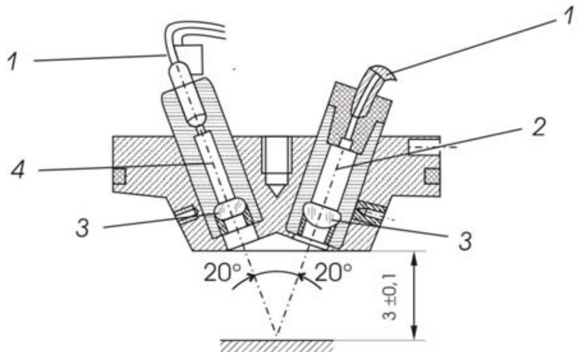

Figure 1. Transmitting-Receiving Device: 1) Optic fiber 2) Receptor 3) lens 4) transmitter

2.2 Automatization of the mechanism

It is known that the optimal angle for a given point on the surface is the maximum voltage obtained by the receptor in a given angle, for which the following methodology is proposed for each line swept on the ***Y*** axis, 10 points are obtained on the longitude of the ***X*** axis of the surface, for each combination of angles, for the transmitter as well as for the receptor, of 0° to 90°, the values of each point are acquired; the results of the highest levels of the 10 points are stored and the average of these is obtained, and the new value will be associated to its respective angles, and with these transmitter-receptor angles, the acquisition of the values of the ***X*** axis line is carried out.

The algorhythm that was created for this angle search methodology is presented in the following pseudocode.

```
/**********************************************/
/**/    Linea=1
                        /**/
/**/    Whle PosY <= MaxY
        /**/
/**/    {
                        /**/
/**/For
(AngEmisor=0;AngEmisor<=90;AngEmisor++)/**/
/**/                    For
(AngReceptor=0;AngReceptor<=90;AngReceptor++
)               /**/
/**/                    {
                        /**/
/**/                         For
(PosX=0;PosX<=10;PosX++)                /**/
/**/                                    {
/**/
        Mueve N_Pasos MotorX        /**/
/**/
        Adquiere Dato de la TAD     /**/
/**/
        VectorVolts[PosX]=Voltaje   /**/
/**/                                    }
/**/
        MatVolts[AngEmisor,AngReceptor]=Prome
dio(VectorVolts)        /**/
/**/                    }
                        /**/
/**/
                        /**/
/**/    VoltMax=0
                        /**/
/**/    For (X=0;X<=90;X++)
                        /**/
/**/            For (Y=0;Y<=90;Y++)
                        /**/
/**/                    If
(MatVolts[X,Y]>=VoltMax) then
                /**/
/**/                    {
                        /**/
/**/            VoltMax=MatVolts[X,Y]
                /**/
/**/    AngOptEmisor[Linea]=X
        /**/
/**/    AngOptReceptor[Linea]=Y
        /**/
/**/            Linea++
                /**/
/**/                }

/***********************************************************
```

2.3 Acquisition of data

As is shown in the experimental device of figure 2, the luminance signal obtained at the exit of the receptor is converted to voltage in the order of millivolts, which is amplified to a range of 0 to 5 volts; this is connected to a data acquisition card, which converts the analogical voltage to digital voltage and this result is sent to a computer [11,12].

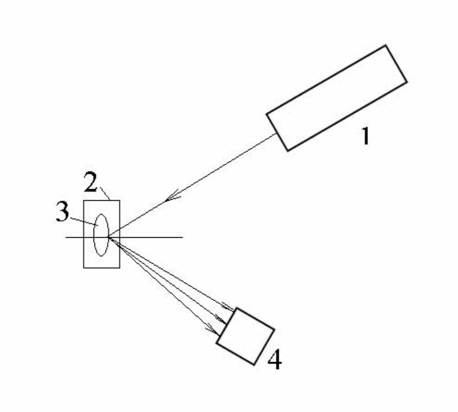

Figure 2. The experimental setup: 1 – laser (semiconductor or He-Ne), 2- cell, 3 – dens, 4 – CCD.

The results are stored matricially in a data file. An RGB image conversion on a 256 color scale of grey is carried out on the data obtained by the acquisition system. The Fourier and Wotherford Transform filters will be applied to them, which allows correction of anomalies in the data.

