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Accuracy of Diffusion Weighted Magnetic Resonance Imaging in Differentiation between Malignant and Non-malignant Maxillofacial Lesions

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ABSTRACT

Objectives: to evaluate the signal characteristics of Diffusion Weighted Magnetic Resonance Imaging (DWMRI) of maxillofacial intraosseous lesions and their corresponding apparent diffusion coefficient (ADC) values and assess their ability to differentiate between malignant and non-malignant lesions.

Methods: This study included 17 patients (10 males and 7 females) selected from the outpatients' clinic of Oral Surgery Department, Faculty of Dentistry, Ain-shams University. They were examined by MRI machine; Philips 1.5 Tesla Achieva, Netherlands using DWMRI, T1 and T2 sequences and ADC values were measured.

Results: There was a statistically significant difference between T1 signal distributions among patients with benign and malignant lesions (P-value = 0.027, Effect size = 0.685) benign lesions showed higher prevalence of low signal while malignant lesions showed higher prevalence of intermediate signal. There was a statistically significant difference between T2 signal distributions among patients with benign and malignant lesions (P-value = 0.029, Effect size = 0.609). Benign lesions showed higher prevalence of high signal while malignant lesions showed higher prevalence of intermediate signal. ROC curve analysis showed a cut-off value of (≤ 1 ´10-3 mm2) with diagnostic accuracy of 94.1%, a sensitivity of 100% and specificity of 91.7% indicating that ADC values less than or equal to 1 ´10-3 mm2 indicate malignant lesion and values greater than 1 ´10-3 mm2 indicate benign lesion (P-value <0.001, Effect size = 3.25).

Conclusion: DWMRI is highly accurate in the differentiation between benign and malignant intraosseous lesions of the jaws.

1. INTRODUCTION

Diffusion Weighted Magnetic Resonance Imaging (DWMRI) has emerged as a functional non-invasive imaging modality that is done without the usage of contrast agents or ionizing radiation and needs only a few minutes. DWMRI check the easiness with which water molecules flow around inside a tissue (primarily demonstrating fluid in the extracellular space) and offers perception into cellularity, each alternate within the water protons actions induces a difference of signal intensity in this sequence. [1, 2]

DWMRI is a short sequence formed via EPI and FASE sequences. Diffusion can be qualitatively assessed on trace images, tissues with facilitated diffusion (no restricted diffusion) are hypo intense on the trace diffusion image and bright on the ADC map. However, Tissues with diffusion restriction are bright on the trace diffusion image and hypo intense on the ADC map. [3, 4].

Diffusion can be also assessed quantitatively by the parameter named apparent diffusion coefficient (ADC). ADC values differ according to the cellular density of the lesion and blood perfusion to the tissue. ADC values are beneficial in the characterization of different tumor types and tracking the affected person after chemo-radiotherapy. [5, 6].

Applications of DWMRI in evaluation of oral and maxillofacial lesions: differential analysis of cysts, tissue characterization among benign and malignant tumors, tracking the therapy reaction and selecting the suitable location for biopsy. [4, 7].

This study aimed to evaluate the signal characteristics of DWMRI of maxillofacial intraosseous lesions and their corresponding ADC values and assess their ability to differentiate between malignant and non- malignant lesions.

2. METHODS

Study population

This study included a total of 17 patients,10 males and 7 females (age range: 13-68 years) selected from the outpatients' clinic of Oral Surgery Department, Faculty of Dentistry, Ain-shams University. We choose patients complaining from swelling in the maxillofacial area or accidentally diagnosed during panoramic x-ray examination. If the patient had a space occupying lesion, panoramic radiography was performed or CBCT as requested by

the surgeon. A written informed consent from all the selected patients were obtained. The consent gives the researcher the right to do complete radiographic examination for evaluation of the lesion and compare the results with biopsy findings. The histopathological diagnosis of those lesions was obtained after surgery. The biopsy was examined by the Oral Pathology Dept. Faculty of Dentistry using optical microscope (Olympus, BX53F2, Tokyo, Japan) with power of 4x, 10x and 20x.

