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Identification of the anatomical elements used in periodontal diagnosis on 40 MHz periodontal ultrasonography

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Abstract

Gingival inflammation is highly prevalent among adult populations in all regions of the world. High rates of chronic periodontitis have been reported worldwide. The methods for assessing the gingival inflammation and periodontal disease would need more precision and less user-dependence. The aim of this study consists in identifying the information for diagnosis and staging of periodontal disease using 40 MHz periodontal ultrasonography. Our *in vivo* study has been made on 49 teeth of 10 patients with marginal periodontal disease. Standard clinical and radiological periodontal examinations were performed. Afterwards the results were compared with the information obtained from images recorded with Ultrasonix SonoTouch used at 40 MHz. On the ultrasound images, were performed very accurate measurements between the cortical bone and the cement–enamel junction or the root wall compared with the measurements made on intraoral digital radiographs. Those measurements could be used to diagnose the bone resorption. In order to monitor the gingival inflammation could be recorded the width of the attached gingival mucosa and the height of the gingival margin on ultrasound images. 40 MHz periodontal ultrasonography is a reliable imagistic method for identifying the necessary anatomical elements in order to make an accurate periodontal diagnosis for the examined area.

***Keywords*:** periodontal diagnosis, ultrasound imaging, bone resorption.

Introduction

Periodontal disease and gingival bleeding is highly prevalent among adult populations in all regions of the world. *World Health Organization* (WHO) data show that 90–100% of 34-year-old adults have gingival inflammation [1]. Approximately 48% of United States adults have chronic periodontitis, and similar or higher rates have been reported in other populations [2]. Kassab & Cohen, based on previous studies, concluded that 88% of people 65 years of age and older and 50% of people 18 to 64 years of age have one or more sites with gingival recession. Most often, this recession occurs on the buccal surface [3].

Irfan *et al.* concluded that periodontal epidemiology needs better methodology of research, including improved definitions for periodontal disease and health; different approaches to measuring periodontal indices of pocket depth and attachment loss [4]. Newman *et al.* [5] state that despite the fact that clinical signs of gingivitis are easy to detect, a universally accepted threshold for the amount or severity of gingival inflammation should exist.

Considering that gingival inflammation and advanced periodontal disease are widely spread, it is mandatory to find new methods of investigation, non-invasive and cost-effective that could compensate the lack of the existing methods. Under these circumstances, ultrasonography is a feasible method which returns reliable results that could be easily interpreted [6]. Zimbran *et al.* [7] have proved in their study in 2013 the possibility to use 40 MHz ultrasonography *in vivo*, for periodontal evaluation. Another choice for non-invasive and very accurate examination of periodontal tissues is Optical Coherence Tomography (OCT). This method is, however, rather limited due to reduced penetrability into the tissues. Because the scanning range is usually several millimeters, hundreds or thousands of pictures may be necessary for a whole lesion. Also, low quality images will be observed with faster imaging speeds due to insufficient processing time. OCT can obtain images in seconds. Users should select a balance between image quality and acquisition time, thus this method becomes time-consuming if aiming for good quality [8, 9]. High frequency ultrasonography encounters almost similar problems, but the advantage is that in a relatively short time, if the user has the necessary experience, one can acquire images with a very good resolution. These images offer the possibility to perform accurate measurements to a few hundredths of millimeters.

The aim of this study consists in identifying the information for diagnosis and staging of periodontal disease using 40 MHz periodontal ultrasonography.

Materials and Methods

The study was conducted on 10 patients (four females and six males, aged 25–65 years) with gingival inflammation and chronic periodontitis. Ethical approval and written informed consent of all patients were obtained. Examinations were performed on upper and lower premolars and frontal teeth for each patient. Only the teeth without any odontal lesions, caries or restorations were examined. For all these teeth, the following examinations were performed: periodontal ultrasonography, clinical examination and digital periapical X-rays.

Ultrasound examination

For periodontal ultrasonography was used Ultrasonix

SonoTouch echographer (Chison Medical Imaging Co., China) with a 40 MHz probe, 1.5 cm footprint. The examinations have been performed using the external transcutaneous approach. A cotton roll was placed between the upper and lower molars in order to obtain a stable half-opened position of the mouth. During ultrasound examinations, the clinician checked, by direct visualization, gently retracting the lip, that the middle of the footprint of the transducer was placed on the middle of the buccal surface of the tooth to be examined. The transductor was placed in the middle of the buccal surface just like Florida Probe handpiece for clinical examination, parallel with the long axis of the examined tooth, obtaining longitudinal sections in frontal or sagittal plane.

