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The Effect of Magnification for Detecting Low and High Internal Root Resorption in Single-Root Teeth in Cone-Beam Computed Tomography (an *in vitro* Study)

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Abstract

Background and Objective: Early detection of Internal Root Resorption (IRR) is considered a challenging issue in endodontics. Processing filters are used to facilitate image interpretation either in diagnostic or treatment procedures. The aim of this study was to investigate the effect of magnification changes on the detection of IRR in Cone Beam Computed Tomography (CBCT) images.

Material and Methods: In this study, a total of 34 healthy single-canal & rooted teeth were split mesiodistally through their medial canal using an ultra-thin metal saw (1 mm). Then, absorption cavities were artificially created in both low and high degree absorption forms. CBCT images with three different magnification levels of 50, 100 and 150 were analyzed by one radiologist and one endodontist before and after artificial cavity creation. Gathered data were analyzed by MacNemar and Kappa tests using SPSS statistical software. Overall accuracy was calculated by the area under the curve (AUC).

Results: Calculated percentages of sensitivity, specificity and overall accuracy for the first (with high image magnification) and second (with low image magnification) observer were the same (100%, 88.24% and 94%, respectively) and there was no significance difference between low and high degree of resorption and also different magnifications with reality.

Conclusion: Depending on its method of application, all levels of magnification for CBCT images are suitable in diagnosis of IRR.

Keywords: Root Resorption [MeSH]; Cone-Beam Computed Tomography [MeSH]; Radiography [MeSH]

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Highlights

- Percentages of sensitivity, specificity and overall accuracy for high and low image magnifications were the same
- Depending on its method of application, all levels of magnification for Cone Beam Computed Tomography (CBCT) images are suitable in diagnosis of Internal Root Resorption (IRR)

Introduction

Early detection of Internal Root Resorption (IRR) is considered a challenging issue in endodontics. Early detection of the lesion would be of great importance in its prognosis as any possible failure to diagnose and treatment will lead to the development of the lesion and eventually weakening of the tooth, and therefore, could makes long-term prognosis of the treatment difficult (1-3). IRR is usually asymptomatic (4). Primary lesions may not be appeared in radiographic images (5). Radiographically, internal resorption appears as a uniform, round to oval radiolucent enlargement of the canal or the pulp chamber. The margins are sharp, smooth and clearly defined, with distortion and expansion of the original root canal outline. The size and location of the resorption lesion are variable (6). Conventional or digital intraoral periapical radiographs are usually used to evaluate this lesion (7-10). One of the main problems in diagnosing external and internal root resorption is that intraoral radiographs provide only limited diagnostic information (1, 11). This limitation could be due to the two-dimensional nature of the images, geometric distortions and anatomical superimposition, or a combination of these factors (12). Also, the diagnostic value of this technique depends on the size and location of the lesion, so that small apical lesions are difficult to be detected (13, 14). The CBCT technique is a new method that uses a reciprocating rotation of a two-dimensional receiver and a conical beam to obtain volume data (15). This method is a new technology that was initially developed for angiography in 1982 and later on became available for maxillofacial imaging (5). Also, digital imagery has the prominent advantage of using image processing software, to improve valuable information and reducing disruptive noises of image quality (17). There are several processing algorithms that improve the quality of digital images (18, 19). Magnification is one of the digital radiographic image processing algorithms that enlarge radiographic images for more details (20, 21). In fact, to magnify, computers duplicate or interpolate the columns and rows that make up the image, causing the image size to increase on the monitor screen (22). In over magnification of image more than certain limit, the image will appear in pixels, which is not desirable. Importance of early detection of IRR in prognosis and treatment plan, limitation of intraoral techniques in early detection of these lesions and insufficient studies on the effect of magnification changes on CBCT images and also efficacy of CBCT in detecting external root resorption, were considered the main reasons to investigate the IRR using cross-sectional images with low, medium and high magnification in this study (16, 23).

Materials and Methods

In this study, 34 healthy single-rooted teeth with only one root canal system that been extracted in dental clinics following orthodontic treatments and without any pathologic problems in Ahvaz City, were selected (as the teeth had already been extracted following orthodontic treatments, the obtaining of informed consent was not necessary). The extracted teeth were stored in sampling containers with physiological saline prior to sterilization. Lack of specific caries, repair or fracture was the main criteria in selection of the teeth. The teeth look clinically healthy without previous decay or restoration after visual inspection with naked eye. Sampling method and size were performed based on previous valid statistical studies (21).

