Nat.Volatiles&Essent.Oils,2021;8(4):10410-10416

Ultrasound Imaging In Endodontic Diagnosis-Literature Review and Current Practices

Dr.Anuradha G [1] Dr. Sai Shamini, [2] Dr.Gautham Kumar N, [3] Dr. KadandaleSadasiva[4]

[1]Professor & HOD, Dept of Oral Medicine & Radiology, SRM Dental College &Hospital, Ramapuram ,Chennai -89(Corresponding author)

[2]Professor, Dept of Conservative Dentistry and Endodontics, Madha Dental College&Hospital, Chennai-600069

[3]Professor, Dept of Periodontics, Madha Dental College &Hospital, Chennai-600069

[4]Professor, Dept of Conservative Dentistry &Endodontics, Chettinad Dental College & Research Institute, Kanchipuram-603103

Corresponding author: Dr Anuradha G

Abstract

Imaging always plays a very important part in the diagnosis of various orofacial diseases, especially various periapical lesions that are diagnosed and treated based on radiological findings. The diagnosis of a periapical cyst or granuloma is important because literature reveals that prevalence of apical cyst is 15% of which 9% are true cyst and 6% are periapical pocket cyst. It is suggested that true cyst may sustain apical periodontitis and thus it becomes important to differentiate the lesions as it can affect treatment outcome. The only reliable diagnostic method, to date is the histologic sectioning of the whole lesion, which is not possible in all cases. Traditional radiographs help in the detection of the lesion but is unableto differentiate them, also the 3 D coordinates of the lesion cannot be assessed. Advanced imaging techniques need to be applied in cases where more information on size, content,healing patterns are to be estimated. Ultrasound with Color Power Doppler is one such advanced imaging technique widely used in the field of medicine with potential applicationsin endodontics. The ability to estimate the content of the lesion (solid, fluid or mixed) and vascularity helps in differentiating lesions of endodontic origin. Other exciting applications include detecting pulpal blood flow in teeth through intact enamel and dentin, monitoring post treatment healing.However the thickness of overlying bone can decrease its diagnostic validity. Other limitations include the need for expertise of operator, smaller probe for endodontic use.

Key words: Advanced imaging, Colour Doppler Ultrasound, Periapical cyst, Periapical lesions, Periapical granuloma.

Introduction

Apical periodontitis results from an initiation of a non specific inflammatory response and a specific immunologic response of periradicular tissues caused by microbial infection.[1,2]These pathologic changes result in destruction of the periapical tissues and such osteolytic lesions represent the clinical hallmark of apical periodontitis.[3]Histopathologically, bone radiolucency can be a periapical cyst or granuloma, the correct diagnosis of which can affect treatment outcome. Literature reveals that prevalence of apical cyst is 15% of which 9% are true cyst and 6% are periapical pocket cyst. It is suggested that true cyst may sustain apical periodontitis and thus it becomes important to differentiate the lesions and treat them accordingly.[2,4,5]

Imaging always plays a very important part in the diagnosis of various orofacial diseases, especially vaious periapical lesions that are diagnosed and treated based on radiological findings.[6]Traditional radiographs form the backbone of routine endodontic practice; usually two projections can help diagnosing a periapical lesion. But the limitation of radiographs is that they only determine the mesiodistal, superior inferior extent of the pathology, but not the buccolingual extent. Even though the size and shape of the periapical lesion, the presence of sclerotic border distinguishes the radiolucent lesion from abscess, granuloma and cyst, many studies prove that solely the size or just presence of sclerotic border does not distinguish a cystic lesion from non cystic lesions.[7]When specific diagnostic information is required for differential diagnosis, understanding the anatomic coordinates of a lesion in three dimension, investigate treatment protocols, an advanced imaging techniques such as CT, spiral CT, CBCT, MRI, ultrasound real time ectomography have been suggested for endodontic lesions.[4,8]

