Implementation of Holographic Research in Periodontal Disease

MARIUS MANOLE[1], ALEXANDRU VICTOR BURDE[1]*, CLAUDIA MILEA[2], ALINA NECSULESCU[2], ROBERT CIOCOIU[2], OCTAVIAN TRANTE[2], COSMIN SINESCU[3], AUREL MOHAN[4]*, DIANA DUDEA[1], DAN CRISTIAN IONEL[5], SORANA BACIU[1]

[1]University of Medicine and Pharmacy Iuliu Hatieganu, Faculty of Dentistry, 8 Victor Babes Str., 400000, Cluj Napoca, Romania

[2]University Politehnica of Bucharest, Faculty of Material Science and Engineering, Department of Materials Science and Physical Metallurgy, 313 Splaiul Independentei, 060042, Bucharest, Romania

[3] Victor Babes University of Medicine and Pharmacy, Faculty of Dentistry, 2 Eftimie Murgu Sq., 300041,Timisoara, Romania

[4]University of Oradea, Faculty of Medicine, 1 Universitatii Str., 410087, Oradea, Romania

[5]Dunarea de Jos University of Galati, Faculty of Medicine and Pharmacy, 47 Domneasca Str., 800008, Galati, Romania

In this paper were evaluated from a quantitative and qualitative point of view the retraction of the marginal periodontal tissues, using a holographic technique, subsequently validated through measurements accomplished with the help of acknowledged, consecrated soft wear.

Key words: dental stone cast, holography, fixed partial dentures, periodontium

Periodontal disease is often present in patients with fixed partial dentures, especially in cases with a longer period of wearing. One of the signs of periodontal disease is gingival retraction. Evaluating the extent of gingival retraction will help establishing a complete diagnosis and guiding the treatment plan.

Holography is defined as a 3D image on a generally bi-dimensional support, so in other words it can be considered as an advanced form of a photographic technique [1]. The recordings are called holograms. The difference between a photograph and a hologram is that each point of a photograph carries the information about the intensity and possibly color of a point or a small area of the photographed object, whilst in holography, the information about each point of the object is distributed over the whole surface of the hologram. Electromagnetic waves reflected by the holographic image are precisely captured on the holographic support and reconstructed at the appearance of the hologram. Thus the hologram becomes an equivalent of a window through which the eye perceives the same light-field produced by the registered image [2].

There are several types of holography. The technical term for a simple hologram is wave front reconstruction. A laser beam along with mirrors and lenses are used to diffract the light into a series of very fine lines (fringes). The resulting hologram is thus a true three-dimensional record of the original object. The interference fringes obtained are registered on a high resolution photographic plate [3]. After development of the plate a light beam with identical position and distribution as the reference wave used for recording, is emitted. The interference fringes recorded on the photographic film act on the beam as a diffraction net, generating a diffracted wave having the same amplitude as the wave coming from the object subjected to holography, producing thus on the retina the same image as the real object [1].

The principle of optical holography – obtaining the recording of the whole image of an object having as source the diffraction figure produced by an object, has two stages: the Fresnel diffraction figure produced by the object illuminated coherent with the bright background is overlapped with a coherent bright background. The resulting interferogram is recorded on a photographic plate creating the hologram which contains the whole information- amplitude and phase of the light beam diffracted by the object; the photographic hologram is submitted to a monochromatic parallel light beam.

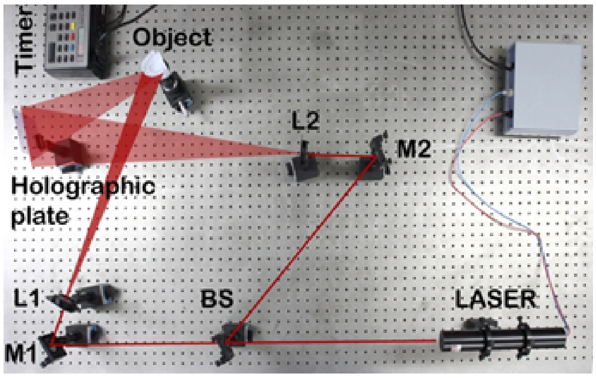


Fig. 1. Schematic representation of the holographic system

Diffraction effect occurs due to the variable optical density of the photographic plate and thus the image of the object is reconstructed.