An approval from the Ethical Aspects of Research Proposal Involving Human Participants was attained before the beginning of the study.

Patients were selected according to the following inclusion criteria:

1- Having intraosseous lesion in the mandible or maxilla.

2- Free from any systemic disease.

3- No previous surgical intervention in maxillofacial area

Exclusion criteria:

1- Lesions extending beyond maxillofacial area.

2- Patients had multiple dental implants or surgical plates

3- Pregnant females

4- Patients with cardiac pacemakers and cochlear implants

Magnetic Resonance Imaging (MRI) examination was carried out in Oral Radiology Department, Faculty of Medicine, Ain-shams University as shown in (Figure 1)

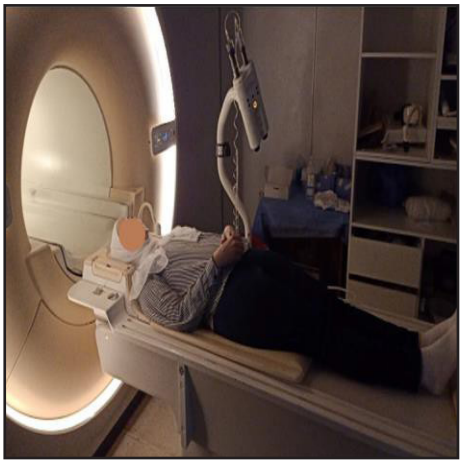

Figure 1— MRI examination

MRI Machine specifications: Philips 1.5 Tesla Achieva, Netherlands with multi-transmit, receive capabilities and 3 coils (ds base, ds head neck, ds posterior).

T1 sequence parameters: repetition time (TR)/echo time (TE),544/14ms, field of view of 260×207×134, Reconstruction matrix size: 672, section thickness: 4 mm, slice gap: 0.8 mm. T2 sequence parameters: TR/TE, 3163/100ms, field of view of 253×200×129, Reconstruction matrix size: 512, section thickness: 4 mm, slice gap: 1 mm. DWMRI sequence parameters: TR/TE, 3730/64ms, field of view of 235 ×235×221 mm, Reconstruction matrix size: 320, section thickness: 5mm, slice gap: 0.4 mm, diffusion gradient encoding in three (x, y, z) orthogonal directions, b values of 0 and 800s/mm^2. At each b value, x, y, and z single-direction DWI and a baseline image (b0 s/mm^2) were acquired; combined ([x _ y _ z]/3) DWI was calculated and performed automatically by the MR instrument.

Image analysis was carried out at Oral Radiology Department, Faculty of Medicine, Ain-shams University. Experienced maxillofacial radiologists (extra than 10 years' experience in head and neck MRI diagnostic imaging,) reviewed all images, evaluated T1, T2 and DWMRI of all the cases with attention to the presence or absence of MRI findings suggestive of intraosseous lesions as shown in (Figure 2). The analysis of data was done to test statistically significant differences between cysts, benign and malignant intraosseous lesions of the jaws and thus calculate the reliability of DWMRI with ADC measurements for diagnosis of intraosseous lesions based on pathologic findings. (Figures 3 and 4) show DWMRI sequence of benign and malignant lesions respectively

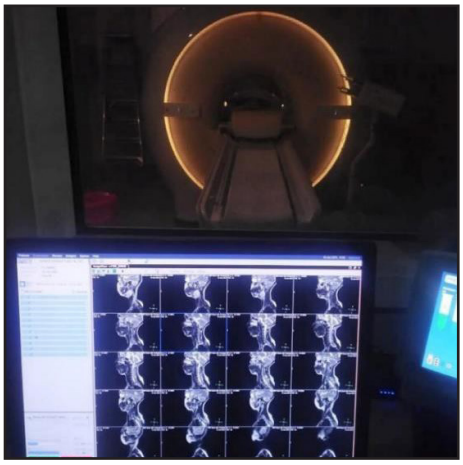

Figure 2—Software displaying MRI images.

