RESEARCH

Evaluation of the visibility of the materials used in furcation perforation in imaging devices

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ABSTRACT

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Background: Variable radiographic techniques are used for postoperative evaluation of the materials used in furcation perforation. Since it is easily accessible clinically and the radiation dose which the patient is exposed to, is lower than the advanced imaging methods, intraoral imaging is applied. In cases that cannot be determined by 2D radiographs, cone beam computed tomography is more relevant because of the absence of superimpositions and allowing for multiplanar imaging. The aim of this study was to assess the diagnostic acceptability of the radiographic visibility of the materials used in furcation perforations and to find out which radiographic technique was efficient to view the materials.

Methods: One hundred and twelve lower molar teeth were used according to the study criteria. Biodentin, BioAggregate, MTA and Endosequence were applied individually to the teeth, in order to repair the perforation zone. Periapical radiographs were obtained with Soredex Digora Optime with photostimulated phosphor plates. Other radiographic images were obtained using Planmeca Dixi 3 CCD, while CBCT images were obtained using Morita Veraviewepocs 3D R100. An endodontist and two dentomaxillofacial radiology specialists evaluated the images of CBCT and periapical radiographs. Teeth were evaluated randomly for the visibility of the repair materials in furcal perforations and scored.

Results: MTA and Biodentine presented low image clarity while Bioaggregate and Endosequence had high image clarity. Morita Veraviewepocs 3D R100 depicted the highest sharpness, but no difference was observed between Soredex Digora Optime and Planmeca Dixi 3 devices.

Conclusion: In the postoperative follow-up of the materials used in the treatment of furcation perforations, the usage of CBCT and the use of Bioagregate and Endosequence, which provide the best image clarity, has been suggested.

KEYWORDS

Cone-beam computed tomography, endodontics, furcation defects

ÖZ

Furkasyon perforasyonunda kullanılan materyallerin görüntüleme cihazlarındaki görünürlüklerinin değerlendirilmesi

Amaç: Furkasyon perforasyonunda kullanılan materyallerin post operatif değerlendirilebilmesi için çeşitli radyografik tekniklerden faydalanılmaktadır. Klinik şartlarda kolay erişilebilir olması ve hastanın maruz kaldığı radyasyon dozunun ileri görüntüleme yöntemlerine göre düşük olması nedeniyle intraoral görüntülemelere başvurulmaktadır. 2 boyutlu radyografilerle belirlenemeyen durumlarda ise süperpozisyonların olmaması ve multiplanar görüntülemeye olanak vermesi nedeniyle konik ışınlı bilgisayarlı tomografiler daha yararlı olmaktadır. Bu çalışmanın amacı furkasyon perforasyonlarında kullanılan materyallerin radyografideki görünürlüklerinin diagnostik açıdan kabul edilebilirliğini ve bu malzemelerin görüntülenmesinde hangi cihazın daha etkili olduğunu değerlendirmektir.

Gereç ve Yöntemler: Çalışma kriterlerine uygun 112 alt molar diş seçilmiştir. Perforasyon bölgesini tamir etmek için dişlere ayrı ayrı Biodentine, BioAggregate, MTA ve Endosequence uygulandı. Periapikal radyografiler fosfor plaklarla Soredex Digora Optime ile, ve Planmeca Dixi 3 CCD kullanılarak, Konik Işınlı Bilgisayarlı Tomografi (KIBT) görüntüleri ise Morita Veraviewepocs 3D R100 kullanılarak elde edilmiştir. Bir endodontist ve iki ağız, diş ve çene radyolojisi uzmanı KIBT görüntülerini ve periapikal radyografi görüntülerini değerlendirmiştir. Dişler tamir malzemelerinin furkal perforasyonlarda görünürlüğü açısından rastgele değerlendirmeye alınmış ve skorlanmıştır.

Bulgular: MTA ve Biodentine düşük görüntü netliği sunarken Bioaggregate ve Endosequence'ın yüksek görüntü netliğine sahip olduğu görüldü. Morita Veraviewepocs 3D R100 en yüksek netliği gösterirken Soredex Digora Optime ve Planmeca Dixi 3 cihazları arasında fark gözlenmemiştir.

