Original Article

Ultrasound evaluation of intra-osseous cavity: A preliminary study in pig mandibles

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ABSTRACT

Aims: To assess the role of ultrasonography as a possible tool for diagnosis of intra-osseous lesions.

Methods: Our sample comprised five macerated pig jaws. The regions of bony crypts of third molars were examined on both sides, totaling 10 examinations. The degrees of difficulty for both ultrasound image visualization and bone translucency were rated by two groups of evaluators (i.e. dental radiologists and physician ultrasonographers).

Results: Our results showed that it is possible to detect images of the intra-osseous cavity at a low-degree difficulty by using both radiographic and ultrasonic techniques (46.6% and 43.3%, respectively). However, the crypts were not fully detected by both groups (16.6% and 13.3%, respectively).

Conclusions: We concluded that ultrasonography is a useful method for evaluation of intra-osseous lesions in jaws, provided that the cortical bone is thin enough to allow ultrasound waves to pass through.

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1. Introduction

The ultrasound imaging technique is widely used by physicians for evaluation of soft tissues. This method of evaluation is non-invasive, painless and performed at lower cost than other imaging methods, allowing for several differential resources such as real-time assessment of blood supply and internal nature of the disease (i.e. solid or cystic), thus making ultrasound a remarkably versatile diagnostic imaging tool for diagnosis.¹

Ultrasound has been successfully used in dentistry and by several researchers who investigate its use for evaluation of temporomandibular joint, periodontal and periapical lesions, and mandibular fracture,^{2–7} as well as its benefits compared to other imaging modalities.^{7,8}

Ultrasound has been shown to be an interesting alternative new tool over the last few years for diagnosis of intra-osseous lesions in jaws, overcoming the limitations of conventional radiography and computerized tomography (CT) due to its availability of real-time multiplanar images, absence of ionizing radiation and accurate analysis.^{1,2,4,5,7,9}

The purpose of this study was to perform an experimental model and assess whether ultrasound is effective for evaluation of intra-osseous lesions in the mandible.

2. Materials and methods

2.1. Bone specimens

The data acquisition and analysis in this study was approved by the University Institutional Review Board. The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Five macerated mandibles from young adult domestic pigs (previously slaughtered for human consumption) were used. The mandibular third molar of pigs has an enlarged bony crypt mimicking an intra-osseous lesion (confirmed by periapical and occlusal radiographs in a pilot study).

2.2. Experimental design

The mandibles were prepared in several steps. Sagittal osteotomy was made along the junction between mandibular body and ramus to expose the germ of the third molar bilaterally. Next, the entire germ was removed to expose a hypoechoic area

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and to confirm the penetration of ultrasound waves by means of a metallic sphere (4 mm in diameter) inserted inside the bony crypt. After the procedure, the bone was re-attached with a rubber tape.

2.3. Ultrasound assessment

Ultrasonographic imaging was performed by using a portable ultrasound machine (Terason t3000, Division of Teratech Corporation, Burlington, MA, USA) operating with a convex probe (model 5C2A, designed for a frequency range of 2–4 MHz and adjusted at 2 MHz). The specimens were immersed into a water tank and aligned on the bottom of it (11). The tank allows a fine and reliable acoustic coupling between transducer and mandibles, warranting that all reflections and reverberations from geometrically and acoustically complex clinical features are received by the transducer probe.^{10,11} The ultrasound probe was positioned on the thinnest area of the crypt, resulting in 10 images from the five mandibles.

2.4. Imaging analysis

The 10 ultrasounds data were coded and independently reviewed by two groups of evaluators: three oral radiologists (Group 1) and three trained ultrasound-trained physicians (Group 2). All the evaluators were contacted in advance and appointments were arranged. Group 1 had evaluators with no experience in ultrasound examinations. They received training about ultrasound image formation. Next, the evaluators in both groups used the ultrasound machine to examine the hemi-mandibles by handling the probe individually and at will in a real-time examination. The ultrasound images were examined on the monitor by the evaluators, who then answered the Question 1 on the degree of difficulty in visualizing them before rating the images as being of low, moderate, or high or if they could not be detected (ND).