On ultrasound images, the following data were recorded, using Ultrasonix SonoTouch software: the distance between alveolar bone crest and the cement–enamel junction (UBJ), the distance between the alveolar bone crest and the free gingival (UBG) margin, the attached gingival width/thickness (UGW) at the limit of the alveolar bone crest, measured on ultrasound images, the ultrasound gingival recession (UGR) as the distance between cement–enamel junction and the free gingival margin was measured in order to assess gingival recession on ultrasound images (UGR), the width of periodontal space at its coronal limit (UWPS), between the alveolar bone crest and tooth root (Figure 1).

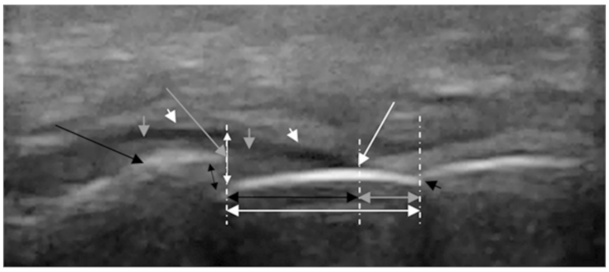

Figure 1 – ***Ultrasound examination 40 MHz, longitudinal section, buccal surface, on tooth axis. Gingival epithelium (short white arrow), hypoechogenic connective tissue (short gray arrow), hyperechogenic cortical bone (long black arrow), cement–enamel junction (short black arrow), free gingival margin (long white arrow), alveolar crest (long gray arrow), gingival recession (UGR) distance between cement–enamel junction and gingival free margin (gray double arrow), UBJ distance between alveolar crest and cement–enamel junction (white long double arrow), UWPS periodontal space width (black short double arrow), UBG distance between alveolar crest and free gingival margin (long black double arrow), UGW attached gingiva width/thickness at the alveolar crest limit (white short double arrow).***

In order to verify the accuracy of ultrasound periodontal examination, the gingival recession measured on ultrasound images was compared with the gingival recession measured clinically with Florida Probe. The measurements on the ultrasound images were performed only on buccal surfaces due to the shape and size of the transducer which best fit there.

Clinical examination

All clinical examinations were carried out in the middle of the buccal surface, at an equal distance between mesial and distal surface, parallel with the long axis of the tooth. The gingival recession (CGR) measurements were clinically recorded with Florida Probe Handpiece, a constant-force, computerized probe (Florida Probe Corporation, Gainesville, USA). Before each patient, the probe was calibrated according to the producers directions of use.

During clinical examination, in order to measure the gingival recession in the middle of the buccal surface it was necessary to identify the cement–enamel junction and the free gingival margin. The cement–enamel junction was identified by direct visualization, in case the patient has gingival recession on the examined buccal surface. If the free gingival margin covers the cement–enamel junction, the gingival recession (CGR) was considered to be 0.

Radiological examination

The periapical radiographies performed with parallel technique, were recorded using the Soredex Minray intraoral digital X-ray unit. For each examined tooth, the distances between alveolar crest and cement–enamel junction on mesial and distal area were measured, using Soredex Minray Software. The mean between those two measurements was calculated (XBJ). The periodontal space width was measured mesial and distal at its coronal limit and the mean of the two values was calculated (XPSW).

Statistical analysis

Statistical analysis was performed using SPSS® v. 18.0 (SPSS Inc., Chicago, IL, USA) and Microsoft Excel 2010®. Significance was assumed when $p<0.05$.

To test the correlation between the variables, the two-tailed Student's test has been used, and the correlation coefficient (R) was calculated.

First part

The statistical study of the data has been performed comparing the same distances on the ultrasound images, gingival recession (UGR), and respectively by measuring during clinical examination the gingival recession, CGR. Also, the statistical study of the data obtained measuring the same distances on ultrasound images respectively on periapical X-ray images has been performed.

Second part

A comparison between the thickness of the fixed mucosa at the limit of the alveolar crest measured on the ultrasound image (UGW) and the distance between alveolar crest and cement–enamel junction also measured on ultrasound images (UBJ) was performed. After that were compared the distance between the alveolar crest and the free gingival margin measured on ultrasound images (UBG) and the distance between alveolar crest and cement–enamel junction also measured on ultrasound images (UBJ).

