# Evaluation of Three Methods in the Diagnosis of Dentin Cracks Caused by Apical Resection

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#### Abstract

**Objective:** To compare three various methods in the diagnosis of dentinal cracks formed in the apical third after root resection.

**Materials and Methods:** One hundred extracted human maxillary central incisors were selected. The root canals were prepared with step-back technique. Then 3mm from the apical end of all roots was cut perpendicular to the long axis of the tooth. The apical end of each root was evaluated to make sure there were no cracks. Fifty specimens were randomly chosen and connected to an apparatus especially designed for application of force (50-60N) by a universal testing machine for crack formation. The cracked (no=50) and non-cracked (no=50) specimens were examined by three methods of fiber optic transillumination, methylene blue staining and combination of the two. Sensitivity and specificity of the methods were evaluated. The most suitable method for detecting cracks was determined using Youden index. To compare agreement between studied methods with the gold standard, kappa statistics and odds ratio of McNemar were utilized.

**Results:** The sensitivity of transillumination, staining and the combination method were 82.0, 50.0 and 90.0%, respectively. The staining technique had the lowest sensitivity and the highest specificity. Both transillumination and the combination method had Youden index of 0.56, but the combination method diagnosed truly cracked samples more than the other techniques.

**Conclusion**: The efficacy of transillumination in identification of apical root-end cracks undetectable by unaided vision was similar to the combination method. However, the efficacy of 2% methylene blue without transillumination was significantly lower than the other two methodologies.

Key Words: Dentinal Crack; Methylene Blue; Transillumination

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#### **INTRODUCTION**

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In some endodontic failure situations, retreatment is impossible. Therefore, surgical methods like retrograde endodontic apical surgery are necessary to save the tooth. In this method, the end of the root is cut surgically and an apical cavity is prepared ultrasonically or using diamond burs [1-4] that sometimes results in microcracks on the apical root-end dentin [5]. These microcracks can create a communication pathway between the root canal and the periodontium. Therefore, the local bacteria in the complex apical ramifications, such as isthmuses, canal fins and lateral canals can leak through these cracks and prevent healing of apical tissues [6,7]. Min et al. [8] in an electron microscopic study of extracted teeth reported an increased appearance of cracks and fissures on using ultrasound tips. These root surface irregularities may in turn provide a location for bacterial growth and the concentration of toxic and peri-root irritating metabolites. Finally these irritants may lead to longterm failure of the surgical procedure because of increasing the risk for apical percolation. Therefore, the ideal aim of apical root surgery is to provide optimum conditions for healing by sealing any way from the root canal system to the periapical tissues and preventing the invasion of bacteria and their by-products [9]. So, detection and treatment of these possible pathways, such as isthmuses, accessory canals, apical root-end cracks in apical surgery is critical to avoid the recurrence of apical leakage with subsequent infection.

Several studies have examined the resected surface of apical roots for detection of probable dentinal cracks, yielding different results. The problem of root-end cracking as a result of ultrasonic apical cavity preparation was first noted by Saunders et al. [2].

Layton et al. [1] found three kinds of cracks (canal cracks, dentin cracks and cemental cracks) among which 18% were observed after root resection and 43% after cavity preparation by ultrasonic instruments. Saunders et al. [2] found dentin cracks in 21% of roots after rootend cavity preparation by ultrasonic instrument tips and high-speed burs. In addition, other main factors involved in crack formation are cavity preparation technique, root thickness and morphology, type of the hand pieces and their speed [3]. Frank et al. [10] reported that root thickness and morphology are important factors in causing cracks. Rainwater et al. [4] also found that cracks have been created in 85% of teeth after root resection and 68% after cavity preparation by ultrasonic and diamond bur preparation with the use of a high-speed hand piece. However, in most instances, unaided vision seems inadequate to evaluate the resected surface root ends during periapical surgery. So, several authors have suggested that the use of aid tools could cause enhanced vision and success rates in apical surgery [11-13]. It is difficult to resect the root tip correctly with unaided vision without magnification. Although an incomplete root-end resection itself might not be a cause of failure, anatomical or iatrogenically induced anomalies in the root canal can be missed. If the root tip was resected completely, unaided vision without transillumination and magnification appears unsuitable for evaluating a resected root surface and managing the anatomical details, such as isthmuses, canal fins and probable apical cracks.