Teeth cutting: Each tooth was split mesiodistally through their medial canal using an ultra thin metal saw (1 mm), left each with two labial and lingual halves.

At first, to produce images without root resorption (as a control group), two halves of each tooth were bond with adhesive wax and then, the teeth were randomly divided into two groups before mounting each group in a mold or block (In this stage, teeth were placed in mold 1 and 2 prior and also after creation of IRR). To simulate jaw bone, molds been made of gypsum and acrylic powder in equal portions (24). To parallelize the samples, the floor of the blocks was leveled with a trimmer. After the teeth were mounted with curve of spee in the anterior-posterior plan and curve of Wilson in the medio-lateral plan, one side of each mold was marked with gutta-percha (a radiopaque material) to determine the position and establish a specific order in the numbering of the teeth CBCT images were prepared separately in the axial plane and multiple cross-sections for each tooth and processed with three different magnifications of low (50), medium (100) and high (150) (Figure 1). In the preparation of images, both, the thickness of the sections and steps was considered 0.5 mm. All images were coded and registered in a specific form (21, 24). The used device for preparing images was Newtom GiANO manufactured in Italy with exposure settings as below:

MA: 3; Kvp: 90; T: 9; FOV: 11×8; Air kerma:5.49mGy; DAP:411.35mGy. 〖cm〗^2;

CTDIw:2.89 mGy; CTDIvol:2.89mGy

Also, the receiver was CMOS detector with dimensions of 11 × 13 cm. The images were prepared in DICOM format in axial multiple cross-sections for the teeth.

Preparation of CBCT Images for the Group with IRR

At this stage, to simulate a low and high IRR, two cavities were created in cervical root area using a round bur with diameters of 0.25 and 0.5 mm in labial halves, respectively. High and low IRR simulated teeth were placed in mold 1 and 2, respectively. After drill of cavities, the labial and lingual halves of the teeth were reattached with a thin layer of adhesive and mounted in the molds in the same position as before prior to imaging with the previous exposure settings (Figure 2).