Computer tomography (CT) for diagnosing periapical lesion is not recommended due to its high dosage of radiation.[9]A dose reduction can be achieved by using spiral CT and also being specific about the area of scan .The CBCT was developed and approved for dental use in 2000 by the US Food and Drug Administration, it reduces radiation and scan time compared to medical grade CT . The viewer software allows the clinician to view the full volume along with the axial, sagittal and coronal view of area of interest simultaneously.[4]Imaging by MRI was suggested for assessing periapical lesions and planning endodontic surgery.[10]The accuracy of MRI and CT was found to be similar, but artefacts caused by metal restorations in CT did not occour in MRI.The disadvantages of MRI were poor resolution compared to radiographs, differentiation between different hard tissues like enamel,dentin or from metallic restorations cannot be done, long scanning time,expensive, claustrophobic and since bony lesions are not well visualized in MRI it was not the choice for visualizing, diagnosing periapical lesions.[8,11]

Ultrasound as a complementary examination was first demonstrated by Lauria,1996, for the diagnosis of intraosseous jaw lesions.[12]In 2002,Cotti et al proposed that ultrasoundmay help to evaluate the exact nature of a periapical lesion determining the histopathological

nature of the lesion and is a precious tool in diagnosing periapical diseases.[13]Ultrasound is one of the most risk free and easier techniques which captures real time images for functional studies without any radiation hazard. In addition, images in digital form are easy to read, storeand reproduce.[13.14]Nevertheless, to-date, histologic serial or semi serial sectioning of the whole lesion is the only reliable method differentiate between cyst and granuloma.[4]This article reviews the various applications of ultrasound in the field of endodontics.

Principle of Ultrasound:

Ultrasound (US) basically depends on the phenomenon of reflection of ultrasound waves (echoes) at the interface between two tissues that have different acoustic properties. The principles and application of ultrasound was first discovered by Curie brothers in 1880

.The Dussik brothers in Austria (1937) were the first to describe the use of ultrasound imaging.[15]Scanners used for sonography have electrical impulses that are converted into ultra high frequency sound waves by a transducer. Most important component of the transducer isa thin piezoelectric crystal or material made up of a great number of dipoles arranged in geometric pattern. The electrical impulses generated by the scanner causes the dipoles in the crystal to realign themselves with electric field and thus suddenly changes the crystal'sthickness. This abrupt change begins a series of vibrations producing sound waves that are transmitted into the tissues being examined. The transducer emitting ultrasound is placed on the body surface and the beam interacts with tissues of different acoustic impedence. These sonic waves reflect towards the transducer and cause a change in thickness of the crystal, in turn the echoes are detected and converted into electric signal that is amplified, processed and then displayed as a digital image on the computer screen.[14]So the transducer acts as atransmitter and a receiver.

A qualitative comparison of echo intensity with that of normal tissue aids in the interpretation of grey values on an image.[16]There is interaction of ultrasound with surrounding tissues and is described by the terms attenuation, reflection, scattering, refraction and diffraction. Attenuation is the decrease in amplitude and intensity of the wave as it travels through a medium. Higher frequency waves are readily absorbed and scattered. Reflection means the waves are thrown back to the transducer. The way ultrasound is reflected when it strikes an acoustic interface is by size and surface of the interface. Refraction means the change in direction of propagation. If sound has been refracted the echoes detected and displayed in the image may be coming from different depths or location that is shown in the display. Increasing the scan angle so that it is perpendicular to the interface minimizes this artifact. Diffraction of the beam spreads out with distance from the transducer .This has the effect of lessening the intensity of beam.[17]Higher the frequency of sound waves higher the image resolution but less the penetration of sound through soft tissues.

The qualitative comparison of echo intensity of normal tissue and tissues of interest help in interpretation of grey values of an image.[13]If an area in a given tissue exhibits total reflection, for example bone, which has high echo intensity, it appears as a white bright spot and is said to be hyperechoic. An area that has low echo intensity is called hypoechoic or transonic and appears as a darker image. Areas with homogenous fluids/ liquids exhibit no reflection, has no echo intensity appear very dark in examinations are called anechoic. Areas that contain different types of tissues show a dishomogeneous echo. Structures in and beyond intact bone are normally not detectable in ultrasound. But if the bone cortex is thinned or perforated, then ultrasound imaging is possible.[3,13,14]

