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MAGNETIC RESONANCE IMAGING FOR THE ASSESSMENT OF PULPOTOMY OUTCOME IN MATURE PERMANENT MOLARS WITH IRREVERSIBLE PULPITIS– A REPORT OF 4 CASES

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ABSTRACT

INTRODUCTION: Pulpotomy has recently been proposed as an alternative to root canal treatment for the management of irreversible pulpitis in mature permanent molars. However, up till now there is no non-invasive diagnostic tool to measure the true vitality of the remaining radicular pulp

OBJECTIVES: This study investigated the ability of using Magnetic resonance imaging (MRI) as a new diagnostic tool for the early evaluation of pulpotomy outcome in four mature permanent molars with irreversibly inflamed pulp.

MATERIALS AND METHODS: A single visit pulpotomy procedure was carried out in four mature permanent lower molars with acute irreversible pulpitis. EndoCem MTA was used as the pulp dressing material. Teeth were then restored with a base of resin-reinforced glass ionomer cement, followed by composite restoration. Clinical and radiographic assessment was done at 1,3,6, 9, &12 months. MRI was done at 6 months to measure the signal intensity from the remaining radicular pulp and compare it to the contralateral healthy pulp.

RESULTS: In the first three cases; MRI analysis showed that there was no sign of alteration in the mean signal intensity of the remaining radicular compared to the contralateral healthy pulps. This was in accordance with the clinical and radiographic criteria of success. However, in the fourth case there was a marked decrease in the mean signal intensity indicating pulp necrosis which was not detected at that time neither clinically nor radiographically.

CONCLUSIONS: MRI could be a very promising diagnostic tool for the early evaluation of pulpotomy outcome.

KEY WORDS: Irreversible pulpitis, mature teeth, MRI, MTA, pulpotomy.

RUNNING Title: MRI assessment of pulpotomy outcome.

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INTRODUCTION

Management of carious teeth with pulp exposure is still one of the controversies in endodontics. Two different approaches are being debated: the conservative approach with vital pulp therapy (VPT) and the more invasive but reliable approach with conventional root canal treatment (RCT) (1). VPT maintains the vitality of the dental pulp which sustains the vascularization, innervation, immunocompetency, neurosensory, and proprioceptive functions of the tooth. In addition, the dentin-pulp complex continues to defend itself by the formation of reparative dentin that acts as a mineralized tissue barrier against future bacterial invasion. VPT is also a more; conservative, simplified, time-saving, and cost-effective procedure than conventional RCT and could be beneficial in difficult endodontic cases (2). Thus, developing a minimally invasive biologically based therapy that preserves the pulp vitality is the key theme within modern endodontics (3).

Vital pulp therapy has long been implemented only in immature teeth, or in teeth with either mechanical or recently traumatic pulp exposures (4). However, with the better understanding of pulp biology, the increased knowledge of healing and regenerative capability of the irreversibly inflamed pulp, and the development of bioactive materials; a new treatment paradigm has developed for the management of mature permanent teeth diagnosed with irreversible pulpitis oriented toward preservation and tissue regeneration (5).

Pulpotomy has been recently proposed as an effective alternative to conventional RCT for treating irreversibly inflamed pulps (6-8). However, before it's considered as a routine procedure in endodontics, it is necessary to conduct good randomized controlled clinical trials with well-defined inclusion criteria, & identical outcome measures (8).

In the year 2016, Zanini et al. (9) systematically reviewed the publications on pulpotomy

as a conclusive treatment for mature permanent teeth with irreversibly inflamed pulp, and discussed the criteria that were necessary to evaluate the outcome. The results of their study had shown that; the criteria to assess whether the vitality of the remaining radicular pulp tissue had been preserved or not varied considerably among the studies. Since it was difficult to measure the pulp vitality objectively, most of the studies used the presence or absence of a periapical infection as the only available method to assess pulp vitality. The signs of the presence of a periapical infection might be clinically diagnosed by tenderness to apical palpation and percussion or by the presence of a sinus tract or a swelling, and radiographically by the presence periapical radiolucency and apical root resorption.