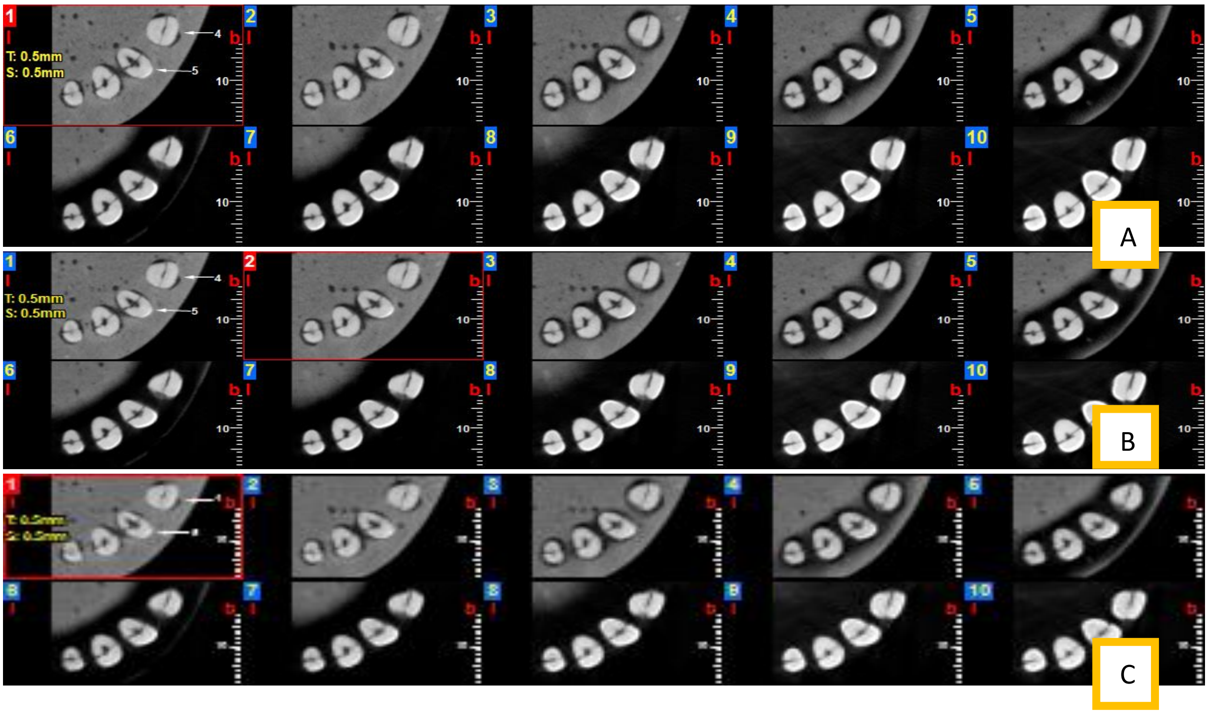

Figure 1. Axial view of control specimens; teeth number 4 to 7 of mold number 1; A) low magnification B) medium magnification C) high magnification

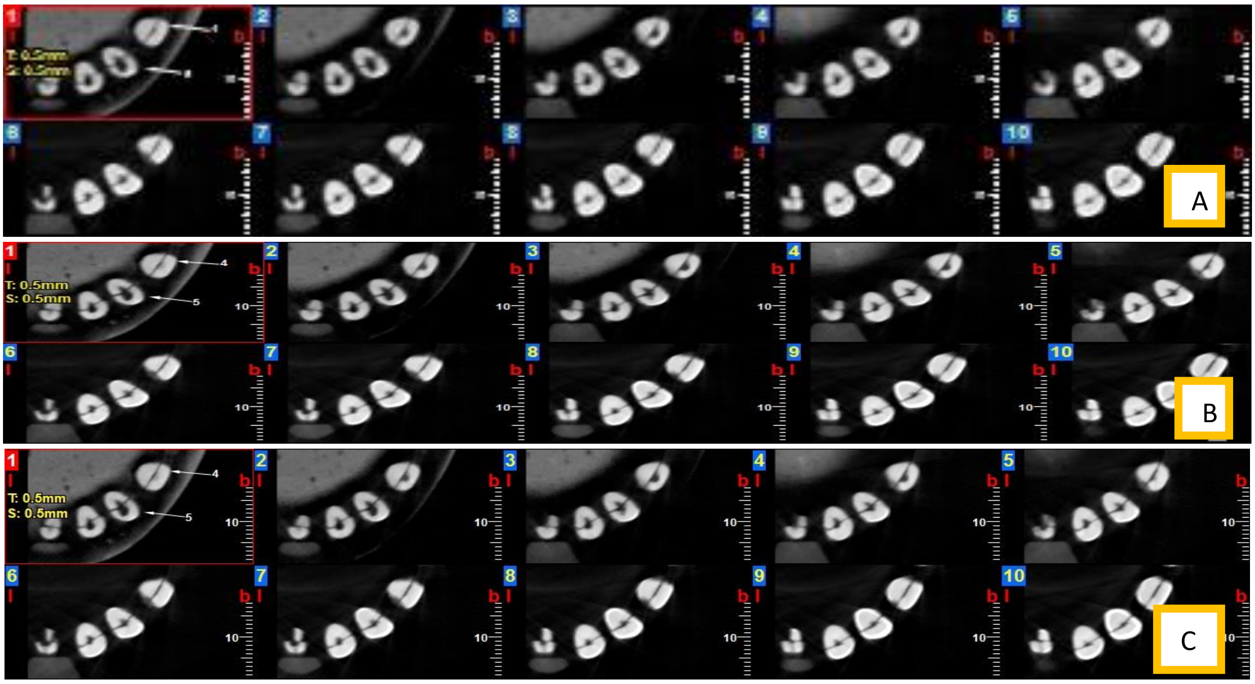

Figure 2. Axial view of the IRR specimens; teeth number 4 to 7 of mold number 1; A) low magnification B) medium magnification C) high magnification

Evaluation of Images

These images were evaluated separately in two sessions by a radiologist and an endodontist who were aware of how the research was conducted but did not know the existence or absence of the IRR and its location. Both observers used a monitor in a windowless room with low light and the same conditions for observing the images. The radiographs were also code named. Under a blind condition, observers reported the presence or absence of IRR after observing the radiographs.

