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Experimental model for measuring and characterisation of the dento-alveolar system using high frequencies ultrasound techniques

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Abstract

Aims: The main objective of the study was the realisation of an experimental model and evaluation to establish whether the high frequency ultrasound method can supply credible information concerning the structure of the periodontal tissues. Materials and methods: We used a 20 MHz, 2D transducer of Dermascan C (CORTEX TECHNOLOGY l) device for examining 20 teeth on 4 healthy pig mandibles. The examination was made in the lateral area of alveolar bones at the lingual surface. **Results:** On the images obtained through this type of ultrasonography we identified the cortical bone, tooth crown, tooth root and fixed mucosa. On the images obtained with Dermascan C ver. 3.0 software, very accurate measurements of periodontal space width (mean= 0,45 mm, Std. Dev=0,078) and thickness of cortical bone (mean= 0,31 mm, Std. Dev=0,134) and fixed mucosa (mean= 0,91 mm, Std. Dev=0,176) were made. **Conclusions:** Considering the non-invasive nature of the ultrasound method for patients and for medical staff during examination, but also considering the advantages generated by the possibility of making exact measurements of different areas, this method could become a reliable alternative for X-ray examinations in patients with periodontal disease. If a miniaturized transducer would be available, it could be used for ultrasound periodontal assessment in humans.

Keywords: periodontal space, cortical bone, high frequency ultrasonography

Rezumat

Obiective: Scopul principal a fost realizarea unui model experimental şi folosirea ultrasonografiei de frecvenţă înaltă pentru a obţine informaţii credibile legate dimensiunile diverselor elemente anatomice ale spaţiului periodontal. **Material si metoda:** Am folosit aparatul Dermascan C (CORTEX TECHNOLOGY) cu un transductor 2D de 20 MHz, cu care am examinat ţesutul parodontal în dreptul a 20 de dinţi de pe 4 mandibule de porc, fără leziuni parodontale. Examinarea a fost facută în zona laterală a osului alveolar la nivelul suprafeţei linguale. **Rezultate:** Pe imaginile obtinute prin acest tip de ultrasonografie am identificat corticala osoasă, coroana dentară, rădăcina şi mucoasa fixă. Imaginile furnizate de software-ul Dermascan C, versiunea 3.0, au permis efectuarea unor măsuratori foarte precise ale grosimii spaţiului parodontal: (media= 0,45 mm, Std. Dev=0,078) ale grosimii corticalei osoase (media= 0,31 mm, Std. Dev=0,134) şi ale mucoasei fixe (media= 0,91 mm, Std. Dev=0,176). **Concluzii:** Deoarece examinarea cu ultrasunete este non-invazivă pentru pacienţi şi pentru personalul medical, şi permite efectuarea de măsuratori exacte ale diferitelor regiuni anatomice, aceasta metodă poate deveni o alternativă reală la examinările radiologice pentru pacienţii cu parodontopatii. Daca ar exista un transductor miniaturizat, acesta ar putea fi folosit pentru examinarea parodontală la om.

Cuvinte cheie: spaţiul parodontal, corticala osoasă, ultrasonografiei de frecvenţă înaltă

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Periodontal disease can be defined as "multifactorial infectious diseases" [1]. It is characterized by clinical symptoms and signs which may include: inflammation visibile or not, gingival bleeding, periodontal pockets, tooth mobility which may lead to tooth loss [1].

In the gingival sulcus, there is always a permanent accumulation of microorganisms followed by inflammation and immunological response on behalf of the host organism, which are the main features of gingivitis and

periodontitis [1]. The destruction of the periodontal tissue consists of apical migration of the junctional epithelium and bone resorbtion.

At present the WHO centralized data from 35 countries worldwide show a prevalence of periodontal disease, for subjects aged between 35 and 44 years, of over 75 % in 7 countries. The same evidences that periodontal diseases affect between 40% and 75 % in 13 countries and less than 40 % in 15 countries [2,3,4].