Classical photography records only the wave amplitude coming from an object while phase information is being lost whereas holographic fringes contain the complete information about the object (amplitude is expressed by contrast of the fringes and the phase in the distance between them). In holography the same source is used both for illuminating the object as well as for producing the coherent background. Leith and J. Upatnieks improved the method showing that, when arriving on the photographic plate, the light beam responsible of the coherent background, forms a relatively high angle with the light beam diffracted by the object, this problem being solved by using a laser source [2,4,5].

Advantages of holography consist in the possibility of evaluating of a phenomenon in a given, specific time [6,7].

The various aspects related to the interface phenomenon appear to be very interesting not just for dentistry [8-12, 36-39], but also for many clinical specializations like orthopedics [13-18], neurosurgery [19-21], cardiovascular surgery [22-24], abdominal surgery [25-28], gynecology [29-31], and other surgical specializations [32-35].

*email: mohanaurel@yahoo.com

Another advantage and application of holography is the microscopic holography characterized through the interference between the object wave followed by the diffraction and propagation of another reference wave resulting in the formation of the holographic image [4].

Experimental part

Material and Method

The present research aims to evaluate from a quantitative and qualitative point of view the retraction of the of marginal periodontal tissues, using a holographic technique, subsequently validated through measurements accomplished with the help of acknowledged, consecrated soft wear.

Impressions were made for 17 partial edentulous patients treated with fixed partial dentures in the frontal area, at the first appointment and the 12th month appointment. Stone models (casts) were poured and holographic registrations were made corresponding to the first appointment and to the 12th month appointment (second appointment).

Holograms were achieved on holographic plates Triring (China) with spatial resolution of 2000 pairs of lines/mm and maximal sensitivity of 633 nm. A HeNe laser beam of 13 mW was used. Holographic plates were exposed to laser light for 32 seconds and developed 4 minutes in D76, then fixed for 5 minutes in photo acid and rinsed 20 minutes under flowing water. A BS beam splitter with 7:3 division ratio, plane mirrors (m1, m2) and convergent lens (L1, L2) with 4.5 mm (L1) / 6,5 (L2) focal range were used.

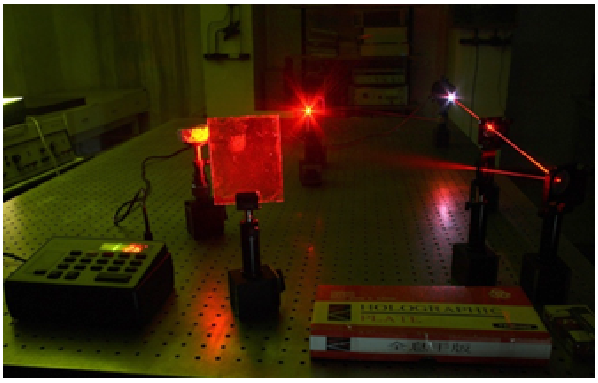


Fig. 2. Experimental view of the holographic system

For each patient an analogic study cast revealing the initial periodontal status was poured, as well as at 12 months. First patients were evaluated from a periodontal point of view initially (appointment 1) and after 12 months were studied (appointment 2). Holograms of the casts obtained at 12 months were superimposed on the analogical physical cast obtained at the first appointment. Straight parallel lines corresponding to the reminded appointments were drawn, highlighting thus periodontal retraction.

The subsequently used method for validating the extent of periodontal retraction was the imagistic quantification Sigma Scan Pro. The superimposed holograms in interference were imported using the above mentioned soft wear. After the initial calibration of the system, measurements were made. Six measurement points were established for each abutment: two points on the mesial and distal surface, one buccal and one lingual. The values were compared with measurements accomplished with an electronic measurement tool (caliper) made directly on the two analogues casts. Results were inserted into a table and compared. Only the measurements which showed different retraction values between the first and second appointment, were considered. Measurements were made by a unique observer for minimizing errors occurred by different operation modus. The validation of the results with the help of the electronic tool, the mean value of three different measurements was taken into account. Evaluations accomplished with the Sigma Scan Pro were exported from the system.