Statistical Analysis

The collected data were analyzed descriptively and analytically with statistical tests using the latest version of SPSS software (version 22).Using different statistical tests, Sensitivity, Specificity, Overall Accuracy, Positive Predictive Value and Negative Predictive Value were calculated and the significant relationship between the observations made by the observer and the existing reality was examined. Significance limit was considered $P \leq 0.05$ for all statistical tests.

Results

After collecting and entering data to SPSS software, research hypotheses were compared in Crosstabs using Kappa and MacNemar tests. As mentioned earlier in materials and method, 34 permanent, healthy single root and canal teeth were studied after creation of IRR using bur and imaging with CBCT. Opinions of each observer were recorded for radiographic images without enhancement and also for images with three different low, medium and high magnifications. Validity estimation indices including sensitivity and specificity were calculated and overall accuracy was determined using ROC (Receiver Operating Characteristic) curve analyzes.

Statistical analysis of low magnification images by the first observer showed that the sensitivity, specificity and overall accuracy were 91.18%, 73.53% and 82%, respectively, and the second observer was 100%, 88.24% and 94%, respectively. The agreement value between the first and second observers in the low magnification mode was 0.760.Kappa and McNemar test showed that there is no statistically significant difference between low magnification imaging and reality for the first observer (p = 0.146) and the second (p = 0.125) (Table 1).

Statistical analysis of medium magnification images by the first observer showed that the sensitivity, specificity and overall accuracy was 100%, 73.53% and 87%, respectively, and in the second observer was 91.89%, 88.24% and90%, respectively. The agreement between the first and second observers in the medium magnification mode was 0.763.Kappa and McNemar test showed no statistically significant difference between the medium magnification imaging and reality for the first observers (p = 0.05) and the second (p = 0.999) (Table2).

Statistical analysis of high magnification images by the first observer showed that the sensitivity, specificity and overall accuracy was 100%, 88.24% and 94%, respectively, and in the second observer was 100%, 82.35% and 91%, respectively. The agreement between the first and second observer in the high magnification mode was 0.820.Kappa and McNemar test showed no statistically significant difference between the high magnification imaging and reality for the first observer (p = 0.125) and the second (p = 0.031) (Table 3).

Table 1. Statistical analysis of low magnification images

	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %	Area under the ROC curve (AUC)
First observer	91.18 (76.32, 98.14)	73.53 (55.64, 87.12)	77.5 (61.55,89.16)	89.29 (71.77, 97.73)	0.82 (0.71, 0.91) P<0/001
Second observer	100 (89.72, 100)	88.24 (72.55, 96.70)	89.47 (72.5, 97.06)	100 (88.43, 100)	0.94 (0.86, 0.98) P<0/001

Table 2. Statistical analysis of medium magnification images

	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %	Area under the ROC curve (AUC)
First observer	100 (89.72, 100)	73.53 (55.64, 87.12)	79.07 (63.96,89.96)	100 (86.28, 100)	0.87 (0.76, 0.94) P<0/001
Second observer	91.89 (76.32, 98.14)	88.24 (72.55, 96.70)	72.09 (75.20, 97.06)	88 (75.67, 98.08)	0.90 (0.81, 0.96) P<0/001

Table 3. Statistical analysis of high magnification images

	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %	Area under the ROC curve (AUC)
First observer	100 (89.72, 100)	88.24 (72.55, 96.70)	89.47 (75.20,97.06)	100 (88.43, 100)	0.94 (0.86, 0.97) P<0/001
Second observer	100 (89.72, 100)	82.35 (65.47, 93.24)	75.56 (70.16, 94.29)	1008 (87.66, 100)	0.91 (0.82, 0.97) P<0/001

Based on results, sensitivity was high for all three magnification modes (low, medium, and high**).** Finally the highest sensitivity, specificity and overall accuracy were belonged to high magnification images.

In the following, for a more detailed review, we will examine the images with high and low level of resorptions for different magnifications.

Statistical analysis of low magnification-high resorption images by the first and second observers showed that sensitivity, specificity and overall accuracy were (80%, 73.33% and 77%) and (100%, 73.33% and 87%), respectively. McNemar test showed that there was no significant difference with reality in both observers (Figures 3 and 4).

Statistical analysis of low magnification- low resorption images by the first and second observers showed that the sensitivity, specificity and overall accuracy were (100%, 73.68% and 87%) and (100%, 100% and 100%), respectively. McNemar test showed that there was no significant difference with reality in both observers (Figures 5 and 6).