The clinical diagnosis and the paraclinical investigations in periodontal disease have a certain degree of relativity. In periodontal disease the follow-up of the periodontal destruction, especially of the bone lesions [1,5,6] is essential. Manual probing of periodontal pockets implies long-time examinations, which often fail to assess small variations of periodontal ligaments insertion level. On the other hand, measurements made on the radiographs offer important details especially if they are made by the parallel technique. The main disadvantage is the irradiation to which the patient is subjected during the investigations, multiple exposures being necessary at each evaluation.

Periodontal disease is often diagnosed in advanced stages of evolution, due to the poor symptomatology in the early stage. There are on-going researches aimed to obtain informations concerning the evolution of periodontal disease by non-invasive or minimal invasive methods.

Ultrasonography is less used for the periodontal assessment and the experience with ultrasound techniques in this field is limited. The main objective of the study was the realisation of an experimental model and evaluation to establish the high frequency ultrasound method can establish credible information concerning the structure of the periodontal tissues. The secondary objective was to find anatomical reference-points of the periodontium anatomy, for the evaluation of the bone levels in normal healthy tissues. These anatomical reference-points could be used for accurate follow-up of diseased periodontal tissues and of the evolution of periodontal diseases in humans.

Material and methods

We used 20 MHz 2D transducer of the device Dermascan C, CORTEX TECHNOLOGY, with which we examined 4 pig mandibles in an experimental model (fig 1, fig 2). The lower jaws were examined no later than 6 hours after the animal was sacrificed, without being refrigerated.

Our prospective research consists of the elaboration of an examination protocol with a ultrasound equippment Dermascan C, CORTEX TECHNOLOGY. According to the study-protocol, the same person did the examination always in standard positions, in the lateral area of alveolar bone, on the lingual side. The transducer was placed parallel to the occlusal plane, at approximately 1 mm below the coronal edge of the cortical bone and the examinations were performed with corono-apical movements. We recorded the values for 20 different lateral teeth. There were obtained images on the PC, which were processed by two trained examiners.

We compared the recorded data to those from the literature regarding dento-periodontal anatomy in the domestic pig (Sus domestica).

For this research we used only mandibules from animals sacrificed for alimentary purposes. All animals were slaughtered in a human manner to prevent needless suffering, in a specialized farm, according to the EU regulations. The study protocol was approved by the local Ethics Commitee.

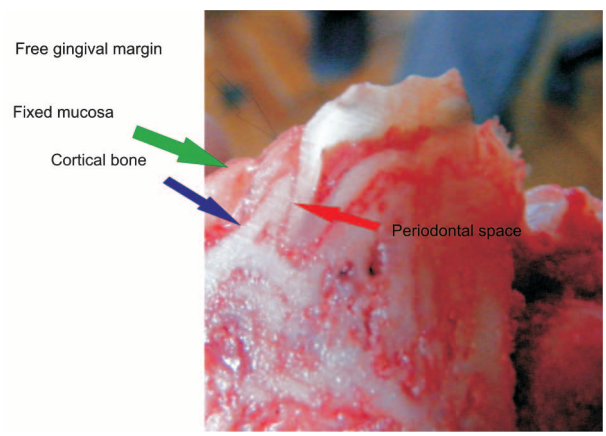


Fig 1. Tooth and periodontium anatomy on a section made by microtom in one of the pig mandibles we examined

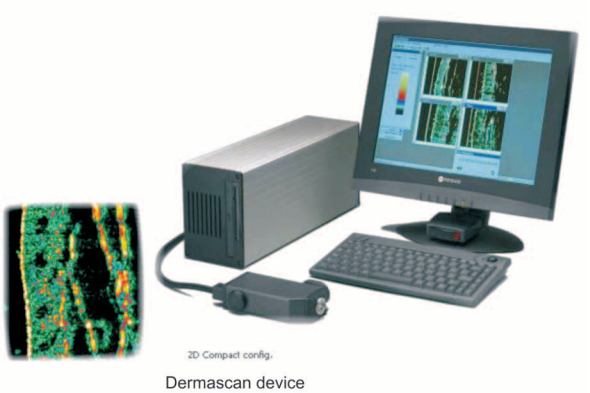


Fig 2. Dermascan C, CORTEX TECHNOLOGY device and its 20 MHz, 2D transductor

SPSS software version 17 was used to perform the statistic analysis of recorded data.