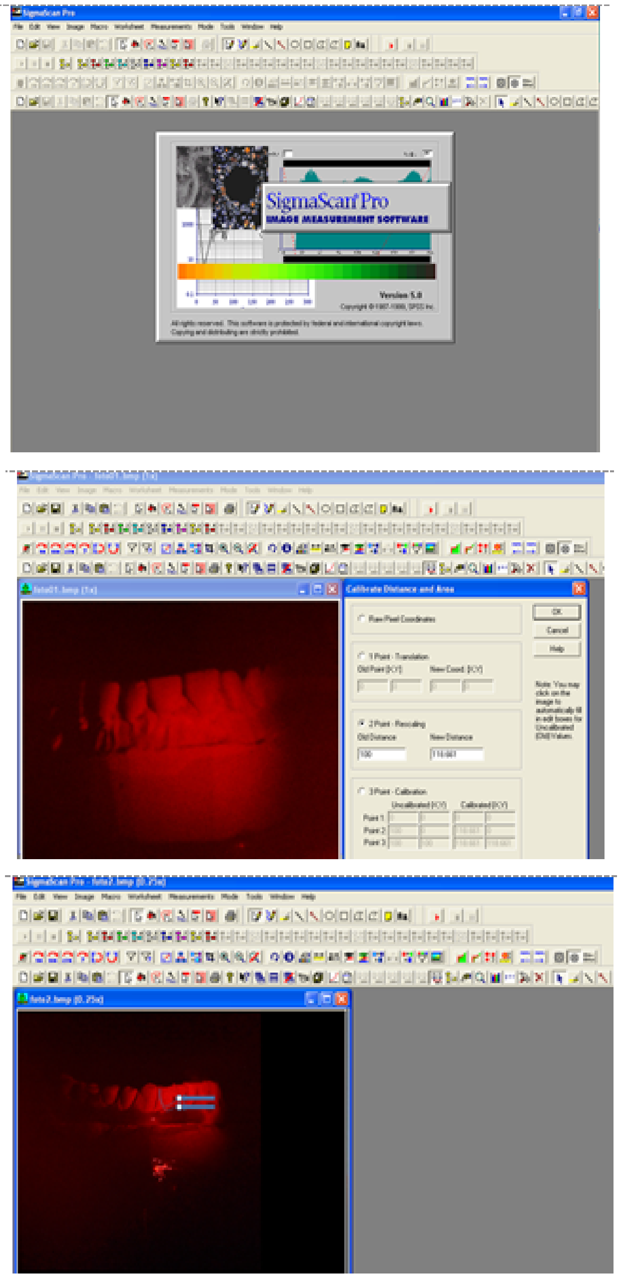


Fig. 3. Representative images for the imagistic quantification using Sigma Scan Pro

Results and discussions

For each patient the mean square error, the mean deviation of holographic measurements compared to the electronic measurements on analogic cast as well as the mean values obtained by measurements on the analogic cast, were made. Descriptive statistical analysis was used to express the differences between the two measuring methods. The displayed values represent the mean of all measurements on each patient for all the teeth included in the study. An example of analogical and digital measurements on patient nr 3 is shown in next figure.

Pacient 3		Analogical measurements	Digital measurements
1.	Vestibular Canin 1.3.	0,022 mm	0,030 mm
2.	Palatinal Canin 1.3.	0,001 mm	0,001 mm
3.	Mezio – Vestibular Canin 1.3.	0,000 mm	0,000 mm
4.	Mezio – Palatinal Canin 1.3.	0,000 mm	0,000 mm
5.	Disto – Palatinal Canin 1.3.	0,000 mm	0,000 mm
6.	Disto – Palatinal Canin 1.3.	0,000 mm	0,000 mm
7.	Vestibular Incisiv Lateral 1.2.	0,002 mm	0,002 mm
8.	Palatinal Incisiv Lateral 1.2.	0,001 mm	0,000 mm
9.	Mezio – Vestibular Incisiv Lateral 1.2.	0,000 mm	0,000 mm
10.	Mezio – Palatinal Incisiv Lateral 1.2.	0,000 mm	0,000 mm
11.	Disto – Palatinal Incisiv Lateral 1.2.	0,000 mm	0,000 mm
12.	Disto – Palatinal Incisiv Lateral 1.2.	0,230 mm	0,230 mm
13.	Vestibular Incisiv Central 2.1.	0,000 mm	0,000 mm
14.	Palatinal Incisiv Central 2.1.	0,001 mm	0,001 mm
15.	Mezio – Vestibular Incisiv Central 2.1.	0,001 mm	0,001 mm
16.	Mezio – Palatinal Incisiv Central 2.1.	0,000 mm	0,000 mm
17.	Disto – Palatinal Incisiv Central 2.1.	0,000 mm	0,000 mm
18.	Disto – Palatinal Incisiv Central 2.1.	0,300 mm	0,320 mm
19.	Vestibular Canin 2.3.	0,202 mm	0,230 mm
20.	Palatinal Canin 2.3.	0,001 mm	0,001 mm
21.	Mezio – Vestibular Canin 2.3.	0,000 mm	0,000 mm
22.	Mezio – Palatinal Canin 2.3.	0,000 mm	0,000 mm
23.	Disto – Palatinal Canin 2.3.	0,000 mm	0,000 mm
24.	Disto – Palatinal Canin 2.3.	0,130 mm	0,132 mm

