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Original

Use of ultrasound, color Doppler imaging and radiography to monitor periapical healing after endodontic surgery

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Abstract: This study evaluated the effectiveness of ultrasound, color Doppler imaging and conventional radiography in monitoring the post-surgical healing of periapical lesions of endodontic origin. Fifteen patients who underwent periapical surgery for endodontic pathology were randomly selected. In all patients, periapical lesions were evaluated preoperatively using ultrasound, color Doppler imaging and conventional radiography, to analyze characteristics such as size, shape and dimensions. On radiographic evaluation, dimensions were measured in the superoinferior and mesiodistal direction using image-analysis software. Ultrasound evaluation was used to measure the changes in shape and dimensions on the anteroposterior, superoinferior, and mesiodistal planes. Color Doppler imaging was used to detect the blood-flow velocity. Postoperative healing was monitored in all patients at 1 week and 6 months by using ultrasound and color Doppler imaging, together with conventional radiography. The findings were then analyzed to evaluate the effectiveness of the 3 imaging techniques. At 6 months, ultrasound and color Doppler imaging were significantly better than conventional radiography in detecting changes in the healing of hard tissue at the surgical site ($P < 0.004$). This study demonstrates that ultrasound and color Doppler imaging have the potential to supplement conventional radiography in monitoring the post-surgical healing of periapical lesions of endodontic origin. (J Oral Sci 52, 411-416, 2010)

Keywords: color Doppler; ultrasound; periapical lesions; periapical surgery; surgical site.

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Introduction

This study was conducted to evaluate whether newer imaging techniques are more effective than conventional radiography in monitoring the post-surgical healing of periapical lesions of endodontic origin. Imaging techniques play a very important role in endodontics. The diagnosis, treatment, and prognosis of periapical lesions of endodontic origin typically rely on radiographic findings. However, radiography is not a perfect diagnostic or monitoring tool, because a lesion may not be obvious and because the extent of a lesion and its spatial relationship to important anatomical landmarks are not easily visualized (1,2). Periapical surgery is sometimes indicated to eliminate, or confirm the presence of, cystic or non-cystic periapical lesions of endodontic origin. Radiographic assessment of lesion healing or expansion is usually subjective and can be impaired by the superimposition of anatomical structures (3). To ensure optimal monitoring of the outcome of surgical and conventional endodontic treatment – and to avoid surgical trauma, in some cases – it is important to evaluate promising methods of imaging periapical lesions.

Ultrasound and color Doppler imaging are straightforward and reproducible techniques that have the potential to supplement conventional radiography in the diagnosis and follow-up of periapical lesions (4-10). They provide specific information regarding the size and the nature of lesion and present no radiation risk. In addition to being noninvasive and radiation-free, these new imaging techniques provide specific information on the healing status of both the surgical site and the related overlying soft tissues, which is not possible with radiography.

Ultrasound relies on the reflection of ultrasound waves (echoes) at the interfaces of tissues that have different acoustic properties (11). As compared with conventional radiographic evaluation of healing in fractured bones, ultrasonography may prove to be more effective in assessing bone micro-architecture, the onset of bone formation, and the surface topography of bone (12-14). In fractured long bone, the intensity of reflected echoes during healing can identify the characteristics of bone apposition (15-16).

The use of color Doppler in ultrasound allows evaluation of the presence, nature and velocity of blood flow in ultrasound images of the examined tissue. It can also reveal the progressive formation of new vessels in bone during the initial healing period. As bone remodeling proceeds, flow signals decrease because the penetration of the Doppler ultrasound diminishes as bone deposition over the affected region increases (17).

Changes in the size and echogenicity of the surgical site, and in vascularity, can be detected by the newer techniques. This provides more precise information regarding the biological activity of the surgical site, as compared with radiography.

The present study used these newer imaging modalities to monitor post-surgical healing of endodontic periapical lesions and to compare the usefulness of these techniques with that of conventional radiography.