Results

On the total of 10 patients, data on the ultrasound images taken from the buccal surface of 49 teeth were recorded. Overall, 245 measurements were performed on these ultrasound images.

The gingival epithelium on the buccal surfaces of the alveolar process was identified on the ultrasound images, as a continuous, white hyperechogenic line, due to its principal cell type, the keratinocyte and the keratohyalin granules produced during the keratinization process. The average thickness of the gingival epithelial layer was 0.22 mm with a standard deviation of 0.08. Due to its reduced content of cells comparing to gingival epithelium and because of the extracellular compartment, which has a high content of water, the gingival connective tissue appears hypoechoic as a darker area between gingival epithelium and the cortical bone or between gingival epithelium and the tooth root, with an average thickness of 1.66 mm. The cortical bone and its high concentration of calcium salts appears hyperechoic as a continuous area. The tooth can be visualized as a hyperecogenic well-contoured area, which is interrupted at the level of the cement–enamel junction. Due to this interruption the crown and the tooth root can be identified (Figure 1).

During the clinical exam, on the tooth with gingival recession, the cement–enamel junction can be identified. The average of the gingival recession (CGR) measured clinically was 0.69 mm. On the same dental surfaces, periodontal ultrasonography was performed, obtaining an average of 0.54 mm (Figure 2). Similar standard deviations (1.05, respectively 0.9) were recorded for the two types of measurements.

The mean values were similar for the width of periodontal space at its coronal limit, 0.35 mm for XWPS (Figure 3) and 0.4 mm for UWPS (Figure 1) with similar standard deviations (0.22, respectively 0.33).

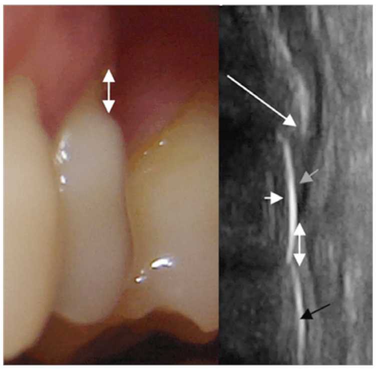

Figure 2 – ***Gingival recession clinically and on ultrasound 40 MHz: tooth crown (black arrow), tooth root (short white arrow), alveolar crest (long white arrow), gingival tissue (gray arrow), gingival recession (white double arrow).***

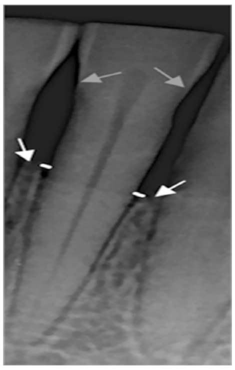

Figure 3 – ***Central incisor, Soredex Minray intra-oral digital X-ray. Cement–enamel junction (gray arrow), alveolar crest (white arrow), periodontal space width at its coronal limit (white line).***

The mean values were 4.27 mm for XBJ and 3.77 mm: for UBJ, both having a similar standard deviation of 2.2, respectively 2.29.

Statistical correlations

First part

The variables CGR and UGR were very well correlated, with a correlation coefficient *R*=0.933 (meaning 93.3%). The *p*-value was 0.000…<0.01, which gives a high statistical significance of the result. UBJ and XBJ were also very well correlated, with a correlation coefficient *R*=0.907 (meaning 90.7%). The result was also statistically significant: we employed the two-tailed Student's test, with the power of the test *p*=0.000…<0.01, which gives a highly statistically significance of the result. UWPS and XWPS were correlated, the correlation coefficient was *R*=0.599 (meaning 59.9%) and the value of the test was *p*=0.000…<0.01, which gives a highly statistically significance of the result.

Second part

The variables UGW and UBJ were relatively well correlated, with a correlation coefficient *R*=0.456 (meaning 45.6%). Also, the *p*-value was 0.000…<0.01, which gives a highly statistically significance of the result. The comparison between: UBG and UBJ showed a better correlation than in the previous case, the correlation coefficient was *R*=0.771 (meaning 77.1%). Again, *p*=0.000…<0.01, which gives a highly statistically significance of the result.