After each evaluator examined the ultrasound images, they were asked to visually examine the macerated jaws at the region of the bony crypts and to answer Question 2, thus evaluating the bones qualitatively in terms of (high, medium, and low) translucency according to their perception. The examinations were performed in a dark room and all hemi-mandibles were positioned side by side (to make comparisons and evaluations easier) on a negatoscope with uniform luminescence.

The statistic analysis of all information collected in the present study was initially performed on a descriptive basis. The qualitative (categorized) variables were analyzed by analyzing absolute and relative (percent) frequency data.

Inference analyses were used to accept or reject the evidence found in the descriptive analysis. Chi-square test and Fisher's exact test were also used to study the association between the answers given by dental radiologists and physician ultrasonographers to Questions 1 and 2. The significance level (α) was set at 5% in all inference analysis.

3. Results

In Group 1 (three dental radiologists and 10 images *per* evaluation), the metallic spheres were not detected in five images. However, they could be observed with low (14; Fig. 1), moderate (4), and high (7; Fig. 2) degrees of difficulty in other images.

In Group 2 (three physician ultrasonographers; 10 images *per* evaluation), the metallic spheres were not detected in four images. However, they could be observed with low (14), moderate (6), and high (6) degrees of difficulty in other images.

Table 1 shows the distribution of answers given by dental radiologists and physician ultrasonographers to Question 1.

Fig. 1. (A) Part of a macerated lower jaw (rated as highly translucent); (B) ultrasound image (considered ease to visualize) showing the hyperechoic image of the metallic sphere.

Fig. 2. (A) Part of a macerated lower jaw (rated as poorly translucent); (B) ultrasound image (considered hard to visualize) showing the slightly hyperechoic image of the metal sphere.

Table 1

Frequency (F) of answers given by dental radiologists (DR) and physician ultrasonographers (PU) to Question 1 (on degree of difficulty in visualizing ultrasound images on the monitor).

Difficulty of visualization	DR1		DR2		DR3	
	F	%	F	%	F	%
Low	5	50	5	50	4	40
Moderate	1	10	1	10	2	20
High	2	20	2	20	3	30
ND ^a	2	20	2	20	1	10
Total	10	100	10	100	10	100
Difficulty of visualization	PU1		PU2		PU3	
	F	%	F	%	F	%
Low	4	40	5	50	4	40
Moderate	2	20	3	30	2	20
High	2	20	–	–	4	40
ND ^a	2	20	2	20	–	–
Total	10	100	10	100	10	100

^a ND: not detected.

Table 2

Frequency (F) of answers given by dental radiologists (DR) and physician ultrasonographers (PU) to Question 2 (on degree of translucency of the mandible as observed on the negatoscope).

Degree of translucency	DR1		DR2		DR3	
	F	%	F	%	F	%
High	2	20	2	20	4	40
Moderate	3	30	2	20	3	30
Low	5	50	6	60	3	30
Total	10	100	10	100	10	100
Degree of translucency	PU1		PU2		PU3	
	F	%	F	%	F	%
High	4	40	3	30	4	40
Moderate	5	50	4	40	3	30
Low	1	10	3	30	3	30
Total	10	100	10	100	10	100

In order to answer Question 2 on degree of bone translucency, the dried/macerated mandibles were examined at the regions of bony crypt by all the six evaluators, who marked one of the three alternatives (high, moderate, or low bone translucency) according to their perception.

In Group 1 (three dental radiologists), the hemi-mandibles (10 *per* evaluator) were rated as being of high (8), moderate (8), and low (14) translucency.

In Group 2 (three physician ultrasonographers), the hemi-mandibles (10 *per* evaluator) were rated as being of high (11), moderate (12), and low (7) translucency.

Table 2 shows the distribution of answers given by dental radiologists and physician ultrasonographers to Question 2.

The possible association between the answers to Questions 1 and 2 was analyzed. Table 3 shows the distribution of answers given by dental radiologists and physician ultrasonographers together to both questions.