Finally, these are the possible causes of failure in previous apical surgery [15, 16]. Of course, the clinician's ability in using these diagnostic tools, identification and correct interpretation of different magnification device findings at the cut root surface are the critical microelements [9,17].

Hence, the accuracy of identification of magnification device findings will play a decisive role in apical surgery. In this study, we have assessed the accuracy of identification of three methods in the evaluation of the cut root surface for detection of probable apical root-end cracks after apical root resection. Therefore, several experimental studies have evaluated and compared the effectiveness of different visual aids in diagnosing cracks after root-end resection. Introduction of microsurgery principles, including well-focused illumination and magnification almost 15 years ago improved the healing outcome of apical surgery because of the increased accuracy of identification using magnification devices [17,18]. Slaton et al. [19] in an experimental study evaluated the effect of increased magnification in the accuracy of crack identification in extracted human teeth, and showed that the accuracy was enhanced (between 39% and 58%). Bellizzi-Loushine [20] and Rubinstein [21] suggested transillumination and zooming systems for this purpose. Several authors have also encouraged the use of multiple sources for improving lightening and magnification including fiber optic loops, surgical microscopes, endoscopes, transillumination and micro-computed tomography, which were useful in identifying the cracks [22,14]. Wright et al. [23] reported the technique providing the best discrimination between cracked and non cracked resected roots was methylene blue plus transillumination in comparison with sodium fluorescein dye, caries detect dye, methylene blue dye along with magnification. So, correct diagnosis of these cracks can be helpful for the success of endodontic surgery because of the high prevalence of these cracks during cutting root or apical cavity preparation, a communication pathway between the root canal and the periodontium is created that is caused apical leakage and failure [2-4, 10]. In addition, sometimes the definitive identification of apical surgery failure may be necessary to apply resurgical exposure and direct inspection of the root end to detect failure reasons. In other words, when endodontic surgery fails, the best treatment plan to solve the problem is determining the possible causes of failure [24]. Therefore, further treatment including extraction, nonsurgical endodontics, resurgery, or intentional replantation is needed [25]. Nonsurgical retreatment is considered the first choice of treatment when improper root filling is the main cause of failure, and the root canal is accessible and negotiable. Otherwise, most cases that fail postsurgically should be repeated surgically or extracted [26], although some studies have reported that resurgery has

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a very poor success rate and might often be contraindicated [27,28]. In this phase, the clinician can advise the patient of the long-term prognosis of detective surgery and maintaining the tooth. The aim of this in vitro study was to evaluate and compare the efficacy of three methods for detection of dentinal cracks after root-end resection in extracted human teeth.

#### **MATERIALS AND METHODS**

One hundred extracted, fully root formed, human permanent maxillary central incisors were selected for this in vitro study from a pool of teeth extracted for periodontal reasons, but the age and sex of the patients at the time of extraction were unknown. Samples were stored in 100% humidity until further use. Periapical radiographs were taken to ensure the existence of a straight canal with no previous RCTs, calcifications, anomalies, and resorptions.

After cutting off the clinical crown at CEJ by diamond fissure burs (MANI, Japan) using a high-speed hand piece with water spray cooling system, an ISO size K-file #10 (MANI, Japan) was inserted into the root canal and instrumented to apical foramen to ensure patency. The working length was defined as 0.5 mm short of the foramen. Then 5 millimeters of the coronal third of each canal was enlarged by no #3, no #2, and no #1 Gates-Glidden drills (MANI, Japan). The remaining of the root canal was hand instrumented with K-file ISO size #25 to #50 (MANI, Japan) using a stepback technique. Each sample was buried vertically from its coronal side in self-curing acrylic resin (Aria Dent, Iran). The apical 3 mm of each root was then cut perpendicular to the long axis using a #0.8 fissure diamond bur in a high-speed hand piece with water spray (Fig 1). The apical end of the cut root was polished with composite polishing bur, rubber cup and bristle brush (MANI, Japan). To ensure that no cracks were present after root resection, the root end surfaces in all samples (no=100) were evaluated at 50x magnification with a stereomicroscope (OLYMPUS, 8ZXI2).



Fig1. The apical end of the cut root of each sample

Fifty samples were randomly selected for creating artificial cracks. Consequently, a cylindrical steel wedge (1.2 millimeter in diameter) was attached to a force application universal testing machine (Instron, Germany) that was used to vertically apply the force to the apical end of the root (Fig 2).