Materials and Methods

The present study was conducted jointly by the Department of Conservative Dentistry and Endodontics, Faculty of Dental Sciences and the Department of Radiotherapy, Faculty of Medicine C. S. M. Medical University, Lucknow, India. The endodontic surgical procedures were performed in the Department of Conservative Dentistry and Endodontics, while monitoring of healing was conducted at the Department of Radiotherapy.

We randomly selected 15 patients aged between 15 and 40 years who presented to the department clinic with periapical lesions of endodontic origin on anterior maxillary or mandibular teeth, and for whom periapical surgery was indicated. All patients gave written informed consent. Periapical surgical procedures were performed using conventional techniques. Healing was evaluated in all patients 1 week and 6 months after surgery.

Before surgery and 1 week and 6 months after surgery, standardized periapical radiographs of each affected tooth were taken with intraoral film using bisecting angle technique. Exposure parameters were 70 kV (peak), 7 mA and 0.12 s. All radiographs were scanned at a resolution

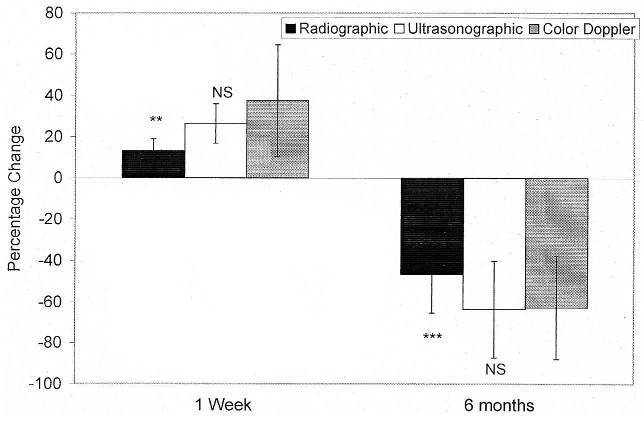

Fig. 1 Comparison of percentage change in the area of the surgical site at 1 week and 6 months.

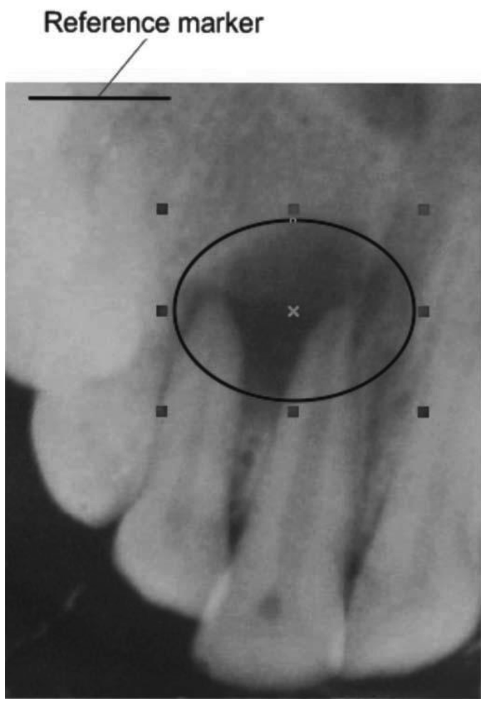

Fig. 2 Radiograph shows calculation of dimension measurements using image-analysis software.

of 300 dpi using a Canon 2000AC flatbed scanner (Canon Japan Inc., Tokyo, Japan) with a transparency module, and saved in the tagged-image file format (TIFF). The relevant dimensions of all patients were measured in the supero-inferior and a mesiodistal directions using image-analysis software (Adobe Photoshop CS; Fig 1). Healing at the surgical site was evaluated by comparing the preoperative dimensions of the radiolucent region with those at 1 week and 6 months after surgery.