2.4 Reconstruction of the rugosity of tooth enamel

To generate the tooth enamel rugosity topography, an algorhythm based on topological measurements was developed. The topological measurement is the distance that exists between two points; this method consists of obtaining the distances between the starting point with the 8 neighbors that are found around this [13].

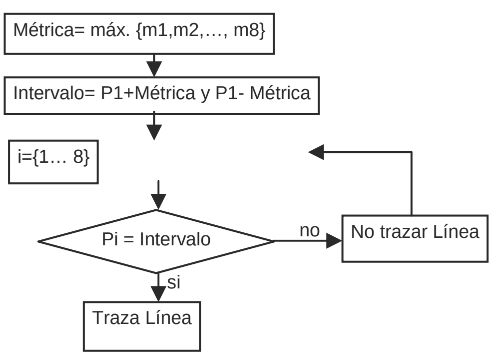

Figure 3 Algorhythm of topological measurement

In figure 3, the surrounding area of 8 neighbors is seen. With the 8 measurements obtained, the greatest, median or least is taken to find the connection between the points. This is done to be able to observe the differences between surrounding areas, with which the topographical reconstruction is generated of each face of the dental pieces, and figures can be constructed within the space to later recognize and identify certain forms that fulfill properties to know the possible defects in out dental samples.

2.5 Interpolation

To generate the topology of the rugosity of the biological material, an interpolation is carried out through topological measurements, for which the following is done:

a) get rid of all the vectors missing attributes,

b) for the ***i-th*** component, find the median value with all the available vectors,

c) for all the component pairs x_i and y_i of the $\boldsymbol{x}$ and $\boldsymbol{y}$ vectors define b_i as,

$$b_i = \begin{cases} 0, \text{si tanto } x_i \text{ como } y_i \text{ no hay similitud} \\ 1, \text{en caso contrario} \end{cases}$$

Then, the proximity between $\boldsymbol{x}$ and $\boldsymbol{y}$ we define as (6):

$$\varphi(x, y) = \frac{l}{l - \sum_{i=1}^{l} b_i} \sum_{\forall i : b_1 = 0} \phi(x_i, y_i) \qquad (6)$$

where: $\phi(x_i, y_i)$ - indicates the proximity between the two scales x_i and y_i $\phi(x_i, y_i) = |x_i - y_i|$ [5]

2.6 Reconstruction of the volume of the dental pieces

Due to the fact that the image of each tooth face is independent, it is necessary to group together said images in order to form the solid; this is carried out by grouping together the borders of each image and filling in the black holes; it also has the characteristics of rotation, translation and scaling. The computer tool will be designed in Delphi, since this is a programming language directed toward objects, which is based on the Pascal programming language, in which the data acquired can be seen matricially on the tooth face the image in 2 dimensions in RGB at 256 color grey scale. To carry out this application and observe the image in three dimensions, a graphic tool named OpenGI is used. This belongs to Silicon Graphics, and adaptations were made so it would work in the Windows operating system.

2.7 Validation of data acquisition

To guarantee that the data obtained from the acquisition card is correct and that there is no variation in a same point in different times, a method based on the calculation of frequencies is carried out, which consists of making ***N*** acquisitions on a same point and taking the value of voltage that is repeated according a validity percentage ***R*** of frequency; the pseudocode is shown later.

```
/*************************************************************
********************************************/
/**/      While(FREC < (N*(R/100)))
/**/       {
                                        /**/
/**/                for (M=0;M<=N;M++)
                                        /**/
/**/                          while(res==0)
                                        /**/
/**/                                    res=Adquiere    dato
de la TAD.                              /**/
/**/                          Volts[M]=res
                                        /**/
/**/                Next M
                                        /**/
/**/                Ordernar(Volts)
                                        /**/
/**/                Max=Volts[0]
                                        /**/
/**/                For(j=0;j<N;j++)
/**/                          {
                                        /**/
/**/                                    val=volts[j]
                                        /**/
/**/                                    if(val==Max)
                                        /**/
/**/                                              FREC++
                                                  /**/
/**/                                    Else
                                        /**/
/**/                                              {
                                        /**/
/**/
          Volts[Pos]=Max                          /**/
/**/
          Frecuencia[Pos]=FREC                    /**/
/**/
          Max=Val;                                          /**/
/**/
          FREC=1                                            /**/
/**/
          Pos++                                   /**/
/**/                                              }
                                        /**/
/**/                          }
                                        /**/
/**/                Volts[Pos]=Max
                              /**/
/**/                Frecuencia[Pos]=FREC
                              /**/
/**/                FREC=1
                                        /**/
/**/                For (j=;j<=Pos;j++)
                                        /**/
/**/                          If (FREC<Frecuencia[j])
                              /**/
/**/                          {
/**/
          FREC=Frecuencia[j]                        /**/
/**/                                    PosFrec=j
                              /**/
/**/                          }
                              /**/
/**/                DatoValido=Volts[PosFrec];
                                        /**/
/**/      }
                              /**/
/*************************************************************
*****************************************************/
```