Statistical analysis of medium magnification-high resorption images by the first and second observers showed that sensitivity, specificity and overall accuracy were (100%, 73.33% and 87%) and (80%, 73.73% and 77%), respectively. McNemar test showed that there was no significant difference with reality in both observers (Figures 3 and 4).

Statistical analysis of medium magnification-low resorption images by the first and second observers showed that sensitivity, specificity and overall accuracy were (100%, 73.68% and 87%) and (100%, 100% and 100%), respectively. McNemar test showed that there was no significant difference with reality in both observers (Figures 5 and 6).

Statistical analysis of high magnification-high resorption images by the first and second observers showed that sensitivity, specificity and overall accuracy were (100%, 73.33% and 87%) and (100%, 53.33% and 77%), respectively. McNemar test showed that there was no significant difference with reality in both observers (Figures 3 and 4).

Statistical analysis of high magnification-low resorption images by the first and second observers showed that sensitivity, specificity and overall accuracy were (100%, 73.33% and 87%) and (100%, 53.33% and 77%), respectively. McNemar test showed that there was no significant difference with reality in both observers (Figures 5 and 6).

In the first and second observers with low resorption mode and all level of magnifications, the detections were almost consistent with reality. In the case of high level of resorption, for the first observer, specificity and sensitivity was higher in the mode of medium and high magnifications and in the second observer, the sensitivity in low and high magnifications and specificity in medium and high magnification modes were higher.

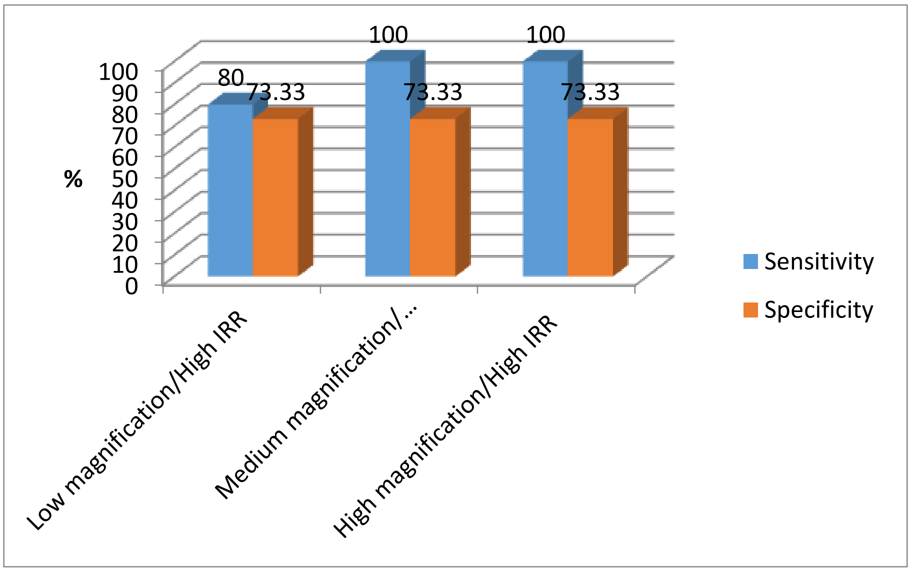

Figure 3. Comparison of specificity and sensitivity with high degree of IRR and different image magnifications for detections by the first observer