Ultrasound examination was performed by senior radiologists using a Toshiba Nemio Model SSA-550A ultrasound scanner (Toshiba Medical Systems, Tokyo, Japan) with a 7MHz to 9MHz transducer, a high-frequency and high-resolution linear probe, and a 6.5-MHz convex TV probe, which was placed extraorally on the skin of the upper and lower lip after application of acoustic ultrasound gel. All lesions were measured on the anteroposterior, superoinferior, and mesiodistal planes, and the dimensions were recorded. Because the acoustic impedances of bone and soft tissue are very different, bony edges are always very well demarcated by ultrasound, and appear as interruptions in the echogenic bony outline. Hard copies of the images were obtained. Color Doppler imaging was performed at each examination to detect blood-flow velocity.

To analyze healing at the surgical site, the following lesion parameters were assessed preoperatively by ultrasonography and color Doppler imaging and then compared with findings obtained at 1 week (Figs. 3a and 4a) and 6 months (Figs. 3b and 4b) after surgery:

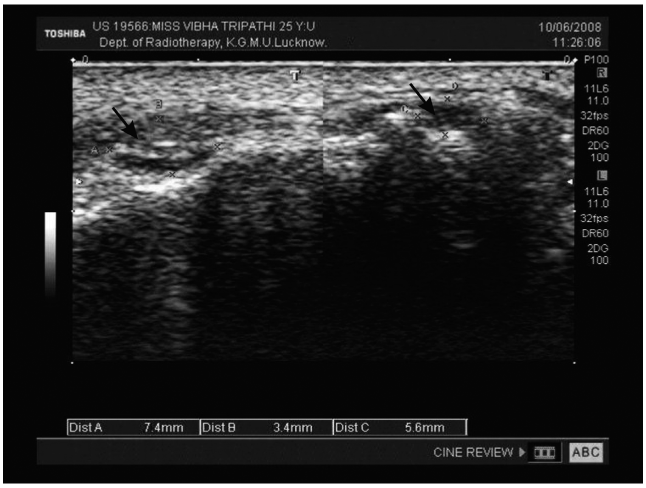

Fig. 3a Postoperative (at 1 week) ultrasound image of a healing periapical lesion.

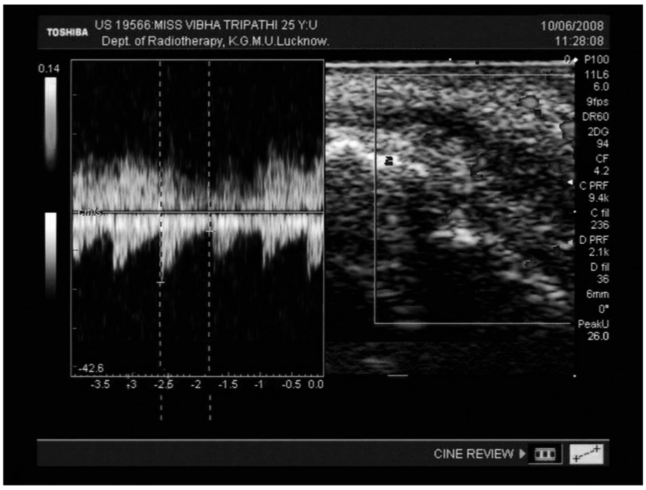

Fig. 4a Postoperative (at 1 week) color Doppler image of a healing periapical lesion.

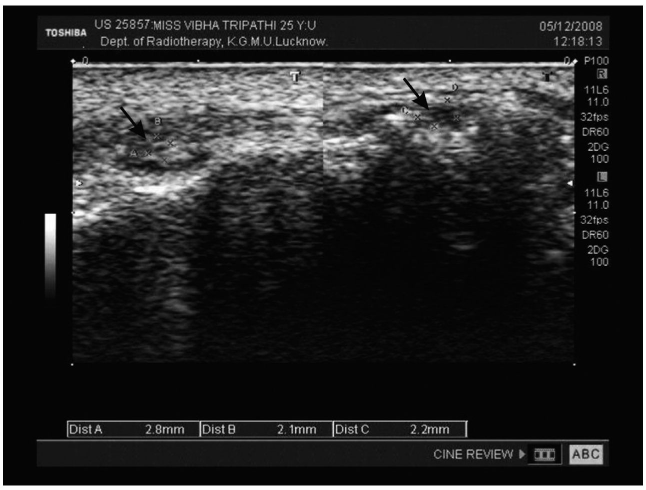

Fig. 3b Postoperative (at 6 months) ultrasound image of a periapical lesion shows healing and bone formation.