In the year 2019, Dammaschke, Galler and Krastl (10) stated that; it is the responsibility of well-designed future clinical studies to find out whether the remaining radicular pulp vitality had been maintained or not if the irreversibly damaged coronal pulp had been removed. Histological evaluation has long been considered the only known method that could assess the true vitality of the remaining radicular pulp (9). However, this is not clinically practical and the clinicians are confined only to the clinical and radiographic assessments that do not provide a true measurement for pulp vitality (9). So, there is a necessity to find a diagnostic tool that can measure the true vitality of the remaining radicular pulp.

Magnetic resonance imaging (MRI) is a completely noninvasive specialized imaging technique that has been recently used in dentistry for soft tissue imaging (11). Unlike the X-ray imaging technology that is based on the tissue mineral content, the MRI technology is based on the tissue water content (12). Thus, it has been used in the diagnosis and treatment planning of oral lesions and TMJ disorders, orthodontic treatment, implant dentistry, and in endodontics (13).

In endodontics, MRI has been used to view the dental pulp morphology, and to assess the pulp vitality and regeneration (14-17). A healthy pulp reveals intermediate to high signal intensity on T2-weighted images (18). This signal intensity might decrease by aging due to the continuous reparative dentin accumulation (19). In case of inflammation (pulpitis), the inflamed pulp has an increase in the water content, thus it shows a marked increase in the MR signal intensity (20). Whereas in case of pulp necrosis there is a marked decrease in the MR signal intensity (21).

Thus, these clinical case reports aimed to investigate the efficacy of using MRI for the early evaluation of pulpotomy outcome in 4 mature permanent molars diagnosed as having symptomatic irreversible pulpitis by measuring the vitality of the remaining radicular pulp tissue objectively.

Case #1&2

A 27 years old female patient that was referred to the Conservative Dentistry and Endodontics Department, Faculty of Dentistry, Alexandria University; complaining of severe pain in the lower right side and seeking an emergency treatment. The pain was severe, intermittent, exacerbated by dramatic temperature changes especially to cold stimuli, lasting for hours and relieved by analgesics. The patient was free from any systemic disease. Upon clinical examination; there was no extraoral facial swelling, no sinus tract, and no cervical and submandibular lymph nodes enlargement. Upon intraoral examination; Soft tissue examination revealed neither a sinus tract nor a swelling, and there was no unusual sensation upon palpation. Hard tissue examination showed deep occlusal caries in the lower right second molar (tooth# 47) (Figure 1B) that was not tender to percussion, and gave an immediate, exaggerated response to thermal tests that lasted for minutes. Radiographic examination showed that the tooth #47 had a deep occlusal caries that extended to involve the pulp, and had intact lamina dura and periodontal ligament space around the root apices (Figure 1A). So, the patient was diagnosed as having symptomatic irreversible pulpitis with normal periapical tissues in the tooth #47 based on the subjective and objective examinations. Three months later, the patient came with symptomatic irreversible pulpitis in the lower left first molar (tooth #36). (Figure 1: G&H)

Case #3

A 25 years old male patient that was referred to the Conservative Dentistry and Endodontics Department, Faculty of Dentistry, Alexandria University; and complaining of severe pain in the lower left side that was exacerbated by dramatic temperature changes especially to cold, lasting for hours and relieved by analgesics. He was free from any systemic disease. Extra oral examination showed that there was no facial asymmetry and no lymph adenopathy in relation to the region of complaint. Intraoral examination revealed normal soft tissues, without any unusual sensation upon palpation. Hard tissue examination revealed a deep occlusal caries in the lower left second molar (tooth # 37) (Figure 3B), that was not tender to percussion, however, it responded immediately with an exaggerated response, that lasted for minutes in response to thermal tests. Radiographic examination, showed a deep occlusal caries, extending to involve the pulp in the tooth #37 with normal periapical tissues (Figure 3A). So, the patient was diagnosed as having symptomatic irreversible pulpitis with normal periapical tissues in the tooth #37.