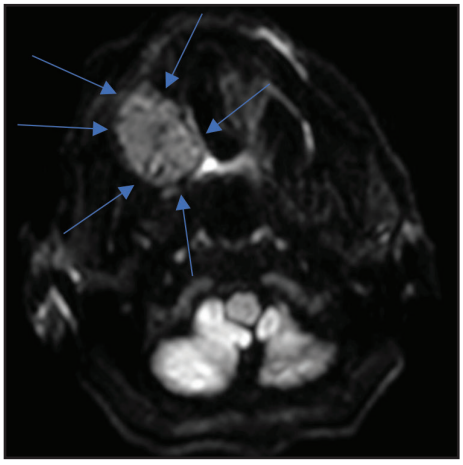

Figure 3— DWMRI sequence of Central Giant Cell Granuloma (CGCG) benign lesion shows facilitated diffusion with ADC measurement =1.4×10^{-3}/mm^2

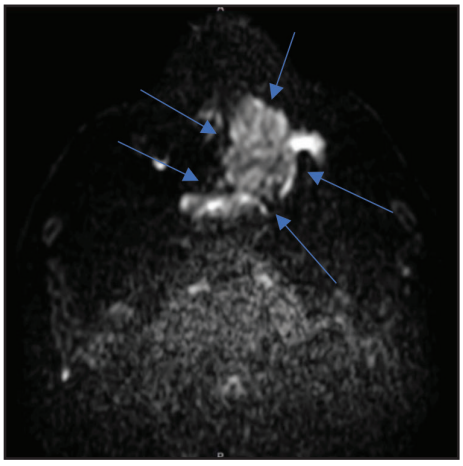

Figure 4— DWMRI sequence of Squamous Cell Carcinoma (SCC) malignant lesion shows diffusion restriction with ADC=0.95 × 10^{-3}/mm^2

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Quantitative ADC measurements

A region of interest (ROI) was used to calculate the ADC values on the ADC maps. For small lesions, The ADC values have been measured through putting ROI of 5mm upon the lesion at the ADC map. For large lesions, The ADC values have been measured through putting three ROIs with similar sizes (5mm) at the ADC map to obtain an average ADC value. The ADC values have been expressed as mean ± standard deviation ($A\times10^{-3}$ s/mm^2) [8]

3. STATISTICAL ANALYSIS

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed parametric (normal distribution). Data were presented as mean and standard deviation (SD) values. Student's t-test was used to compare between benign and malignant lesions. Qualitative data were presented as frequencies and percentages. Fisher's Exact test was used to compare between benign and malignant lesions. ROC (Receiver Operating Characteristic) curve was constructed to determine the cut-off value for differentiation between benign and malignant lesions. ROC curve analysis was performed with MedCalc® Statistical Software version 19.5.1 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2020). The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

4. RESULTS

The present study wasconducted on 17 lesions: 12 benign lesions (70.6%) and five malignant lesions (29.4%).

1. Comparison between benign and malignant lesions

1.1 ADC (x10^{-3} mm^2)

The current study showed that the mean ADC value for benign lesions ($1.646 \pm 0.305 \times10^{-3}$ mm^2/s) was significantly higher than that in malignant lesions ($0.758 \pm 0.153 \times10^{-3}$ mm^2/s /s; $p < 0.001$, Effect size = 3.25). The detailed data are presented in Figure 5 and in Table 1

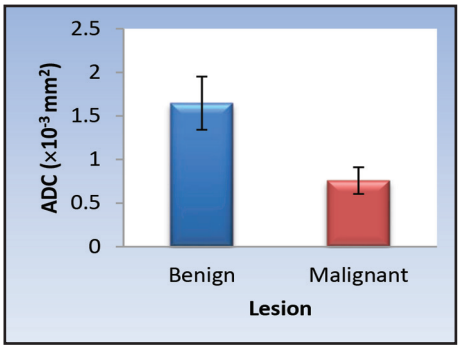

Figure 5— Bar chart representing mean and standard deviation values for ADC in benign and malignant lesions