Results

Based on the obtained ultrasound images, we were able to identify the lingual cortical bone, tooth crown, the root (fig 3) and the attached gingiva (fig 4).

On the images obtained with Dermascan C version 3.0 device, we succeeded in measuring e very precisely the periodontal space width (fig 5), the thickness of attached gingiva (fig 6) and the thickness of cortical bone at its coronary edge.

The main results obtained are as follows:

- periodontal space width (average = 0,45 mm, Std. Dev = 0,078), (fig. 7)
- thickness of attached gingiva (average = 0,91 mm, Std. Dev = 0,176) (fig 8)
- thickness of cortical bone (average thickness = 0,31 mm, Std. Dev = 0,134) (fig 9)

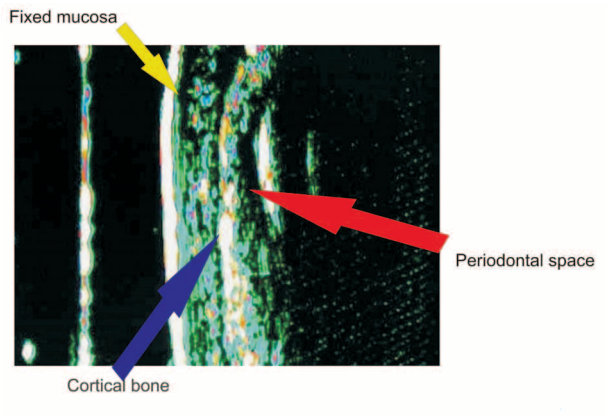


Fig 3. Identification of anatomical reference areas on the images obtained by high frequency ultrasound examination : the lingual cortical bone, tooth crown, the root

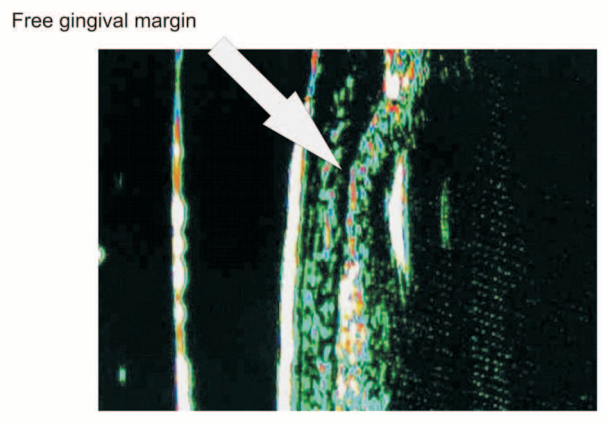


Fig 4. Identification of anatomical reference areas on the images obtained by ultrasound examination: the free gingival margin