Discussion

Because there is a correlation coefficient of more than 93% between the gingival recession measured clinically and the computerized probing and charting by Florida Probe System (CGR) and gingival recession measured on ultrasound images (UGR), we consider that the data obtained on ultrasound images are highly reliable. The highly correlation coefficient (90%) between the measurements made on ultrasound images UBJ and those made on intra-oral radiographs XBJ proves that valuable information can be obtained by periodontal ultrasonography, similar to that obtained on X-rays. The correlation coefficient may be lower, 59.9%, for periodontal space width (UPSW with XPSW) because of the smaller values measured, less than 0.5 mm, and because the Soredex Minray Software can measure only units of tenth of a millimeter. The correlations, which exist between the horizontal bone loss and the gingival size, even if they are smaller, could signify that there is an accelerated bone resorption when a gingival inflammation persists.

The ultrasound measurements values related to the dimensions having as a reference the alveolar bone crest (UBJ, UWPS) are very useful in assessing the bone resorption. The periodontal width values UWPS were similar to those in previous studies regarding periodontal disease [10, 11]. The measurements of the gingival thickness and height (UGW, UBG) related to the alveolar crest, can be used in the future for evaluating the gingival inflammation. Within weeks, the gingival inflammation level can change due to different treatments. The bone changes needs longer periods of time, so it can be used as an anatomical landmark for assessing the gingival inflammation evolution.

Periodontal ultrasonography has not been used yet to its true potential. Most likely, this is because the size of the visualized area is much smaller compared to X-ray images. This makes more difficult to interpret the ultrasound images of the marginal periodontium. It is much easier to interpret a bigger image taken by CBCT, where one can easily identify the bone reference points, necessary for assessing the horizontal or vertical bone loss [12]. It is necessary to acquire several ultrasound images in order to identify anatomical elements based on which one can make a diagnosis. Once the necessary experience is gained, the examination time decreases significantly and this method becomes easier to use. On buccal surfaces, it is quite easy to obtain the necessary information for periodontal diagnosis, while on the lingual surfaces if the size of the transducer is better adapted in the future, the necessary information will very likely be obtained. For now, with the existing ultrasound devices it is difficult or even impossible to examine the periodontal tissues on proximal surfaces, at mesial or distal level [13]. The lack of irradiation and the fact that it has no side effects on the patients, gives this method an important advantage. The high doses of irradiation for CBCT and the high number of serial intraoral radiographies (between 14 and 20) needed for a complete periodontal diagnostic and treatment planning [5, 14, 15] make the radiological method impossible to use for following up the evolution of the disease. According with the existing literature, it seems that there is still no imaging method which could be used on a regular basis for monitoring gingival inflammation. The only possibility is the inspection and palpation during clinical examinations, which are highly subjective [5, 16, 17].

Ultrasonography is a reliable and reproducible, cost effective method for evaluating and monitoring periodontal tissues [6]. Most of the studies until now were performed *in vitro* and were pilot studies [18, 19].

In our study, the gingival recession was chose as a parameter to verify the accuracy of the measurements. No foreign objects as landmark (which can interfere with the soft tissue) or bony defect intentionally made were used. The comparison with complete intraoral series of radiographs, which is a part of the standard protocol for diagnosing the periodontal disease [5, 20, 21], made also this study realizable *in vivo*. Until now, most of the periodontal diagnosis was focused more on bacteriological analysis, than on inflammation effects assessment [16, 22–24].

Future *in vivo* research should correlate the measurements on ultrasonography images with the expression of matrix metalloproteinase (MMP)-9 in the gingival tissue often used in previous studies as a biomarker for the presence of inflammation in the hypertrophied gingiva, especially considering that the expression of MMP-7, -8, -9 and -13 in the gingiva of the young patients with aggressive periodontitis and T1D was found positive [25], thus these MMP are valuable markers of the inflammation. Special target groups which need frequent follow-up, such as patients with diabetes and periodontitis [21, 25] should be considered for future research.

Conclusions

40 MHz periodontal ultrasonography is a reliable, non-invasive and cost effective imagistic method for identifying the necessary anatomical elements in order to make an accurate periodontal diagnosis for the examined area. It is able to clearly show all anatomical landmarks that are important for periodontal disease diagnosis, staging and follow-up.

Conflict of interests

The authors declare that they have no conflict of interests.

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