Sonuç: Furkasyon perforasyonlarının tedavisinde kullanılan materyallerin postoperatif takibinde, KIBT'nin kullanılmasını ve en iyi görüntü netliğini sağlayan Bioagregate ve Endosequence kullanmanılması önerilebilir bir sonuç olarak bulunmuştur.

ANAHTAR KELİMELER

Konik ışınlı bilgisayarlı tomografi, endodonti, furkasyon defekti

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The furcation perforation is a complication caused by caries, resorptive defects and iatrogenic causes in endodontics.[1] It gives rise to the formation of an artificial opening between the pulp cavity and periodontium, which may cause periodontal defects and loss of teeth.[2,3] The furcal perforations have worse prognosis than perforations in the middle and apical regions of the roots.[4] Materials used to repair the perforation, passing time after perforation, the size and the location of the perforation affect the prognosis of endodontic treatment.[5]

In the repairment of the perforation, it is recommended to seal off the perforation area as soon as possible in order to prevent bacterial infection of the wound area. Many materials have been used as repair materials for perforations such as Cavit, IRM, amalgam, glass ionomer, composite resin, and MTA.[6] Amalgam, calcium hydroxide, IRM and glass ionomer cement are previously recommended materials for the repairment of the perforations. They do not provide the properties of ideal material used to repair an endodontic root perforation due to the lack of osteogenic, cementogenic or antibacterial, and non-sealing properties.[7] It is suggested that MTA, which is accepted as the gold standard for furcation repair, has higher properties as biocompatibility, less bacterial leakage and better adaptation to dentin walls. Recently, it is recommended to use calcium silicate contented bioactive materials, which are both regenerative and biocompatible in the repair of perforations. Bioceramic materials are biocompatible, antibacterial, osteogenetic effective, wash resistant materials with short application time.[7]

Two-dimensional imaging techniques such as periapical and panoramic radiographs are insufficient for the diagnosis of the furcation perforations because of the projection geometry and superimposition problems. Cone beam computed tomography (CBCT) provides accurate and reliable high resolution images in all spatial dimensions with volumetric acquisition technique.[8,9] Petersson et al[10] reported that - especially for endodontic cases- CBCT imaging is more accurate and sensitive than conventional diagnostic imaging modalities. In the assessment of marginal bone contours and three-dimensional defects such as infrabony and furcation, CBCT may play a role for treatment planning and prognosis.[11,12]

The aim of this study was to evaluate the images of the materials used in furcation perforations obtained with different imaging devices. Also, to determine the radiodiagnostic adequacy of these materials and to assess which tecnique is more effective in imaging these materials.

MATERIALS AND METHODS

Inclusion and Exclusion Criteria

The study group consisted of 154 extracted human lower molar teeth. They were selected from approximately one thousand teeth extracted in the Oral and Maxillofacial Surgery Department, Ankara University Faculty of Dentistry between 2017-2018. Inclusion and exclusion criteria were as follows; teeth which were extracted for periodontal and prosthetic reasons and without any restorative procedure, without caries or with minimal rot, apexes were closed, and roots separated from each other. The teeth with pulp stones and calcified pulp chamber were excluded from the study. The debris around the teeth was removed with periodontal curettage. The teeth were stored in distilled water containing % 0.1 thymol crystal[13] at room temperature until they were used in the study.

Preparation of Samples and Creating Perforation Areas

The height of crowns were measured and marked with digital caliper 3 mm above the cemento-enamel junction of the teeth and the crowns of the teeth were removed from the marked area. The root parts of the teeth were amputated 3 mm below the furcation area using diamond discs under water cooling with No.4 long round bur. Then, under water cooling with No. 4 long round bur. The non vital pulp tissue and residues were removed with a sharp excavator and the cavities were washed with % 2.5 sodium hypochlorite (NaOCl) (Sultan Healthcare, New York). The thickness of dentin in the furcation area was measured with a caliper. The teeth with the range of 2.0-2.5 mm dentin thickness were included in the study. The perforation areas were formed in furcation zones under water cooling using a long round bur. Perforation areas were washed with saline to remove dentine residues. The samples were then placed in saline soaked sponges in plastic cylinders to mimic in vivo conditions.