The machine had a sensitive pen to measure the applied forces and register it on graduated paper. Immediately after a crack formed on the root-end surface, a serrated line was registered on the paper. The amount of applied forces was between 50 and 60 N.

In order to confirm artificial cracks, the same stereomicroscope was used at 50x magnification (cracked samples), but samples with visible cracks by unaided vision were excluded from the study and replaced with new ones. Subsequently, all parts of each sample were covered by a rubber dam except for 2 mm of the apical third (Fig 3).

Four dental students who were blind to the procedures of this study, evaluated all 100 specimens (cracked=50 and non-cracked=50) using each of the following diagnostic methods. Between four blind observers, the observer with the least correct diagnosis was excluded. Then, the diagnoses of the three other observers were recorded. In the final analysis, minimum two observers with a similar opinion was considered.



Fig 2. A force application machine (Instron, Germany) was used to vertically apply the force to the apical end of the root

**In method-1,** samples were assessed by transillumination using a 2-mm-diameter fiber optic.

**In method-2**, 2 mm of the resected surfaces of the apical third of the root was stained with 2% methylene blue for 30 seconds. Subsequently, the samples were washed and dried for 5 seconds by water and air spray. The samples were examined under a surgical microscope (GLOBAL ST, Swiss) at 8x magnification.

**In method-3,** the samples were painted with 2% methylene blue and examined by a 2-mmdiameter fiber optic transillumination, as a combination method (Fig 6).

Prior to the main study the inter-observer reliability was measured in a pilot study.

Sensitivity and specificity were calculated by the following equations:

	Number of True Positive				
Sensitivity =	Number of True Positive + Number of False				
	Negative				
	Number of True Negative				
Specifity =	Number of True Negative + Number of False				
	Positive				

To select the suitable method for detecting cracks, Youden index was used.



Fig3. A sample with cracks



Fig4. A sample without cracks

To compare agreement between studied methods and the gold standard, kappa statistics and odds ratio of McNemar were calculated. To compare sensitivities and specificities between different methods, Cochran's Q test was performed and adjusted p-values for pair wise comparisons were reported. In this study, pvalues of less than 0.05 were considered statistically significant.

#### RESULTS

The results of this study showed that the sensitivity of transillumination, methylene blue dye and the combination of transillumination and 2% methylene blue were 82.0, 50.0 and 90.0%, respectively.There was a statistically significant difference among all three methods (p<0.001) except for between transillumination and the combination of transillumination and 2% methylene blue (p-value=0.82). In addition, this study showed that the sensitivity of 2% methylene blue was significantly less than that of the two other methods (P<0.001), but the specificity of 2% methylene blue was significantly more than the two other methods (94.0% vs. 74.0 and 66.0%; P=0.003 and p<0.001, respectively). On the other hand, methylene blue had more specificity for diagnosing true non-cracked samples than the two other methods, but abouttrue crack samples, only 50% of true cracked samples could be identified and the other 50% true cracked samples were not diagnosed correctly.

Although transillumination and the combination method both had a Youden index of 0.56, since the combination method had more sensitivity for identifying true cracks than transillumination (90.0% vs. 82.0%), it may be a preferable method for using in practice to identify apical root-end cracks (Table 1).

Table 1. Diagnostic Indices of Different Methods for Detecting Apical Root End Cracks

Method	Sensitivity	Specificity	Youden Index	Карра	P-Value	OR*	P-Value
Transillumination	82.0	74.0	0.56	0.56	< 0.001	1.44	0.52
Methylene Blue 2%	50.0	94.0	0.44	0.44	< 0.001	0.12	< 0.001
Transillumination Plus Methylene Blue 2%	90.0	66.0	0.56	0.56	<0.001	3.4	0.02



**Fig5**. A sample was covered by a rubber dam except for 2 mm of the apical third



The dilemma of diagnosing and possibly treating apical root-end dentinal cracks continues to present as a challenge in endodontics.

During apical surgery, root-end cutting and apical cavity preparation are commonly performed using burs or ultrasonic tips that could reveal or potentially create cracks in apical root-end dentin [1-5]. Sometimes these microcracks (complete cracks) can create a communication pathway between the root canal and the periodontium. These pathways can produce leakage of bacteria and their by-products into the surgical area and prevent the healing of apical tissues [2, 6-8]. So, the ideal purpose in apical surgery is to produce a suitable condition for healing by sealing any pathway such as isthmuses, accessory canals, cracks or microcracks from the root canal to periapical tissues to avoid the recurrence of microleakage [9,14]. A large number of studies have shown that cracks usually occur in endodontic surgeries [1,3].