Fig.4. Example of analogical and digital measurements on patient no. 3

For each patient mean square error was calculated, the mean deviation of the holographic measurements compared to the electronic measurements on analogic cast was expressed, as well as the mean value on the analogic cast.

Mean values of the measurements accomplished with the two measuring methods were also expressed as it can be seen in the comparative chart below (figure 5). On the horizontal axis the patient's number is displayed. The blue bars represent the analogue measuring method, while the magenta bars, the holographic measurements (mm).

Percentage value of mean deviation between the two measuring methods (holographic vs. analogic) was is shown in the table 1.

The standard deviation/ mean square error was expressed in figure 6.

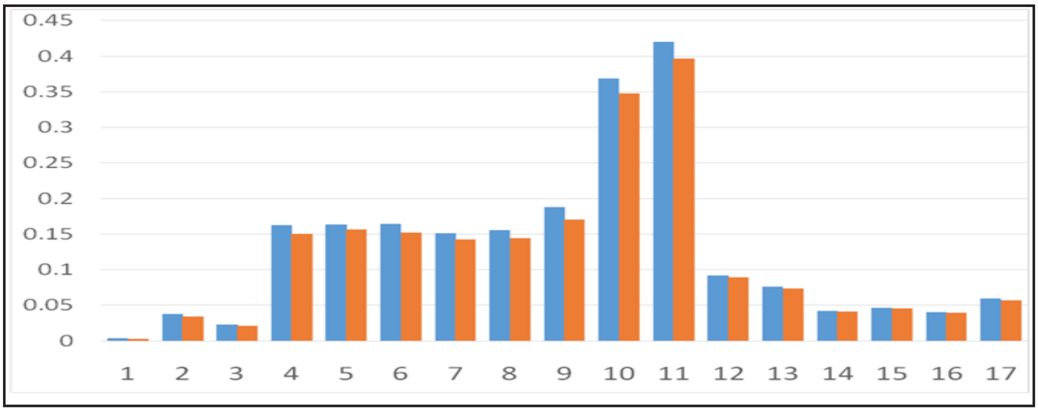
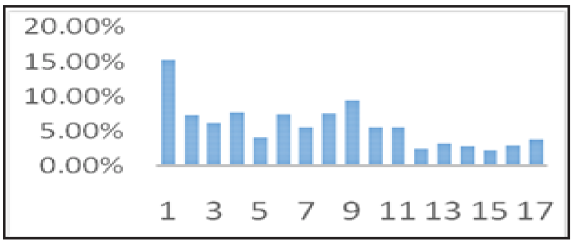


Fig. 5. Mean values of the measurements accomplished with the two measuring methods

Table 1. EXPERIMENTAL RESULTS ON HOLOGRAPHIC MEASUREMENTS COMPARED TO THE ELECTRONIC MEASUREMENTS ON ANALOGIC CAST FOR ALL 17 PATIENTS

Patient Nº	Mean square error(mm)	Mean deviation holographic measurements compared to the electronic measurements on analogic cast	Mean value on the analogic cast(mm)
1	0.0005	15.27%	0.0033
2	0.0028	7.25%	0.0372
3	0.0014	6.22%	0.0225
4	0.0124	7.64%	0.1623
5	0.0067	4.11%	0.1630
6	0.0122	7.44%	0.1640
7	0.0084	5.56%	0.1511
8	0.0117	7.52%	0.1556
9	0.0178	9.47%	0.1880
10	0.0204	5.54%	0.3682
11	0.0234	5.57%	0.4201
12	0.0219	2.39%	0.9163
13	0.0024	3.17%	0.0757
14	0.0012	2.84%	0.0423
15	0.001	2.16%	0.0463
16	0.0012	2.97%	0.0404
17	0.0023	3.87%	0.0594