Sealing of Perforation Areas

After the procedures applied for 154 teeth, 112 teeth were included in the last study group and teeth were randomly divided into four different groups (n = 112). 28 teeth were identified in each group. A different perforation closure material was applied to each group of 28 teeth. Images were obtained separately using 3 different radiography methods for each group. In accordance with the instructions, Biodentine (Septodont, Niederkasssel), BioAggregate (Innovative BioCeramix, Vancouver, Canada), Endosequence (ES, Brasseler USA, Savannah, GA) and MTA (Dentsply Maillefer, Ballaigues, Switzerland) were placed in the perforation areas using a plugger and condensed with a gentle pressure for each tooth individually. After the fillings were cleaned with a thin probe, a damp sponge piece was placed inside the pulp chamber for setting of the material.

All materials were placed in the perforation area using dental loop. All samples were then incubated for 7 days in an incubator device which provided a 100% humid environment at 37°C for setting of the materials.

Device Information

Three different radiography methods were applied for each group and this was repeated four times for each biomaterial. The periapical radiographs were taken with Morita Veraview iX at 60 kVp for 0.16 sec (J Morita Mfg. Corp., Kyoto, Japan) and processed by Soredex Digora Optime (Soredex Medical System, Helsinki, Finland). (Figure 1) Second periapical radiography images were created using Planmeca Dixi 3 CCD with 60 kVp 0.02 s (Planmeca Oy, Helsinki, Finland). (Figure 2) The periapical radiographs were obtained using a parallel technique with the film-holder apparatus to provide standardization. The radiographs were taken with two different angles as buccolingual and mesiodistal. The CBCT images were obtained using Morita Veraviewepocs 3D R100 (J Morita Mfg. Corp., Kyoto, Japan) with 0.160 mm^3 voxel size and two different FOVs (8x8 cm and 10x8 cm). (Figure 3) The periapical and CBCT images were obtained by Morita Veraview iX and Morita Veraviewepocs 3D R100 devices, respectively, in Dentomaxillofacial Radiology Department, Faculty of Dentistry, Zonguldak Bülent Ecevit University.

Figure 1

Positioning of the PSP in the right mandibular molar region

Figure 2

Obtaining periapical radiographs by Planmeca Dixi 3

Figure 3

Mandible Positioning for CBCT image acquisition

Image Evaluation

All of the digital scan images were saved as DCM file format.

EIZO RadiForce MS 230 W 23-inch Class Color LCD monitor (23- inch flat-panel screen) (Eizo Nanao Corporation, Ishikawa, Japan) was used to display all images. (Figure 4) The observation conditions were optimized such as viewing distance and the lights during the examinations. An endodontist experienced with CBCT technique and two experienced dentomaxillofacial radiologist examined all of the images for the visibility of repair materials in different sessions. After one month, the measurements were repeated. Second measurements were recorded because no significant difference was found statistically. All teeth were evaluated randomly for the visibility of repair materials in furcal perforations and scored using a 5-point scale, as follows; 5 = best; 4 = well; 3 = moderate; 2 = bad; 1 = worst.

The observers visualized all of the three images at the same time. There was no time restriction for observation. The adjustment of brightness and contrast were done with tool bar in software.

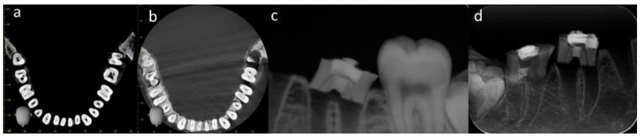

Figure 4

Cropped radiographic image of MTA material (a) CBCT image taken in 10 x 8 FOV size (b) CBCT image taken in 8 x 8 FOV size (c) Periapical radiography obtained by CCD sensor (d) Periapical radiography obtained by PSP

Statistical Analysis

Statistical analysis was performed using SPSS 20.0.1 program (SPSS Inc., Chicago, IL, USA). The normality of the variables' distribution was analyzed using the Shapiro-Wilk test. The homogeneity of the variables' was evaluated by Levene's test. Two-way ANOVA test was employed for factor analysis and post hoc Tukey testing with Bonferroni. Correction (a=0.05) was used for multiple comparisons with the significant level of the 0.05. Kappa statistics were used to the interobserver agreement and intraobserver agreement.