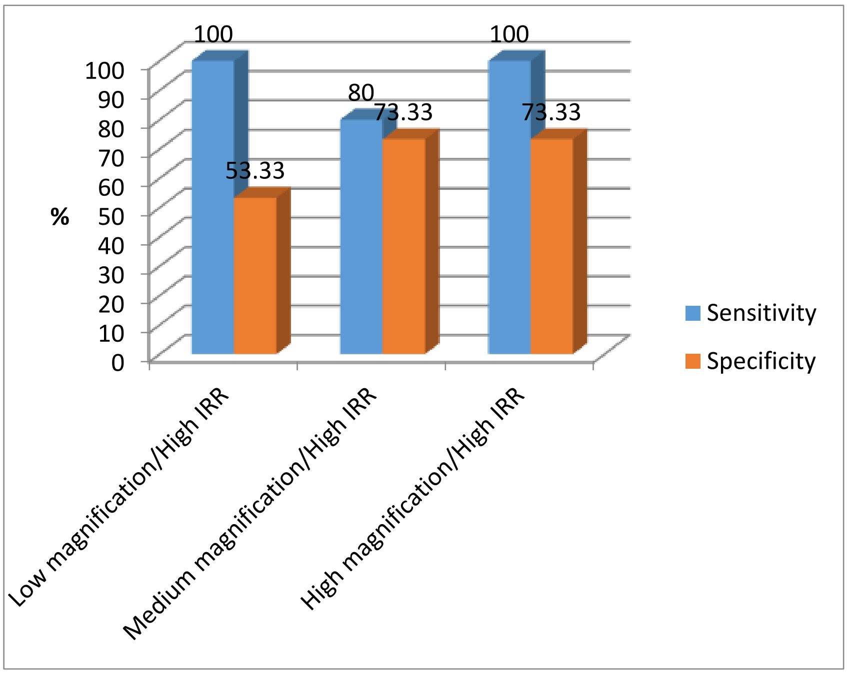

Figure 4. Comparison of specificity and sensitivity with high degree of IRR and different image magnifications for detections by the second observer

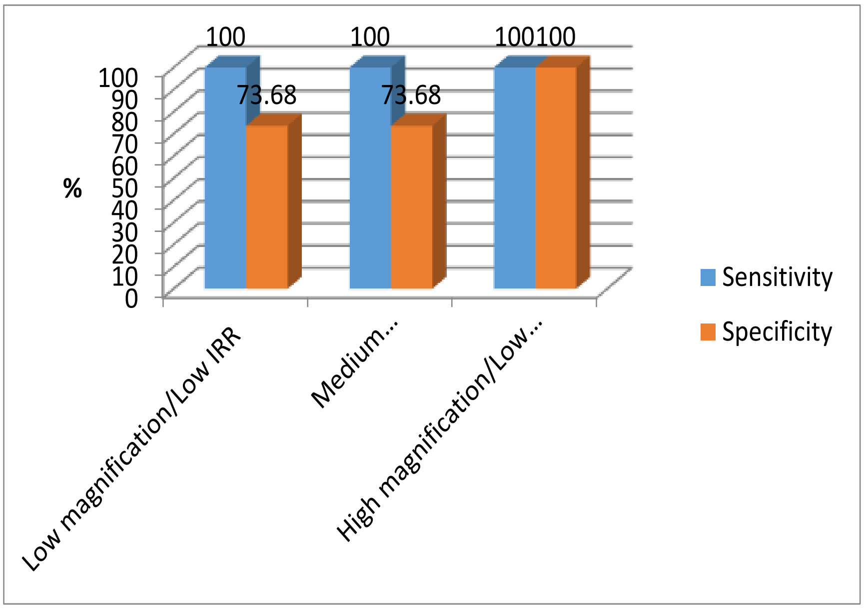

Figure 5. Comparison of specificity and sensitivity with low degree of IRR and different image magnifications for detections by the first observer