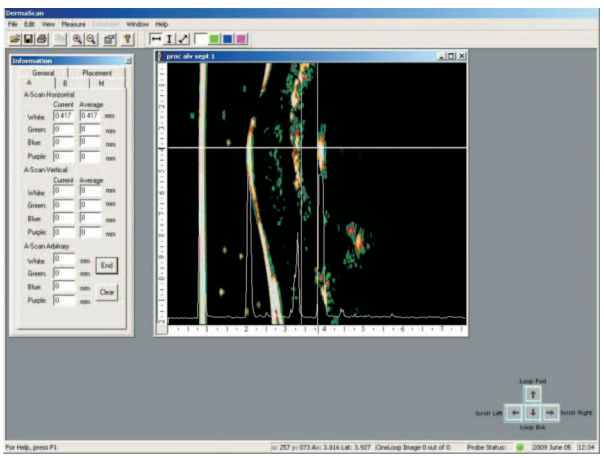


Fig 5. Measurements of the widths of the periodontal space

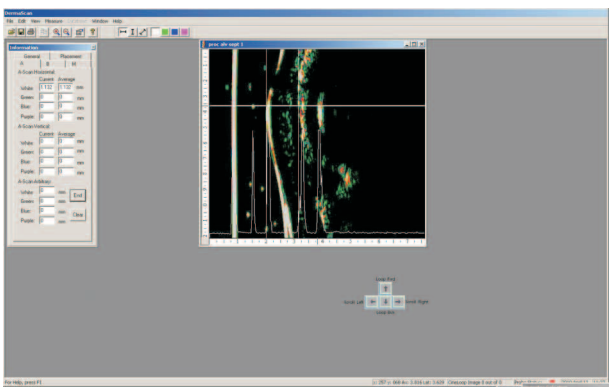


Fig 6. Measurements of the thickness of attached gingiva

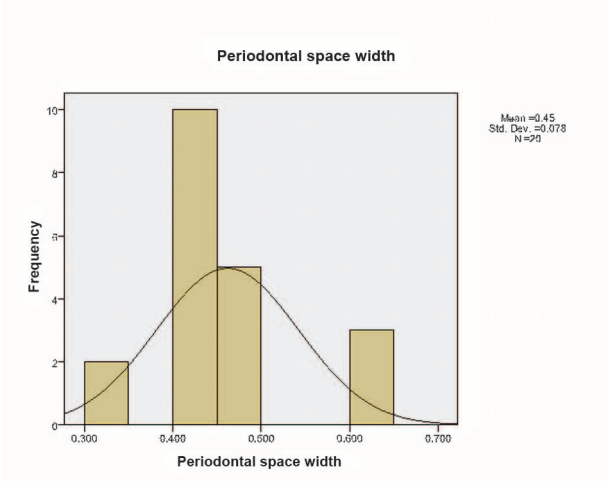


Fig 7. Histogram of periodontal space width

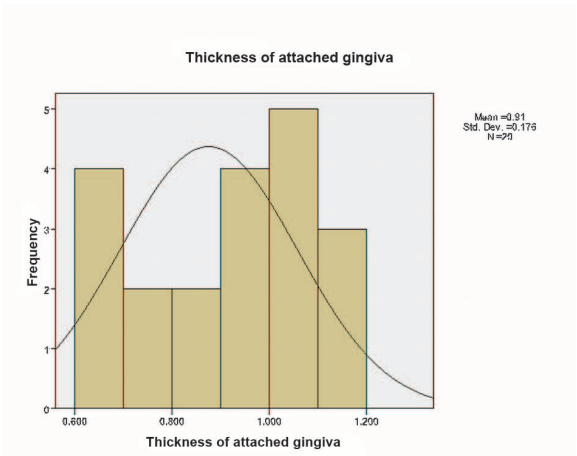


Fig 8. Histogram of thickness of attached gingiva

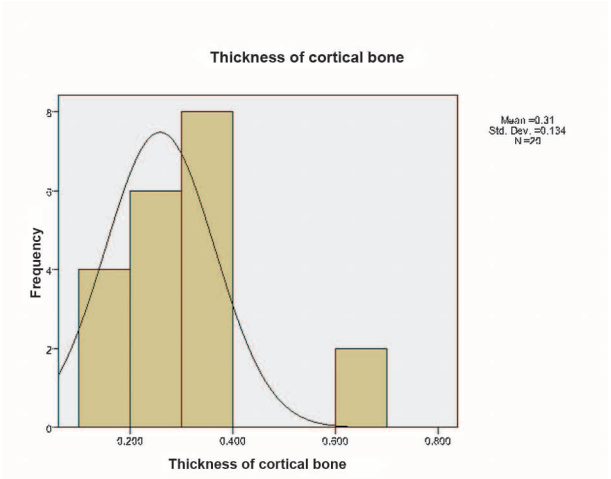


Fig 9. Histogram of cortical bone thickness

Discussions

Periodontal disease has a high prevalence with potential repercussions on the general health of the patients [7], besides the social and psychological implications of gingival bleeding, oral malodor, tooth mobility and tooth loss. Due to its high prevalence an early depiction and individualised follow-up of this disease is necessary.