RESULTS

Interobserver results are seen as good and perfect agreement, by these kappa values and as a result of the kappa test, intraobserver compatibility 0.95, interobserver compatibility 0.88 values were found to be perfect.According to the results of two-way ANOVA test, device factor, material factor and device-material factor interaction were found to be statistically significant ($p < 0.05$) (Table 1). There was no statistically difference between Biodentine and MTA ; among Bioaggregate, Endosequence and the control group in terms of image clarity. Bioaggregate, Endosequence and control group showed higher image clarity than Biodentine and MTA group(Table 2).
While there was no statistically significant difference between the devices Planmeca Dixi 3 and Soredex Digora Optime; a difference was observed between the Morita Veraviewepocs 3D R100 and other two devices. The image clarity of the images taken from the Morita Veraviewepocs 3D R100 was determined to be more (Table 2). In all statistical tests, the significance value was accepted as $p<0.05$.

Table 1.

The results of the two-way ANOVA test

	Type III Sum of Squares	df	Mean Square	F	Sig.
Device	5,605	2	2,802	7,684	,,001
Material	95,602	4	23,901	65,54	,,000
Device*Material	29,971	8	3,746	10,27	,,000

Table 2.

The Mean and Standard Deviations of Image Quality. Different superscript letters lowercase, in row and uppercase in columns, indicate statistically significant difference between groups (p<0.05).

	Planmeca Dixi 3	Soredex Digora Optime	Morita Veraviewepocs 3D R100
Biodentine	2,6250± 1,060	2,75±0,462	3,75±0,462
Bioaggregate	4,625±1,060	4,5±1,069	4,875±0,353
Endosequence	5,000±0,0	5±0,0	5±0,0
MTA	2,0000±0,89	2±0,0	4,166±0,752
Control	4,875±0,353	5±0,0	3,75±0,462

DISCUSSION

Furcation perforations could be caused by iatrogenic conditions in the root canal treatment or in the preparation of the canal at the base of the pulp chamber or in posterior teeth cavity preparation. It can also occur with biological events such as caries and pathological resorption.[14,15,16]

Furcation perforations have an important place in terms of prognosis of endodontic treatment. The perforation size, location, passed time after perforation occurrence and whether the perforation area is hermetically sealed or not are important in the success of the treatment.[17,18]

To avoid bacterial contamination, the perforation area should be repaired immediately with a biocompatible material. Perforation repair material, ideally, should provide adequate sealing, be biocompatible, not be affected by blood contamination, stimulate bone formation and healing, mineralization and cementogenesis and also should be easy to manipulate.[19] Ideal repair material should also provide sufficient radiopacity which easily distinguishes it from anatomical structures.[20]

Periapical radiography is most commonly used imaging modality in endodontics to evaluate the prognosis and outcomes of treatment. However, because of the appearance of three-dimensional structures in a two-dimensional plan, the superimposition limit adequate assessment. [21,22] After a comprehensive clinical examination and obtaining the appropriate conventional radiographs, CBCT the appropriate conventional radiographs, CBCT imaging should be indicated if adequate diagnostic information cannot be obtained.[23]However, artifacts from high density neighboring structures such as enamel and radiopaque materials such as metal post, restorations and root filling materials may affect the image quality and diagnostic accuracy of CBCT images.[24]

In this study, the radiodiagnostic quality of repair materials used in furcal perforations, was evaluated with different imaging devices. Among the materials used in our study; in image clarity, Bioaggregate and Endosequence showed higher values than Biodentine and MTA group.

In a study Tanalp et al. Biodentine, evaluated the radiopacities of MM-MTA and MTA Angelus. They used dentine material with 1 mm thickness as a control group. All samples were obtained at 65 Kvp 8 mA and processed with phosphor plate scanner (Digora Optime Scanner, Soredex, Helsinki, Finland). Biodentin showed significantly lower radiopacity values than other materials (P = 0.001), but there was no significant difference between MTA Angelus and MM-MTA. (P = 0.109). All materials have shown significantly higher radiopacity compared to dentin.[25]