Case #4

A 30 years old female patient that was referred to the Conservative Dentistry and Endodontics Department, Faculty of Dentistry, Alexandria University; complaining of severe pain in the lower left side that radiates to the head and seeking an emergency treatment. The pain was severe, sharp spontaneous exacerbated by dramatic temperature changes especially to cold, lasting for hours and not relieved by analgesics. The patient was free from any systemic disease. There was no unusual observation during both the extraoral examination and the intraoral soft tissue examination. However, the intraoral hard tissue examination revealed extensive distal caries in the lower left first molar (tooth

36) (Figure 4 A&B), that was not tender to percussion, but responded immediately to thermal tests with an exaggerated response that lasted for minutes. Radiographic examination showed a deep occluso-distal caries in tooth #36 with intact lamina dura and periodontal ligament space around the root apices. So, based on the subjective and objective examinations, the patient was diagnosed as having symptomatic irreversible pulpitis with normal periapical tissues in the tooth # 36.

Clinical protocol for pulpotomy

After the approval of the research Ethical Review Board (IORG0008839) on the 23rd of April 2018, at Faculty of Dentistry, Alexandria University, the risks and the benefits of MTA coronal pulpotomy procedure over the conventional RCT were explained for the 3 patients and an informed oral and written consent was obtained from each one. Local anaesthesia was administered and rubber dam isolation was done. All caries was removed using a sharp excavator & the access cavity was adjusted using the endo Z bur. The inflamed coronal pulp tissue was amputated using another sterile sharp spoon excavator until the canals' orifices. In the four molars being treated, bleeding was visible from all canal orifices and hemostasis was achieved within 5-8 minutes using a sterile cotton pellet soaked with 2.5% NaOCl (Figures: 1C,1I, 3C, &4C). The Endocem MTA (Maruchi, Wonju, South Korea) was mixed according to the manufacturers' instructions and was gently packed onto the pulp chamber floor and covering the pulp wound in the canal orifices to a thickness of 2-3 mm, and then it was allowed to set for 4-5 mins. The teeth were then restored with resin reinforced glass ionomer (Riva LC, SDI Limited, Victoria, Australia) until the cavity is 3 to 4 mm deep and the remaining cavity was restored with Tetric EvoCeram composite restoration (Ivoclar-Vivadent, Schaan, Liechtenstein). An immediate postoperative periapical radiograph was taken using a paralleling device to evaluate the quality of the procedures and for the future comparisons (Figures: 1D,1J,3D, & 4D).

Follow up:

The patients were recalled after one week to check the postoperative pain. Patients were instructed to score the pain experienced by them using the Numerical Rating Pain Scale (NRS) (22) that was given to them. Pain was recorded every 24 hrs. until the seventh day after treatment. Pain on the NRS was further classified as: No pain (0), Mild (1–3), Moderate (4–6), and Severe (7–10) pain.

The patients were then recalled after 1,3, 6, 9, & 12 months for clinical and radiographic evaluation. Clinically, the teeth were examined for any signs or symptoms of pathosis, including pain, discomfort, sinus tract or swelling, probing depth, mobility, integrity of the coronal restoration, and the response to cold testing. Radiographic examination included assessment of the periapical health according to the periapical index (PAI) developed by Orstavik et al (23). PAI at the end of follow-up (T1) was compared with baseline (T0). The assessment of the treatment outcome was performed according to the criteria developed by Zanini et al (2016) (9). The pulpotomy procedure was considered successful when the patient experienced no pain (either spontaneous or on chewing), clinical examination revealed no sinus tract or swelling and the coronal restoration was intact, and radiographic examination showed that the PAI at T1 = 1. The outcome of pulpotomy was considered uncertain if similar symptoms as successful category however, the PAI at T1 = 2. Finally, the pulpotomy was considered a failure/unhealed if the pain persisted, or clinically there was a sinus tract or swelling, and the PAI at T1=3.