The diagnosis methods used nowadays are based on clinical examination (pocket probing, evaluation of the mobility, of the gingival bleeding), imagistic techniques and microbiological methods.

Within the imagistic techniques the most used is the radiological method, which implies irradiaton of the patient and the staff during investigation. The radiographs for periodontal monitoring are not frequently indicated, not sooner than 5 years for screening purposes and only once in every 12-18 months in the problem areas. According to the FDA (U.S. Food and Drug Administration) recommendations, it is not advisable to make neither panoramic, nor serial X-rays for screening purposes sooner than 5 years. Bite-wing X-rays made every 12-18 months of problems areas are considered to be sufficient for periodontal disease follow-up and for possible modification assessments [1].

Most of the on-going research are focused on 3-D reconstruction using X-rays and mostly CT or cone-beam CT [8-13]. These above mentioned CT methods and softwares allow very accurate reconstructions, extremly useful in various medical and dental diagnostics and treatment plannings, but mostly in orthodontics, in maxillo-facial surgery and in prosthetics. For the follow-up in periodontal disease and also for periodontal screening such techniques would imply a far too large radiation dose to be clinically acceptable.

The existing methods [8-10,14-17] for 3D reconstruction of teeth, periodontium and bone ridges are very expensive and demand a highly specialised equipment, specifically trained medical staff with a complex knowledge of information technology.

Both periodontal pockets probing and dental radiographs offer a retrospective analysis of bone and attachment loss.

Therefore a less invasive alternative still has to be found. In this respect, ultrasonography represents a non-invasive method, which does not imply patient and medical staff irradiation. Also, the periodontal ultrasonographic examination can d be performed more times during the follow-up of the disease.

Our findings and measurements are similar to those of veterinary literature [18-21] ($p<0.05$). Our results correspond to the average data of swine anatomy. Data from

the literature reveals that ultrasonography provides a highly accurate and reapetable technique for periodontal assessment in experimental models [22].

The ultrasound examination in our study was performed with a 2D transducer, designed for skin evaluation. The large size of the 2D transducer makes access to the small attached gingiva and the alveolar bone in humans difficult. Having access only to this 2D transducer, we chose to examine pig mandibles, which have larger attached gingiva, and a more flat surface of the bone than in humans, allowing the application of this transducer.

We were able to record slight modifications when passing from the enamel to the cementum, therefore this area could be used as a reference for measuring the horizontal bone atrophy. On the images obtained with Dermascan C version 3.0 device, we obtained anatomical reference areas of the periodontium. Thus we could measure very precisely the periodontal space width, thickness of attached gingiva and of the cortical bone at its coronary edge. Further studies are required to find a safe and exact method to assessthe vertical bone atrophy as well as the horizontal one.

There is a need for precise minim invasive or non-invasive diagnosis methodswhich could be used for the individualised follow-up of the periodontal disease.

The ultrasound method of high frequency could be a valid method, having the following advantages: the measurement is simple, reproductible, precise. The ultrasound method has the potential to be an alternative to radiographs, especially during the monitoring of the disease.

The limits of our study are related of the reduced number of examined teeth and the imperfect large size transducer for dental use, the transducer being dedicated for dermatological use.

Conclusions

For the prognosis of patients with periodontal disease the follow-up is mandatory. The method should be minimally invasive, with relatively low costs and it should provide very precise data. The ultrasonographic method could be an alternative to radiological examinations during the periodontal follow-up, having the advantage of eliminating the irradiation of both patients and medical staff during examination.

The method offers also quantitative informations, precise, repeatable measurements of different areas of periodontium, which means that the ultrasound method could have clinical applications in periodontology.

For the examination of the periodontal tissues in humans a smaller size transducer would be necessary, in order to be applied on the irregular, convex morphology of the alveolar bone.

We consider that a smaller 3D transducer and a software able to generate 3D models based on the ultrasonic images recorded could provide data for constructing three-dimensional models of teeth and alveolar bones, which could enable the clinician to monitor over a period, with high precision, the evolution of periodontal disease

Conflict of interest: none

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