These cracks can result in the failure of endodontic treatment due to the leakage of remaining apical bacteria into the surgical area [1-3,10].

Some studies have also evaluated the reasons for creating these cracks. Others have surveyed the methods used to detect these cracks.



Fig 6. The combination method

However, the majority of these studies have been carried out in vitro and only a few have evaluated cracks clinically. Leslie et al. [29] evaluated root-ends for crack after root resection and again after ultrasonic root-end preparation in patients undergoing endodontic

surgery and did not find evidence of cracks after root resection. Results from this in vivo study agreed with the study conducted by Calzonetti's et al. [30] on cadaver teeth after ultrasonic preparation in which no cracks were found. These findings demonstrate that the periodontal ligament plays a protective role to prevent cracking in clinical conditions—the fact which is not present in vitro. In this study, samples were placed vertically from its coronal side in self-curing acrylic resin to simulate clinical settings as much as possible.

Many authors have also evaluated the surfaces of resected apical root-ends before and after root-end preparations using various tools and methods, reporting variable results [1-3,5].

Therefore, apical root-end dentin cracks can create in the apical surgery after root resection or apical cavity preparation with various tools such as fissure burs with high speed handpieces [31] and ultrasonic tips. Several studies have reported various results in evaluating the accuracy and efficacy of the different diagnosing methods. The present study evaluated the identification of apical dentine cracks after root-end resection in extracted human maxillary central teeth. Transillumination, methylen blue dye, and methylen blue plus transillumi

nation (as a combination method) were the visual aids tested. The main findings of the present study were that transillumination, and the combination of transillumination and 2% methylen blue both produced higher scores in sensitivity than specificity, which implies that these methods were better at disclosing which apical root ends had cracks and which did not. On the other hand, these two methods were more suitable at determining which samples were truely cracked, but 2% methylen blue produced a higher score in specificity (94%) than sensitivity (50%) implying it was a more appropriate method in diagnosing which samples were truly crack-free. On the other hand, the low sensitivity for methylen blue was the result of the high number of false negative cases, with 50 false negative out of 100 samples. This implies that the efficacy of 2% methylen blue was the lowest with respect to other methods for disclosing apical root-end cracks. Transillumination and the combination method had a Youden index of 0.56, but methylen blue had a Youden index of 0.44 that was less than those of the other two methods. The combination method showed a less number of false negative cracked samples than the two other methods. Methylene blue in respect of the two other methods showed the highest number of false negative cracked samples and true negative samples, (Se=50% and Sp=94%). Therefore, the combination method can be a preferable method for use in practice to identify apical root-end cracks and 2% methylen blue can be better for diagnosing non-cracked samples.

Similar results were recently presented in a study that assessed the identification of artificially created cracks in extracted human permanent incisors after root-end resection. It showed that the magnification and illumina-

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tion play an important role in the detection of apical root-end dentin cracks with unaided vision [19]. In another study, transillumination in combination with a dye was shown to be the most efficient way in diagnosing root-end dentinal cracks [23]. Wright et al. [23] compared the effectiveness of transillumination and dyes including methylene blue, sodium fluorescein dye, caries detection dye and methylene blue plus transillumination with each other to detect dentin cracks. They reported that by any detection technique, the differences were insignificant among raters, but the methylene blue plus transillumination method was more able to detect cracks in cracked and non-cracked samples. In the present study, unlike the study performed by Wright [23], methylen blue plus transillumination and transillumination provided the best discrimination between cracked samples (positive groups) and non-cracked (negative groups) and were superior to methylen blue alone. So, in this study unlike Wright et al., methylene blue was more able to correctly detect true non-cracked samples than true cracked samples, but the combination method was more able to identify true cracked samples. One probable cause of difference between these two studies could be relevant to differences in methodology. In the study by Wright et al., experienced examiners were included such as three endodontics and one endodontic resident, but in the present study less experienced observers i.e., dental students cooperated. Moreover, staining (with methylen blue alone) may not necessarily enhance the detection of cracks because the dye cannot flow into craze lines unless there is a break in the surface. Once a crack has propagated into a fissure or fracture, it can be stained with dyes [14]. One of the other findings in the present study was that the opaque condition appeared around the area of strain on the apical root-end dentin. Slaton et al. [19] also reported this frosted or opaque condition. They speculated that these findings may be the result of the formation of many microscopic cracks that had not changed to a macrocrack. Therefore, these findings should be considered by the clinician that a crack may be present.