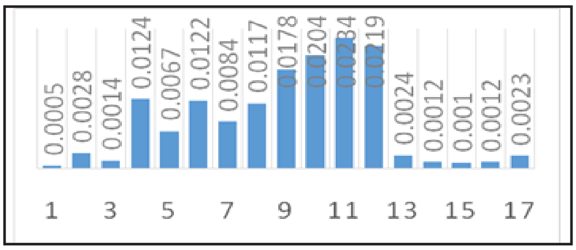


Fig. 6. The standard deviation/ mean square error for experimental measurements

Our method can be improved with the help of gingival masks, avoiding thus the cast of two models for each patient and saving time. Also the gingival mask technique used in other studies [7], helps emphasizing the differences between the periodontal status at the specified juncture, simplifies the procedure and minimizes errors. The technique presumes creating a gingival mask corresponding to the first appointment, generating a hologram and removing this mask from the cast without modifying its position. Afterwards a second mask is build, corresponding for the second appointment and a second hologram is generated. In the end the interference on the superimposed holograms will reveal the extent of periodontal retraction.

Percentage value of mean deviation between the two measuring methods (holographic vs. analogic) had dispersed values of the percentage expression which shows that not always the results of the measurements are reproducible.

The standard deviation or the mean square error expresses the extent of the distance until which the signal fluctuates compared to the mean value, so it is an expression of dispersion.

The mean square error equals to the square radical of the arithmetic mean of the squares deviations values of the mean and was calculated using the following formulas were:

$$e_i = \frac{1}{N}\sum_{j=1}^{N} \frac{\sqrt{(h\,ij - aij)^2}}{1}$$

Formula for mean square error

$$a_i = \frac{1}{N}\sum_{j=1}^{N} a_{i-j}$$

Formula for mean measurement on the analogic cast

·e_i represents the mean square error for patient I;

·N represents the number of measurements made for each patient;

·h_{ij} represents the holographic measurement j of the patient i;

a_{ij} represents the analogic measurement j of the patient i;

The mean deviation of the holographic measurement compared to the analogical measurement is a percentage expression of how much the holographic measurement varies compared to the analogical one and is at the same time a mean of showing the quality of the holographic registration. The table shows that the more precise the holographic registration is, the higher is the value of the analogical measurement. Thus the lower the absolute value measured on the analogical cast is, the higher is the value of the measurement error on the holographic registration.

Holography is an important stage in recording and storing dental casts. They can be visualized at any time, without loss of information (e.g. resolution) as time passes by. Furthermore, the dimension of a holographic film has the size of an A4 sheet and a thickness of 0.5 cm. Thus, hundreds of holograms can be stored using the same space as needed for 2-3 stone casts. The main disadvantage consists in the expensive and arduous technology that assumes the existence of an optical bank. .

The possibility of accomplishing interferometric measurements on the given hologram, is highly dependent on the precision of the holographic recordings. Likewise, depending on the precision of the holographic recordings is the calculation of tensions occurred in the investigated structures [7,8].

Holographic recordings of the periodontal status at the second appointment (at 12 months after the first appointment) were made, and were compared to the initial state (first appointment). The progress of gingival retractions was illustrated through parallel lines corresponding to the upper limit of the periodontium, for each studied case. The images in the present study show the steps for establishment of the area of interest for measuring periodontal retractions on the buccal face, creating landmarks for the initial state of the periodontium, evaluating of periodontal retraction for the lateral incisor, imagistic quantification of periodontal retraction for the upper canine, as well as image calibration. Thus evaluation was made mainly on the buccal side of the casts, leaving unexplored areas and thereupon loosing precious 3D regarding the periodontium.

Conclusions

Holograms were generated and superimposed in coherence for allowing evaluation in six points of each abutment. The measurements accomplished with a consecrated soft (Sigma Scan Pro) were validated by the direct measurements achieved with an electronic caliper.

Values of the analogical measurements had mostly higher values than those obtained by using the previous acknowledged soft. Physical measurements took into account the visual assessment of retraction areas, which imply human error. Keeping in mind the errors which can arise in physical, analogical measurements, we can state that the holographic techniques are sensitive and precise and that they can emphasize in the optimal way periodontal retractions. Holography offer new nondestructive possibilities for bridging the gap between in vitro and in vivo measurements in dentistry, and thus increase the possibility of achieving more accurate and sometimes more objective diagnosis and therapy. The use of stone and plaster study models is an integral part of any dental practice and is required for research.

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Manuscript received 23.01.2018