Table 1— Comparison between ADC values (x10^{-3} mm^2) in benign and malignant lesions

Benign (n = 12)		Malignant (n = 5)		P-value	Effect size (d)
Mean (x10^{-3})	SD (x10^{-3})	Mean (x10^{-3})	SD (x10^{-3})		
1.646	0.305	0.758	0.153	<0.001*	3.25

*: Significant at $P \leq 0.05$

1.2. T1

There was a statistically significant difference between T1 signal distributions among patients with benign and malignant lesions (P- value = 0.027, Effect size = 0.685).

Benign lesions showed higher prevalence of low signal while malignant lesions showed higher prevalence of intermediate signal. The detailed data are presented in Figure 6 and Table 2.

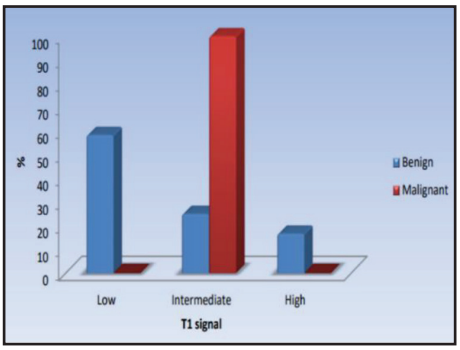

Figure 6— Bar chart representing T1 signal distributions among patients with benign and malignant lesions

Table 2 — Comparison between T1 signal distributions among patients with benign and malignant lesions

T1 signal	Benign (n = 12)		Malignant (n = 5)		P-value	Effect size (v)
	n	%	n	%		
Low	7	58.3	0	0		
Intermediate	3	25	5	100	0.027*	0.685
High	2	16.7	0	0		

*: Significant at $P \leq 0.05$

1.3. T2

There was a statistically significant difference between T2 signal distributions among patients with benign and malignant lesions (P-value = 0.029, Effect size = 0.609). Benign lesions showed higher prevalence of high signal while malignant lesions showed higher prevalence of intermediate signal. The detailed data are presented in Figure 7 and Table 3.

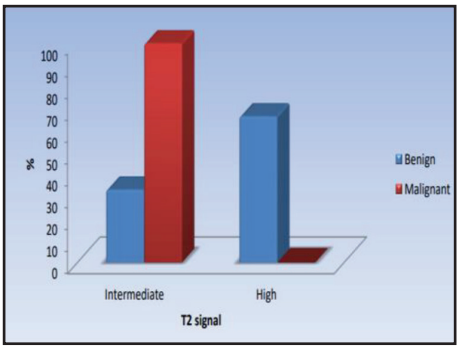

Figure 7— Bar chart representing T2 signal distributions among patients with benign and malignant lesions

Table 3 — Comparison between T2 signal distributions among patients with benign and malignant lesions

T2 signal	Benign (n = 12)		Malignant (n = 5)		P-value	Effect size (v)
	n	%	n	%		
Interme diate	4	33.3	5	100	0.029*	0.609
High	8	66.7	0	0		

*: Significant at P ≤ 0.05

Diagnostic accuracy of ADC

A receiver operating characteristic (ROC) curve analysis of ADC for differentiation between benign and malignant lesions showed a cut-off value of ($\leq 1 x10^{-3} mm^2$) indicating that ADC values less than or equal to 1 $x10^{-3} mm^2$ indicate malignant lesion and values greater than 1 $x10^{-3}$ mm^2 indicate benign lesion. At this cut-off value, the diagnostic accuracy was 94.1% with a sensitivity of 100% and specificity of 91.7%. The detailed data are presented in Figure 8 and Table 4