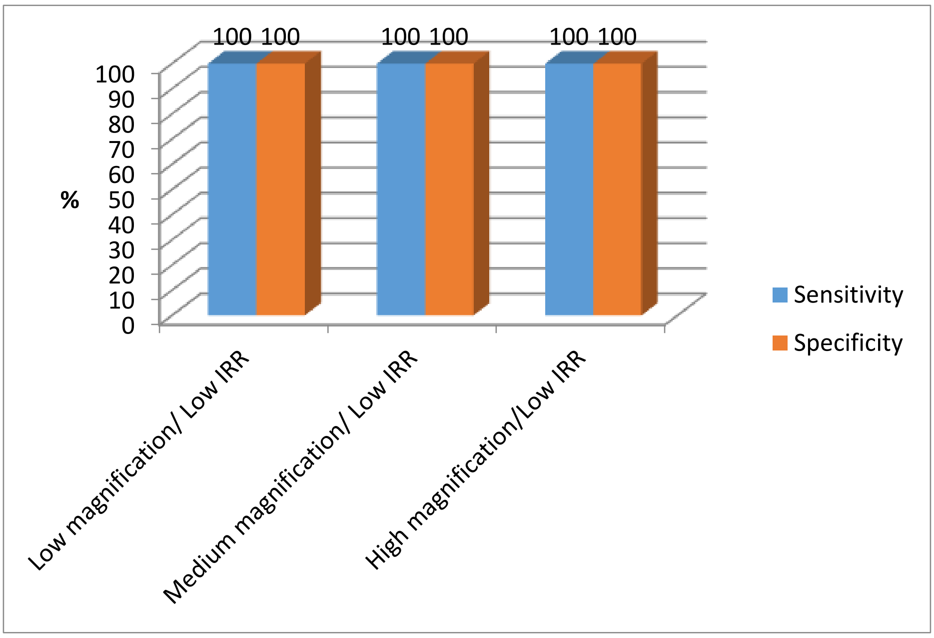

Figure 6. Comparison of specificity and sensitivity with low degree of IRR and different image magnifications for detections by the second observer

Discussion

Radiographic observation is a helpful tool that can show the presence of dental abnormalities which, along with clinical examinations and medical history, leads to diagnosis and treatment plan. Basically, any diagnostic method for IRR lesions must have the ability to make a correct diagnosis (25). IRR is an inflammation process initiated within the pulp space with loss of dentin and possible invasion of cementum. Most articles in the field of resorption have mostly focused on external root resorption, while IRR is also considered an important challenge for practitioners. These lesions are difficult to diagnose and routine X-ray radiography is often inadequate whereas, the CBCT method is a more powerful tool that allows early and more accurate diagnosis of these lesions (18). Today, all digital direct imaging systems provide a variety of image processing techniques which comprised of different methods that are available to the dentist in the form of digital system enhancements software. These filters are used in dentistry to facilitate the interpretation of images either for diagnostic or treatment purposes, although their diagnostic value is still controversial (26, 27).

Prior to the present study, no other study on the effect of magnification on the diagnosis of IRR has been performed, but in the field of external resorption, we can refer to the study of Habibikia et al, in 2018in which, the effect of magnification and brightness changes of CBCT imaging (high, medium and low) on determining the external resorption of the middle area of the tooth in single-rooted teeth due to the proximity of the impacted tooth was investigated. According to their findings, comparison of specificity, sensitivity, and overall accuracy of the images showed that images with high magnification and brightness used to detect the resorption in middle area of root for embedded teeth can be accepted as a valid processing filter (27). So far, no other studies were found on the effect of magnification changes on internal root resorption.

In present study, the highest sensitivity, specificity and overall accuracy are belonged to images with high magnification which is not consistent with the study of Habibikia et al, in 2018 on external resorption, which may be due to the different location of internal and external resorption relative to the root surface and its different visual impact on the view of observers.

It should be mentioned that McNemar test did not show a significant difference with reality in any of the different magnification modes and resorption. In the first observer, the highest number of true positive responses was for high magnification images, and in the second observer, it was for low and high magnification images.

The statistical analysis of observed images with medium magnification and low IRR by the first and second observers showed that the sensitivity, specificity and overall accuracy are 100%, 100% and 100%, respectively, and therefore in cases with low IRR and medium magnification, all diagnoses were consistent with reality. Although, the study was on single-rooted teeth, due to the complete elimination of anatomical structures in In-vitro studies, and in fact we did not encounter the problem of superimposition.

The artificial creation of a round cavity with definite boundaries using a bur which is not completely characteristic of physiological lesions was one of limitations in this study. Different depth of the cavities together with lack of anatomical superimposition due to the In vitro nature of this research, were also among other limitations in this study.

One of the valuable aspects of this research was the application and study of the effect of different level of magnifications using NNT software in detection of IRR for the first time.

Recommendations for improvement of future studies: 1.Investigating the effect of different image processing filters in detecting IRR using CBCT devices. 2. Possibilities for detection of IRR in different sections of root canal. 3. Possibilities for conducting an In-Vivo studies and comparison of its results with present study.

Conclusion

Based on results, sensitivity was high for all three magnification modes (low, medium, and high).For the first observer, the overall accuracy was higher at high magnification mode. For the second observer, the overall accuracy was high in all three magnification modes, and in the low magnification mode, the overall accuracy was higher than the two other magnifications modes.

No significant differences were observed between the three overall accuracies and as a result, magnification, regardless of whether it is low, medium or high, will help in detection of IRR.

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Conflict Of Interest Statement

None declared

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