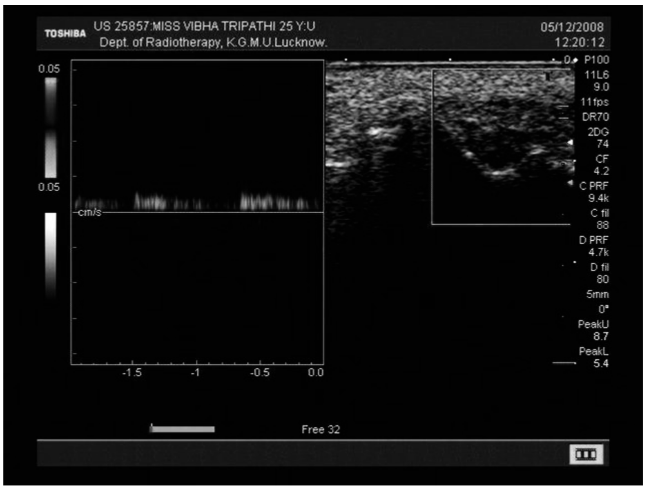

Fig. 4b Postoperative (at 6 months) color Doppler image of a periapical lesion shows healing and bone formation.

1) dimensions of the periapical lesion,
2) change in dimensions of the surgical site, and
3) quantitative and qualitative analysis of vascularity in the affected area. Data from the radiographic assessment and from ultrasound and color Doppler imaging were compared with respect to their effectiveness in monitoring the healing of surgical sites at 1 week and 6 months. Color Doppler imaging was used as the reference standard for these comparisons.

Statistical analysis

The data were compared using the *t*-test and paired *t*-test.

Results

On radiographic evaluation, the mean percentage change in the area of the surgical site was 13.09 ± 5.77% at 1 week after surgery and -46.78 ± 18.82% at 6 months after surgery. On ultrasound, the mean percentage change in the area of the surgical site was 26.40 ± 9.53% at 1 week and -63.81 ± 23.52% at 6 months. However, on color Doppler imaging, the mean percentage change in flow (vascularity) was 37.44 ± 27.03% at 1 week and -62.97 ± 25.07% at 6 months. There was a significant difference for all 3 techniques between the values recorded at 1 week and 6 months after surgery ($P < 0.001$). All 3 imaging techniques showed an increase from baseline at 1 week, and a decrease from baseline at 6 months (Table 1).

In the comparison of radiography and ultrasonography with color Doppler imaging (the reference standard), the mean percentage change on radiography was significantly different from that on color Doppler imaging both at 1 week ($P < 0.01$) and 6 months ($P < 0.001$); however, there was no statistically significant difference in mean percentage change on color Doppler imaging and that on ultrasonography either at 1 week or 6 months ($P > 0.05$), which indicates that ultrasonographic findings were closer to those obtained by color Doppler imaging.

Discussion

Radiographic examination shows evidence of bone healing only after mineralization of the callus starts to occur, which can lag behind the physiological events of bone healing by a number of weeks (18-20). Therefore, radiographs are of limited value in monitoring early changes during the process of bone regeneration (19), and cannot show the response of the soft tissue envelope that surrounds the bone. However, ultrasound is able to detect developing callus before radiographic changes are evident, and therefore can be used to assess early changes during bone healing (21). Thus, research into alternative noninvasive imaging techniques is necessary to determine if they can provide endodontists with more information regarding periapical healing, while simultaneously reducing radiation exposure.

The present study demonstrated that newer imaging modalities, such as ultrasound and color Doppler imaging, can be effective in monitoring the post-operative healing of periapical lesions.