Magnetic resonance imaging (MRI) analysis was performed on the 6th month follow up, by a specialist at Mostafa Kamel Military hospital, Alexandria Egypt, using a 3 Tesla MRI machine (Philips, Netherlands 2012), and according to the protocol performed by El Kateb et al 2020 (15). MRI data acquisition included an MRI survey scan to build the entire head and neck, axial T2-weighted images, and 3-dimensional (3D) T2-weighted images. The examination included the standard MRI turbo spin echo sequence. The following parameters were taken for the T2 axial: repetition time of 54,500 milliseconds, echo time of 100 milliseconds, flip angle of 90º, acquisition voxel of 1.3 × 31.3 mm, and 3-mm slice thickness. For the 3D T2 images, the following parameters were used: repetition time of 1500 milliseconds, echo time of 160 milliseconds, acquisition voxel of 1.3 × 31.3 mm, 2.5-mm slice thickness, turbo factor of 40, and a scan time of 3.50 minutes. The raw MRI data were then collected from the extended workstation (R2.6.3.1, Philips) and analyzed. Reconstruction of the MRI images was carried in both Sagittal and cross sectional (axial) views. The mean signal intensity of the remaining radicular pulp tissue, was measured from the cross sectional (axial) view from the distal canals (as they represented sufficiently large surface area for accurate measurement of the signal intensity) of the treated teeth and compared to the mean signal intensity of the radicular pulp of the distal canal of the contralateral non-affected tooth with clinical vitality and without any additional past treatment at both coronal and middle thirds.

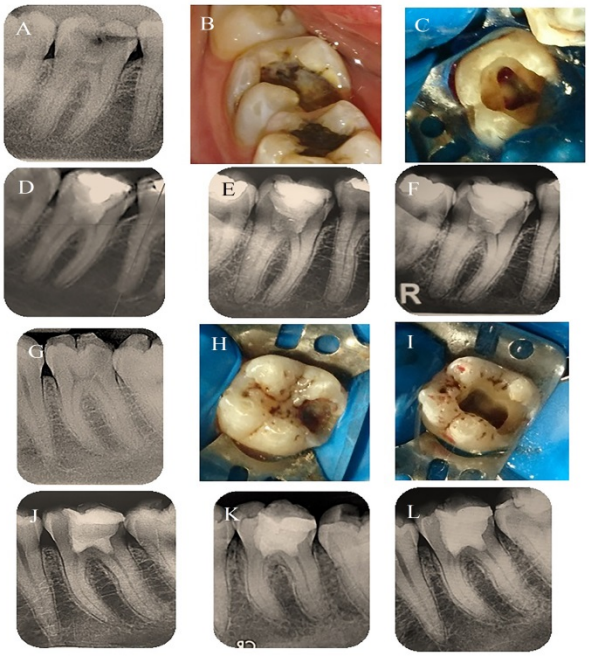
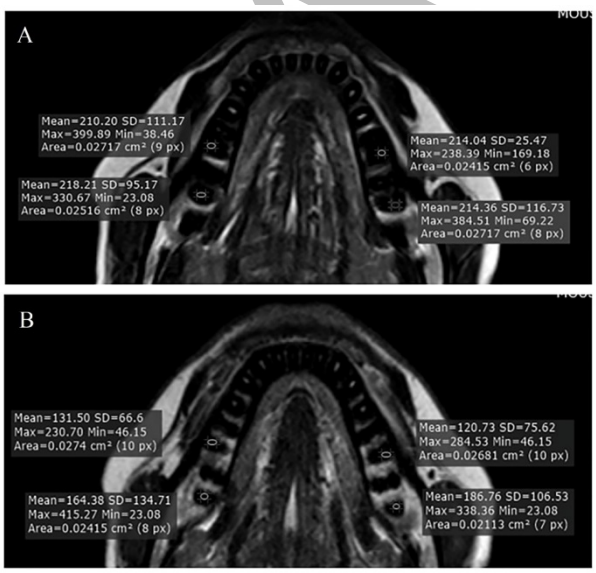