3 Experiments and results

The methodology carried out for the experiment was as follows. It was carried out with extracted dental pieces. The extraction was carried out through an incision and the gum was separated from the bone. The bone was eliminated, exposing the radicular portion of the dental organ. The tooth extraction was carried out through elevators without having contact with the enamel, so it would suffer no damage. These pieces were preserved in containers with artificial saliva, as shown in figure 4.

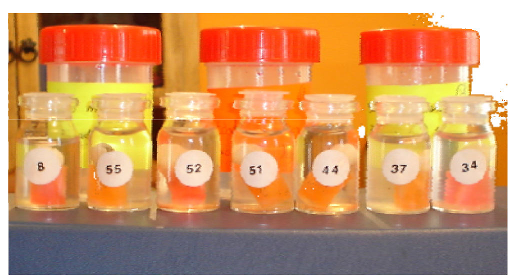

Figure 4. Preservation of teeth

In particular, an extracted tooth that is a first upper right premolar has the following measurements: on the labial face 7.8 mm on the longitudinal axis (center of the crown), 8.9 mm mesial third, and 9.6 mm in the distal third.

This tooth was placed in the scanning mechanism to obtain the reflex data. See Figure 5.

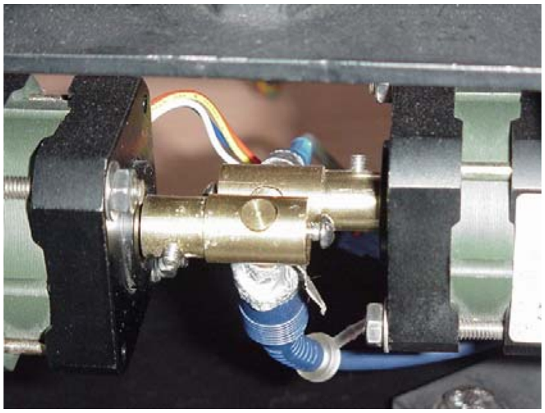

Figure 5. Scanning mechanism

To observe the matricial form data RGB image and the reconstruction in 3D of the teeth, software was designed, which is shown in figure 6, with data from our experiment. This software shows the face type, face data, face image in RGB, face image in 3 dimensions.

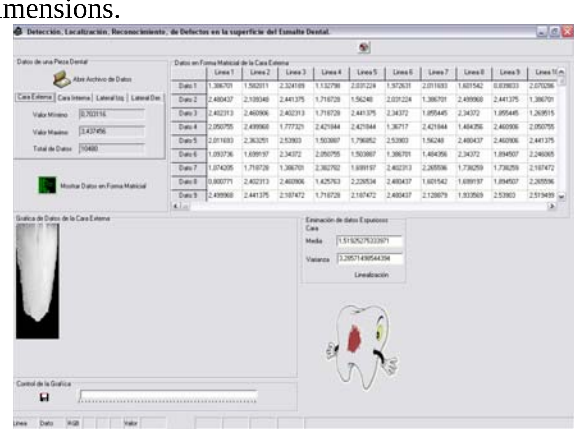

Figure 6. Screen with matricial image and data

In figure 7, we see the RGB image on a grey scale. This is generated from a data matrix obtained by the automatic mechanism.