On radiographic examination, the dimensions of the surgical site for all patients were measured in the superoinferior and mesiodistal directions using image-analysis software, as was the case in a number of previous studies (22). The results of the present study showed, that there was an increase in the size of the surgical site after 1 week, as compared with the preoperative dimensions of the lesion. According to Maddalone et al. (23), one goal of periradicular curettage is to remove the reactive tissue from the alveolar bone surrounding the root. When the zones of infection, irritation, and contamination are removed and the root canal system is properly sealed, repair should result in circumferential ingrowth of viable granulation tissue, and, ultimately, replacement with bone (23). In the present study, as healthy bone regenerated, there was a reduction in radiolucency at the surgical site at 6 months. However in 3 patients, there was no significant change in radiolucency at the surgical site at 6 months, perhaps

Table 1 Percentage change from baseline in lesion area (radiography/ultrasound)/flow (color Doppler) at 1 week and 6 months after surgery

Period of follow-up	Radiography	Ultrasound	Color Doppler imaging
1 week	13.09 ± 5.77**	26.40 ± 9.53^{NS}	37.44 ± 27.03
6 months	-46.78 ± 18.82***	-63.81 ± 23.52^{NS}	-62.97 ± 25.07
1 wk vs 6 months			
t	11.838	13.237	8.308
p	< 0.001	< 0.001	< 0.001

Values are mean ± SD
*$P < 0.05$; ** $P < 0.01$; *** $P < 0.001$
NS, no significant difference as compared with changes in color Doppler imaging

indicating inadequate healing.

Hypoechoic areas were observed on preoperative ultrasound and color Doppler imaging.

At 1 week there was no change in the echogenicity of surgical sites; however, after 6 months these sites became hyperechoic. Craig et al. (24) noted that, during bone healing, callus is easily visualized with ultrasound, and that it typically has a hyperechoic or mixed hypoechoic-hyperechoic appearance. Callus is visible on ultrasound before it can be seen in radiographs. Of the 15 present patients, only 3 had hypoechoic areas after 6 months follow-up, due to the presence of much less bone regeneration at the surgical sites in those cases. These findings indicate the absence of significant healing, as compared with the other cases.

Color Doppler imaging was used to observe, blood-flow velocity in lesions. All cases showed increased blood flow at the surgical site after surgery, as compared with preoperative findings. This increase in blood-flow was caused by the presence of inflammation at 1 week after surgery. Inflammatory mediators that increase blood flow are present at the surgical site. During the process of healing, inflammation subsides and blood-flow velocity decreases. Among the 15 cases, 2 showed no evidence of blood-flow at the surgical site at 6 months, probably because Doppler cannot penetrate the area of the surgical site owing to the presence of complete bone formation on the surface or because of very slow baseline flow (25).

Arterial flow indicates the presence of healing, while venous flow confirms its absence (25). In the present study, all cases showed arterial vascularity. Only ultrasound with Doppler (color, spectral, and power) can distinguish venous from arterial flow, quantify the amount of flow, identify the anatomy of feeding vessels, and offer a visual demonstration of vascularity (25).

In the present study, there was no significant difference at 1 week among the 3 techniques used. However, at 6 months there was a statistically significant difference between ultrasound and conventional radiography. Ultrasound in combination with color Doppler imaging yields considerable information on the nature of bone healing and vascularity; analysis of decrease in the area of radiolucency on conventional radiography only provides information on healing at the surgical site.

The use of ultrasound does have some limitations. Ultrasound with color Doppler cannot penetrate, and thus confirm the presence of, a periapical lesion, unless there is a breach or perforation in the buccal bone plate.

Despite the limitations of the present study, our findings indicate that ultrasound with color Doppler is an effective tool in monitoring the healing of periapical lesions after surgery. By providing data on changes in echogenicity and vascularity at the surgical site, ultrasound with color Doppler imaging allows for an assessment of postoperative healing that is not possible with the use of conventional radiography alone.

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