The answer given by the evaluators to Question 1 is associated with the answer given to Question 2 ($P < 0.001$). Evaluators who answered that the images were of high translucency (Question 1) also answered that they had a low difficulty in visualizing them (Question 2). In fact, 73.7% of the evaluators answered high translucency in comparison to 40.0% ($P = 0.035$) and 23.8% (23.8%) ($P = 0.004$) of those who answered moderate and low transparency, respectively. It should be emphasized that the statistical test showed significant association between the answers given to both

Table 3

Absolute frequencies of answers given by evaluators to Questions 1 (on degrees of difficulty in visualizing ultrasound images) and 2 (on translucency of the hemi-mandible as observed on the negatoscope).

Question 1 (difficulty)	Question 2 (translucency)			Total
	High	Moderate	Low	
Low	14 (73.7%)	8 (40.0%)	5 (23.8%)	27 (45.0%)
Moderate	4 (21.1%)	7 (35.0%)	–	11 (18.3%)
High	1 (5.3%)	4 (20.0%)	8 (38.1%)	13 (21.7%)
ND ^a	–	1 (5.0%)	8 (38.1%)	9 (15.0%)
Total	19 (100.0%)	20 (100.0%)	21 (100.0%)	60 (100.0%)

^a ND: not detected.

questions, which means that the thinner the cortical bone, the easier is to observe it.

4. Discussion

Some authors report that ultrasound has limitations for bone tissue examination,¹² pointing that the ultrasound waves are reflected to the transducer because cannot pass through this tissue. However, they agree that the bone cortex could be examined provided that it could have some alteration (e.g. cortical step-off, irregularity, or discontinuity). Our results are in agreement with the reports by other authors, who state that ultrasound examination of intra-osseous lesions is possible.^{1,2,4,5,7–9,13,14}

We emphasize that the bone cortex must be thin for intra-osseous examination using ultrasound, which was confirmed by statistical analysis in the present study. This is generally observed in maxillofacial osseous defects as the development of lesions causes internal (intra-osseous) expansion and reduces the cortical bone, allowing ultrasound waves to pass through.^{2,14} However, the wave passing through is blocked at regions which are still integral or thicker. Lauria et al.,² faced problems in obtaining ultrasound images in cases of keratocystic odontogenic tumors, which develops mainly in the mesio-distal direction. This was also observed in the examination of some dried mandibles in our research.

Observation of discontinuity of the cortical bone by means of ultrasound is possible and makes examination of osseous fractures feasible, enabling us to reduce the amount of radiographies requested for fracture evaluation.^{15,16} In the present study, we were able to observe discontinuity lines caused by osteotomy, although this was not the focus.

Monitoring of therapies or the progress of lesions are additional possibilities of ultrasound. Quickness, painless, and low cost are other advantages compared with other imaging techniques, since ionizing radiation is not used in the ultrasound imaging.^{9,17} It can also be used in the intra-operative period.¹⁸

The possibility of examining the lesion's content is admittedly one of the advantages offered by ultrasound, both in soft and hard tissue examination.^{1,2,4,5,9,14,19}

The possibility of using Doppler for real-time evaluation of the degree of lesion vascularization is another differential feature of ultrasound as it allows alterations to be evaluated depending on their degree of activity/aggressiveness.^{1,14} Moreover, Rajendran and Sundaresan²⁰ described that the use of ultrasound allows verifying whether the blood flow is arterial or venous.

According to Jones and Frost,²¹ professional experience is essential for examination and interpretation of such images and, therefore, for a successful use of this imaging method. As observed in the present study, visualization of structures by the group of physician ultrasonographers was slightly easier than that by dental radiologists, who were not equally familiar with the method. On the other hand, it was also observed that ultrasound examination was adequately performed by dental radiologists, although with a little more difficulty as it was their first contact with this methodology. This observation indicates that examination and interpretation of images using ultrasound is relatively easy to be learned and used.

5. Conclusions

Intra-osseous cavities, such as jaws, can be examined by ultrasonography, provided that the cortical bone is thin enough to

allow ultrasound waves to pass through. Dental radiologists were able to use ultrasound imaging and to understand the images, considering examination and interpretation of them easy, although access to and familiarity with this methodology were lower compared to physician ultrasonographers. Further studies should be conducted to better explore the benefits and advantages the ultrasound imaging technique can offer in the area of dentistry.

Conflicts of interest

The authors have none to declare.

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