Figure (1): Showing the clinical, & radiographic assessment for the tooth #47 (A-F) & #36 (G-L) in the first case. (A,&G) Pre-operative periapical radiographs for tooth # 47, &#36 respectively; (B,&H) showing pre-operative clinical photos of tooth #47with extensive occlusal caries, & #36 with extensive occlusodistal caries respectively. (C,&I) clinical photos of tooth #47,& #36 after pulpotomy & control of bleeding respectively; (D-F) periapical radiographs taken immediate post-operative, after 6 months ,& after 12 months of follow up respectively for tooth #47; (J-L) periapical radiographs taken immediate post-operative, after 6 months ,& after 12 months of follow up respectively for tooth #36.



Figure(2): Showing MRI assessment at 6 month follow up for tooth #36, & 9 months for tooth #47 showing in axial slice comparing the mean signal intensity of the radicular pulp of the distal canal of pulpotomized teeth (#36 & #47) as compared to that of the distal canal of the contralateral normal radicular pulp in the coronal (A) & middle (B) thirds respectively. Note that the mean signal intensities are almost the same indicating vitality of the remaining radicular pulp.

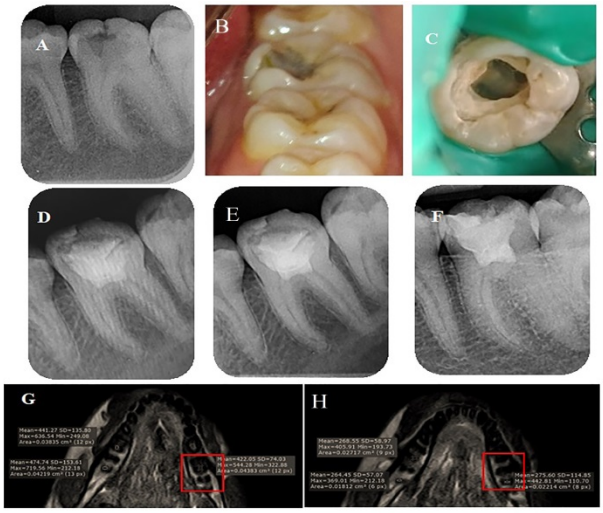


Figure (3): Showing the clinical, radiographic, & MRI assessment for the case no. 2. (A) Pre-operative periapical radiograph for tooth # 37; (B) showing pre-operative clinical photos of tooth #37 with extensive occlusal caries; (C) clinical photo of tooth #37 after pulpotomy & control of bleeding; (D-F) periapical radiographs taken immediate post-operative, after 6 months ,& after 12 months of follow up respectively; (G&H) MRI at 6 month follow up showing axial slice comparing the mean signal intensity of the radicular pulp of the distal canal of pulpotomized tooth (#37) as compared to that of the distal canal of the contralateral normal radicular pulp in the coronal & middle thirds respectively. Note that the mean signal intensities are almost the same indicating pulp vitality.