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Similarly, M. Tanomaru-Filho et al. in their study evaluated the radiopacities of 5 different root-end filling materials (white MTA-Angelus, gray MTA-Angelus, IRM, Super EBA and Sealer 26). All samples were imaged using a GE-1000 (General Electric, Milwaukee, WI, USA) operating at 50 kV, 10 mA with an occlusal radiograph. Sealer 26 and IRM showed the highest radiopacity values ($p < 0.05$), while white / gray MTA and Super EBA showed the lowest radiopacity value ($p < 0.05$).[26] In another study, Helvacioglu-Yigit et al. used a CBCT device and 4 different root end filler materials, to conclude which cause more artifacts. Biodentine, MTA and Super-EBA were reported to produce less artifact than amalgam.[27]

In our study, there was no difference to determinate the visibility of the repair materials among the periapical radiography devices; Soredex Digora Optime and Planmeca Dixi 3. The images obtained by the Morita Veraviewepocs 3D R 100 are more clearly defined. Comparing with previous studies, publications have been supported this situation.

Stavropoulos and Wenzel performed ex vivo study of pig jaws to determine the accuracy of periapical digital and conventional radiography (Dixi2, Planmeca CCD sensor and Insight film) with CBCT (NewTom 3G) for the detection of periapical lesions. NewTom 3G was found to be statistically better in the detection of periapical lesions in terms of sensitivity (%54), positive (%82.6) and negative (%44.5) predictive values and diagnostic accuracy (%61) compared to digital radiographs. No difference was observed between two periapical (digital and conventional) radiography.[28]

Estrela et al, in the determination of apical periodontitis CBCT (3D Accuitomo XYZ Slice View Tomograph; J Morita Mfg Corp), panoramic (Veraviewepocs panoramic, J Morita Mfg Corp.) and periapical radiography (Max S-1, J Morita Mfg Corp) the accuracy of the CBCT images showed high accuracy for the detection of apical periodontitis. In addition, the accuracy of periapical radiographs was found to be significantly higher than that of panoramic radiographs.[22]

In our study, CBCT device was found to give a better image in the presence of obturation material. In another study; Adel et al. artificially performed strip perforation on the teeth before and after the filling the root canal; obtained images of the teeth with a periapical x-ray device (Planmeca, PlanmecaOy, Helsinki, Finland) and a CBCT device (Promax three-dimensional 3D, Planmeca, Roselle, IL, USA). According to results of Adel et al.'s study; CBCT images obtained before root canal filling was found to be a more effective method for detection of strip perforation, but it was reported that periapical radiographs obtained by 3 different horizontal angulations after root canal filling were more successful in imaging perforation area.[29]

In their study, Eskandarloo et al. compared three different CBCT devices [Cranex 3D (Soredex, Tuusula, Finland), NewTom 3G (Quantitative Radiology, Verona, Italy), Promax 3D (Planmeca, Helsinki, Finland)] and a periapical x-ray device (Minray; Soredex, Tuusula, Finland) for detecting fenestration defects around dental implants. It is reported that NewTom has the highest sensitivity (%75.81) and specificity (%100) for detecting fenestration, but there is no significant difference among 3 different CBCT devices.[30]

In their study, Lindh et al evaluated the visibility of the mandibular canal with periapical radiography (Siemens Heliodent), panoramic radiography (Model OP5, Siemens and Scanora, Soredex), hypocycloidal tomography (Universal Polytome, Massiot / Philips), spiral tomography (Scanora) and computed tomography (Somatom DRG, Siemens). They compared devices and reported that the visibility of the mandibular canal was better on computed tomography than periapical and panoramic radiographs.[31]

Kamburoğlu et al, investigated the CBCT imaging and diagnostic accuracy of a digital intraoral sensor in detecting artificially formed maxillary molar furcation perforations. Images of each tooth inserted in the maxilla were obtained using the ProMax 3D Max CBCT scanner (Planmeca) with a flat panel sensor using the low artifact reduction mode operating at 96 kVp, 1–8 mA, 55 x 50 mm FOV and the digital intraoral sensor (Digora Optime DXR-50; Soredex, Tuusula, Finland). Actual perforation width correlated highly with CBCT width measurements and they reported low-resolution CBCT imaging can be preferred for furcation perforation diagnosis.[32]

CONCLUSION

According to the results of our study, it is recommended to use CBCT for detailed multiplanar evaluation for postoperative follow-up of the materials used in the treatment of furcation perforations. And also for the radiographic follow-up of repair materials, Bioagregate and Endosequence usage is a better choice.

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