In other studies, resin replicas and impressions from cross-sectioned roots were utilized and the impression surfaces were evaluated under SEM [32] and a fluorescent microscope [33] to detect dentin cracks. The use of these tools in clinic is both very expensive and complicated with special clinical limitations; therefore, it is practically impossible to use these tools. Holcomb et al. [34] first used the transillumination method to detect root cracks. The results showed that 26% of the teeth that were obturated with lateral condensation of gutta-percha had root cracks. In clinical situations, sometimes transillumination may be difficult to be used if the root end is bone-leveled after resection [14]. Wright et al. [23] suggested removing a small amount of buccal bone overlying the root surface or transilluminating through bone. In an effort to make the present study as clinically relevant as possible, the teeth were examined with only 2 mm of the roots exposed above the rubber dam so that only the apical portion could be transilluminated (Fig 3). Each sample was also buried vertically from its coronal side in self-curing acrylic resin (Aria Dent, Iran) for stimulating the periodontal ligament (Fig 1). In addition, the observers had no permission to reposition the samples in order to have the same and fixed position for every observer. They could only reposition the fiber optic instruments in the range of 4 to 8 o'clock regions. However, necessarily, the results and conditions of an in vitro study can not always be applicable to all clinical conditions. According to the statistics available [35], the surgical microscope is one of the most common instruments used in endodontic surgeries and has become widely accepted and recommended in conventional and surgical endodontics. Of course in some studies, complicated instruments have been proposed for identification of cracks in the apical resected root-end dentine. Mattew et al. [22] used micro-CT and SEM to explore dentin cracks in human extracted molars and elephant tusks. The new methods demonstrated in this study are expected to be used for clinical and scientific studies investigating the etiology and treatment of dentinal cracks in the teeth, but are very expensive and complicated in clinical conditions. Thomas et al. [14] assessed the cut root faces with microscopy at×16 and ×64 magnification and with endoscopy at  $\times 8$  and ×64 magnification (four visual aids) and SEM. They showed that the highest sensitivity for crack identification was through using endoscopy at 64× magnification, irrespective of the applied methodology. In complicated methods, in addition to complexity and expensiveness, higher skill and education is necessary for interpretation of the findings. During most of the previous studies, such as those carried out by Wright et al. [23], Morgan et al. [31] and Thomas et al. [14], there was a complicated problem that challenged all the studies, such as the grooves and irregularities on the cut surfaces of the roots created by burs during apical cutting of the roots. These irregularities can result in light reflections during use of the fiber optic method and also accumulation of dye in these grooves that can wrongly be diagnosed as cracks. In the present study, according to the study carried out by Morgan, the apical end of the cut root was polished with composite polishing rubber cup and bristle brush in order to decrease these grooves to minimum. However, it can be claimed that these irregularities were the main confounding factors in the present study, resulting in some false positive results.

Another problem in this study was lack of a clear definition for cracks. Pitts et al. [36] reported that the important point in this respect is the differentiation of cracks with cracked lines which do not extend into the root canal and have no clinical significance. So, in the study conducted by Thomas et al. [14], the correct identification of intradentin cracks were low with endoscopy and nonexistent with

microscope. A high number of the falsepositive incomplete canal cracks and intradentin cracks was showed with endoscopy at  $64 \times$  magnification rather than the other visual aids. So, for calibrating the observers in the present study, true cracks were defined as follows:

The definition of "Every dark line on the sectioned surface that causes incompetency in dentin is a crack" was applied in the present study for observers. In addition, interpretation of the observers was subjective and led to false positive and false negative results and influenced the statistical analysis. The observers were low-experienced dental students that could influence results of methods and consecutively the statistical analysis. Therefore, it is suggested that more comprehensive studies should be accomplished clinically for evaluating the efficacy of these methods.

## CONCLUSION

The efficacy of transillumination in identifying apical root-end cracks in samples that were not possible to detect by unaided vision, was similar to that of the combination of transillumination and methylene blue dye methodology. Nevertheless, the efficacy of using 2% methylene blue without transillumination was significantly lower than the other two methodologies. It could be concluded that the combination method was preferred in practice ito identify apical root-end cracks.

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