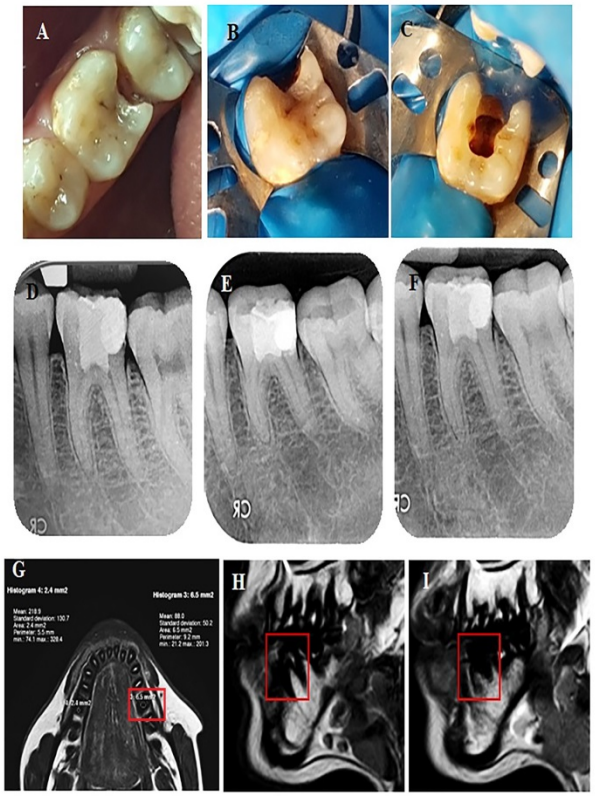


Figure (4): Showing the clinical, radiographic, & MRI assessment for the case no. 3. (A&B) showing pre-operative clinical photos of tooth #36 with extensive distal caries. (C) clinical photo of tooth #36 after pulpotomy & control of bleeding; (D-F) periapical radiographs taken immediate post-operative, after 6 months ,& after 8 months of follow up respectively; (G-I) MRI at 6 month follow up showing in (G) axial slice comparing the mean signal intensity of the radicular pulp space of the pulpotomized tooth (#36) as compared to that of the contralateral normal radicular pulp; (H&I) Sagittal slices in the normal contralateral tooth in (H) & pulpotomized tooth in (I). Note the lack of signal in the pulpotomized tooth at 6 months follow up indicating pulp necrosis.

RESULTS

Pain incidence at 24 hours; 2 cases reported moderate pain (score 5), while the other 2 reported mild pain (score 3). On subsequent days, the pain scores decreased in all cases. By the seventh day postoperatively; 3 cases had no pain (score 0) and 1 case had mild pain (score 1). Immediate failure did not occur in any of the cases. At 1,3, and 6 months follow up, all cases were considered successful as clinically there was no pain or discomfort, neither sinus tract nor swelling, and the coronal restorations were adequate. Radiographically, all cases had normal periodontal ligament space and normal trabecular bone pattern, absence of canal obliteration and lack of internal root resorption. (Figures 1(E & K), 3(E), & 4(E)). In addition, in the 6th month follow up the 1st, 2nd, and 3rd cases started to respond to the cold testing, while the fourth case did not. After 12 months, the first 3 cases were successful clinically & radiographically PAI at T1 = 1 (Figures 1(F & L), & 3(F), and they responded to cold testing. On the other hand, the last case presented with spontaneous pain after 8 months; clinically, there was neither sinus tract nor swelling, but there was tenderness to percussion, the tooth did not respond to cold stimulus, clinical examination revealed leakage around the coronal restoration and increased probing depth at the distolingual & mesiolingual aspects. Radiographically there was widening in the periodontal ligament space, PAI = 1 (Figure 4F). Therefore, the case was considered a failure and root canal treatment was initiated.

The mean signal intensities of magnetic resonance imaging (MRI) of the distal canals of the pulpotomized teeth in comparison to that of the contralateral healthy pulps in the coronal & middle thirds after 6 months are presented in (table 1). Analysis of the data from the first 3 cases showed no signs of alterations in the mean signal intensity of the pulpotomized teeth as compared to that of the contralateral healthy teeth (Figures 2(A&B), 3(G&H)) indicating vitality in the remaining radicular pulps. This was in accordance with the clinical and radiographic criteria of success. However, in the fourth case there was a marked decrease in the mean signal intensity of the remaining radicular pulp space in the distal canal of the pulpotomized molar compared to that of the distal canal contralateral healthy pulp in the coronal & middle thirds sections indicating pulp necrosis (Figure 4G). The sagittal view showed lack of signal from the pulpotomized tooth compared to that of contralateral again indicating pulp necrosis (Figure 4(H&I)). On the other hand, this case was considered successful at 6 months follow up based on clinical and radiographic findings.