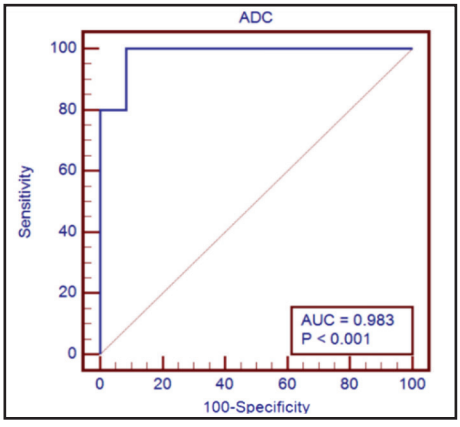

Figure 8— ROC curve of ADC to differentiate between benign and malignant lesions.

Table 4 — ADC Cut-off values, sensitivity, specificity, predictive values, diagnostic accuracy, Area Under the ROC curve and 95% CI of AUC for differentiation between benign and malignant lesions

Cut- off value	Sensitivity %	Specificity %	+PV %	-PV %	Diagnostic accuracy %	AUC	95% CI
≤1	100	91.7	83.3	100	94.1	0.983	0.777 – 1

+PV: Positive Predictive Value, -PV: Negative Predictive Value, CI: confidence interval

5. DISCUSSION

DWMRI is a process of signal contrast formation primarily based totally on the variances in Brownian movement. It increases a new dimension to the MRI examinations through the addition of functional information to the largely anatomical information collected by the traditional sequences. DWMRI offers information on biological and functional aspects of tumor vascularization and inner microarchitecture so it could have the ability to distinguish among benign and malignant tumors. ADC maps derived from DWMRI afford a quantitative non-invasive functional evaluation of cellularity at the molecular level. [2, 9]

The current study showed that DWMRI is precious in differentiation among non-malignant and malignant lesions of the jaws. Malignant lesions appear restricted as evidenced through retained high signal on diffusion and low signal on ADC maps because of tough restriction of the motion of water molecules as end result of the increase in cell density within the tumor matrix and increase in cell membranes. However, Cystic and Benign solid lesions appear mainly facilitated as evidenced through low signal on diffusion and high signal on ADC maps because of free diffusion of water molecules as end result of the decrease in cellularity and restrictive cell membranes. Differentiation between cystic and benign solid lesions that appear facilitated by: T1 and T2. Cystic lesions are hypo intense on T1 and hyper intense on T2. However, benign solid lesions show intermediate signal on T1 and T2.

The current study showed that the mean ADC value for benign lesions ($1.646 \pm 0.305 \times 10^{-3}$ mm^2/s) was significantly higher than that in malignant lesions ($0.758 \pm 0.153 \times 10^{-3}$ mm^2/s; $p<0.001$). ROC evaluation revealed an optimal threshold value for the differentiation among malignant and benign lesions with an ADC cut-off value ($\leq 1 x10^{-3}$ mm^2 with diagnostic accuracy of 94.1%, a sensitivity of 100% and specificity of 91.7%) indicating that ADC values less than or equal to $1x10^{-3}$ mm^2 imply malignant lesions and values greater than $1x10^{-3}$ mm^2 imply benign lesions.

The present study showed that there are some exceptions such as odontogenic keratocyst that showed restricted diffusion compared to the other cysts due to the presence of keratin. The results of our study agreed with Sumi M et al [10], who confirmed that the OKC showed restricted diffusion as The contents of those cysts consist of glycosaminoglycans, specifically hyaluronic acid and the presence of desquamated keratin which rise the viscosity of the contents of OKC, this possibly explains the findings of restricted diffusion and low ADC values in those cystic lesions.

The effectiveness of DWMRI with ADC measurements in differentiation among benign and malignant lesions recommended that DWMRI need to be accomplished routinely.

6. CONCLUSION

DWMRI is highly accurate in the differentiation among benign and malignant intraosseous lesions of the jaws.

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