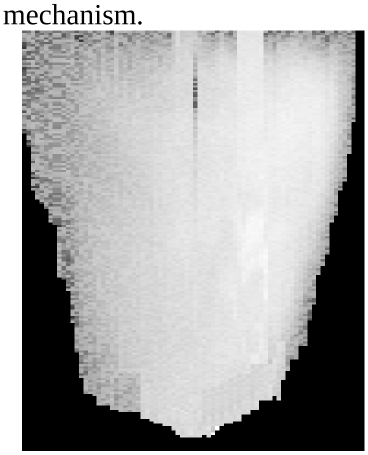

Figure 7. Image of the tooth on a grey scale.

In figures 8 and 9, the image of low pass and band pass is shown.

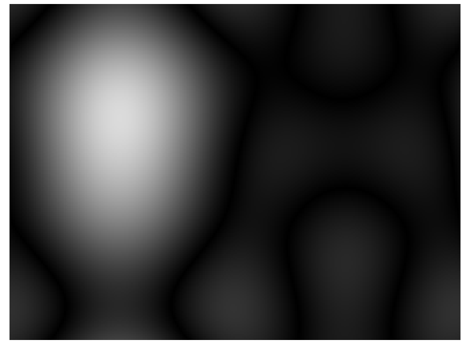

Figure 8. Filtered Image of low pass.

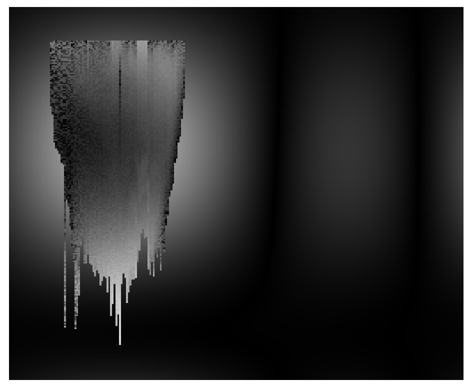

Figure 9. Filtered Image through the band of the dental piece.

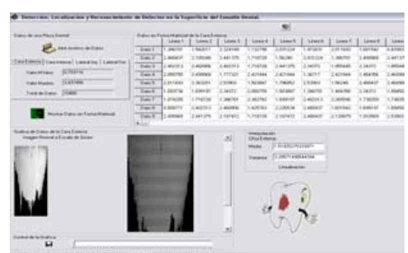

Figure 10. Image with an interpolation

Figure 11,12,13 shows the construction of the volume in which the defect done manually and validated with a metallographic microscope can be seen.

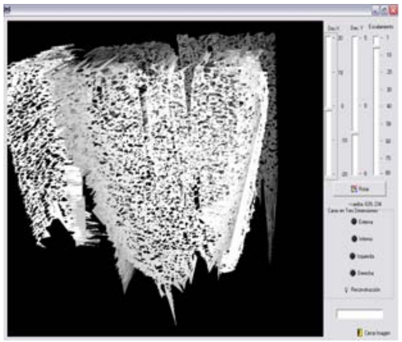

Figure 11. Reconstruction of the volume in 3D.

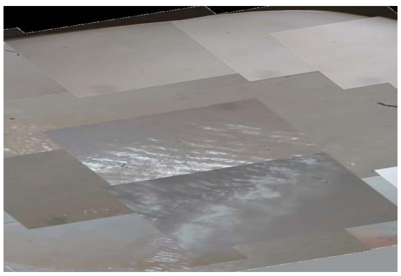

Figure 12. Tooth with demineralization observed from the microscope.

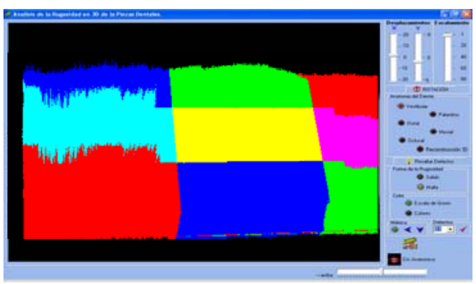

Figure 13. Tooth with location of the defect

4 Conclusion

Software was obtained that allows visualization of the image in three dimensions. The reconstruction of the volume of dental pieces from the data generated by the APDSED optoelectronic device that analyzes the rugosity of the dental enamel, from which it gives a diagnosis of the possible surface defects.

The results show that the rugosity of the dental pieces varies. It also contributes a methodology and software for the preventive diagnosis in the stage of defects in the dental enamel, based on the non-invasive technique of non-contact that will allow the physical study of the tooth rugosity visually.

5 Acknowledgments

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