Table 1: Showing the mean signal intensities of the distal canals of the pulpotomized teeth in comparison to the mean signal intensities of the distal canal of the contralateral healthy pulps in the coronal & middle thirds.

Mean signal intensity	1st case		2nd case		3rd case		4th case	
	#37	control	#46	control	#37	control	#36	control
Coronal 3rd of distal canal	218.21	214.36	214.04	210.2	422.05	441.27	88	218.9
Middle 3rd of dista	164.38	186.76	120.73	131.5	275.6	268.55	62.74	188.02

l canal								

DISCUSSION

Managing mature permanent teeth with signs and symptoms suggestive of irreversible pulpitis is usually invasive via conventional RCT. However, in recent years there has been a growing evidence suggesting that the coronal pulpotomy procedure could offer a less invasive and reliable treatment option.

Several factors have been proven to contribute to the success of coronal pulpotomy mainly; the diagnosis of the initial pulp status, complete isolation during the procedure, together with the maximum coronal seal for the remaining radicular pulp to prevent bacterial leakage (24).

Analysis of literature emphasizes that two types of failure might be occurring following pulpotomy procedure: early failure within days of treatment and leading to symptomatic pulpitis, and long-term failure detected several months after treatment and characterized by the presence of a periapical lesion following pulp necrosis (8). Early failures could be related to misdiagnosis of the initial pulp status or insufficient removal of the inflamed pulp tissue, whereas late failures could be related to the adequacy of the coronal restoration (8). In this study, absence of immediate failures might reflect the careful clinical diagnosis of the initial pulp status, and could support the notion of selecting the cases for pulpotomy by relying on the time needed to control bleeding (25).

In the present study, patients had preoperative severe pain ranging between score 7-8 on numerical rating scale (NRS). After 24 hours, pulpotomy was able to reduce the postoperative pain to mild (score 2) in 2 cases and moderate (score 5) in the other two cases. During the first week, complete pain relief was achieved in 3 cases (75%) which was in accordance with the previously reported 85% mean pain reduction (26).

The duration of the follow-up period is still a controversial issue. In the year 2016, Zanini et al (9) stated that a 6 months follow-up seems to be sufficient to tentatively assess the outcome. However, they reported that there are possible complications that might occur later on and that during this latent period the final outcome can't be clearly assessed, so, they suggested the term uncertain to denote such cases. The European Society of Endodontology (3) recommended that the tooth should be monitored clinically and radiographically at 6 and 12 months, and that if there is uncertainty regarding the outcome the tooth should be kept monitored without reintervention for a longer period of time in order to reveal the late failures.

There is a great heterogeneity among the studies in reporting the pulpotomy outcome. Some studies considered the absence of pain and the presence of the tooth functioning in the arch a successful outcome (27). Other studies considered that maintaining the vitality of the remaining radicular pulp is a satisfactory outcome (10). However, in pulpotomized teeth it's difficult to assess the vitality of the remaining radicular pulp objectively as; the pulp sensibility and the pulp vitality tests are unreliable because of the size of the coronal restoration and the depth of tertiary dentin formed under the pulp capping material. Thus, they might lead to an increased risk of false negatives (9). Some studies considered the formation of a mineralized barrier under the pulp capping material and canal obliterations as an indication for pulp vitality (28). However, this is difficult to visualize radiographically and might be only confirmed histologically (29). Thus, most of the studies used the presence or absence of a periapical infection as the only available practical method to assess the vitality of the remaining pulp tissue. In our study, we used criteria described previously (Zanini et al. (9), and Taha et al. (30)) to assess the outcome clinically and radiographically and we assured the vitality of the remaining radicular pulp using MRI as a new diagnostic tool.

In our study, pulpotomy seemed to provide success in 100% of cases at 6 months follow up clinically and radiographically. However, this percentage decreased to 75% by the 8th months as one of the cases presented by severe spontaneous pain, so according to Zanini et al (9) this case was considered a failure and RCT was initiated. At 1 year follow up, the percentage remained constant (75% success). This was comparable to the 75%–95% reported success rate of full pulpotomy after 1 year by the European society of Endodontology (3).

This failure might have been due bacterial leakage via the marginal gap of the class II composite restoration, or via the periodontal pocket that was present in the follow up period. In the year 2016, Kumar et al. (31) in their randomized controlled clinical trial excluded teeth having proximal caries; as proximal lesions might have compromised the perfect isolation and good coronal seal which are among the most important factors affecting the success of pulpotomy.

Regarding the vitality of the remaining pulp, the MRI analysis at 6 months follow up was able to assure vitality of the remaining radicular pulp in the first 3 cases (75%) & necrosis in the last case (25%) which was at that time not detected neither clinically nor radiographically. This was in accordance to Zanini et al (9) who stated that after pulpotomy we have the 3 biological outcome probabilities that we cannot differentiate between them clinically without invasive reintervention; either we have a healthy pulp, or necrobiosis, or septic necrosis. Also, it supports the notion that; despite of the successful outcome criteria (clinically and radiographically) the pulpotomized teeth might not contain vital pulp at one-year follow-up as teeth with pulp necrosis could remain asymptomatic and without any radiographic evidence of disease (32). Thus, MRI could be an effective, noninvasive tool that might detect early pathological changes in the dental pulp before the clinical and radiographic manifestations of pulp pathosis and so, it could provide a measure of predictable outcome, thus eliminating the need for longer follow up.

In our study, base line MRI readings were not performed pre-operatively or immediately after pulpotomy, to serve as control for follow up readings, because this study was conducted on patients with symptomatic irreversible pulpitis which required emergency treatment. In addition, according to the recommendations of Assaf et al. (17) in the follow-up examination after dental traumatic injuries MRI follow up readings could be compared to that of the contralateral nonaffected teeth with clinical vitality and without any additional past dental treatment. Thus, in our study there was no need to have immediate post-operative MRI as long as we have contralateral healthy tooth, especially that MRI examinations are expensive.

While MRI seems to be a very promising diagnostic tool, it has some draw backs. First, the clarity of the images is highly affected by the patients' un wanted movements and by the presence of any metal in the field such as orthodontic brackets and wires, and metallic crowns (18). The MRI device itself might cause some image artifacts because of the inhomogeneity in the magnetic field or even some reading errors (20). Secondly, the MR examinations are contraindicated in patients with biomedical devices and implants such as artificial cardiac pacemakers, cochlear implants used for hearing, implanted neurostimulators used to relief symptoms of neurological disorders, intravenous infusion pumps, cerebral aneurysm clips implanted to treat brain aneurism, and fixed metal prostheses; since the magnetic field of MR machine might cause damage to these devices thus causing a life-threatening situation, or might cause dislocation (because of the torsion), or might cause soft tissue burns in patients with fixed metal prostheses and aneurism clips (because of the absorption of radiofrequency energy) (33). Finally, the MR examinations are expensive. However, when considering the added costs and radiation hazards the patient will go through for further conventional follow up, MRI may very well become a strong dental diagnostic tool in the future.

CONCLUSIONS

MRI could be a new noninvasive diagnostic tool for the early evaluation of pulpotomy outcome in mature permanent teeth with irreversibly inflamed pulp by assessing the vitality of the remaining radicular pulp tissue objectively rather than evaluating the outcome by only excluding clinical and radiographic signs of periapical inflammation or infection.

Recommendations

Large, well-designed clinical trials comparing pulpotomy with other treatment modalities using MRI as a method of assessment of pulp vitality are needed before pulpotomy becomes a true alternative to conventional RCT.

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