The application of color power Doppler (CPD) flowmetry to ultrasound allows evaluation of vascularity and direction of the blood flow within the tissue of interest to be observed. The intensity of the Doppler signal appears as color spots on the gray scale image. Blood moving toward the transducer (positive Doppler shifts) are represented in red, blood moving in the opposite direction (negative Doppler shift) are represented in blue. Power Doppler is associated with color Doppler and improves sensitivity to low flow rates and can disclose the minor vessels. The use of contrast media (intravenous injections) increases the echogenicity of the blood making the color power Doppler examination more sensitive. Rapid developments of sonography such as 3D and 4D visualization permit spatial representationsof vascularity in tissues of interest in the field of medicine.[3,18]

In endodontics, ultrasound imaging is now been widely used due to its numerous advantages over other imaging modalities. The indications include the need to assess the content (solid, fluid or mixed) and vascularity of a lesion ,assessment of immediate post operative follow up of treatment or post surgery, assess vitality of the tooth,need for very low risk non ionizing imaging technique.[3]In addition the images are in a digital form and could be stored and reproduced. [3,10]A hyperechoic well contoured cavity surrounded by reinforced bony walls which are fluid filled and no evidence of vascularity is considered as a cystic lesion. Poorly defined hypoechoic area showing rich vascular supply on colour Doppler examination is granuloma.A mixed lesion is predominantly hypoechoic with focal anechoic areas,vascularity in some areas on colour power Doppler.[19]

Ultrasound in Endodontics

In 2002, Cotti et al demonstrated the potential role of ultrasound in endodontics by studying the size, content and vascularityof periapical lesions of endodontic origin in 12 patients.[13] Further studies by Cotti et al in 2003evaluated the possibility of making a differential diagnosis in lesions based on echographic study.[14]Eleven cases with periapical lesions scheduled for surgery was assessed by real time ultrasound imaging with the application of color power Doppler. A tentative differential diagnosis was made between a cyst and granuloma after the images were analyzed with an expert echographist along with an endodontist. Further histopathological evaluation of the lesions confirmed the ultrasound diagnosis in 100% of the cases.They concluded that studying the shape,echo content and vascularity of the lesion may help in the differential diagnosis between a cyst and granuloma.[14]

Gundappa et al, 2006, evaluated the efficacy of conventional radiograph, digital radiograph and ultrasound in the differential diagnosis of periapical lesions. Patients with lesions in the maxillary or mandibular teeth requiring surgery were selected. The conventional and digital radiograph were able to diagnose the existence of the periapical disease but not its nature whereas ultrasound underestimated the lesion size but was able to accurately determine the nature of the lesion in 100% of the cases.[6] In both studies by Cotti and Gundappa, the apical biopsies were not removed in-toto with the root apex, making the diagnosis of true cyst or pocket cyst impossible. The role of ultrasound to assess the true nature and type of a lesion needs to be established.[8]

In another study,Raghav et al 2010 studied 21 patients with periapical lesions. Conventional radiographs, digital radiographs were obtained by paralleling technique and were assessed by three specialist observers. This was followed by ultrasound study for size, content and vascularity of the lesions by three ultrasonographers.All the lesions were curetted to enable histological examination. The accuracy of diagnosis of periapical lesion by conventional radiograph was 47.6%, digital radiograph was 55.6% and ultrasound 95.2%. Ultrasound exhibited the highest specificity of 1.00 and highest sensitivity of 0.95.[7]

Comparision was done between conventional radiography and ultrasound with color power Doppler application in 30 patients with periapical lesions in the maxillary or mandibular anterior teeth by Goel et al,2011. Ultrasound detected cyst and granuloma significantly better than conventional radiographs. There was also a definitive correlation between the echo texture and histopathological findings in all except one case, which was attributed by the author to one of the reasons such as surgical error or histopathological processing error, or secondary infection in the lesion.The specificity for diagnosis of a cyst byultrasound and radiograph was 90.91% and 45.4% respectively; sensitivity was 100% and 78.9% respectively. The specificity to detect granuloma by ultrasound and radiographs was 100% and 78.9% respectively, the sensitivity 90.91% and 45.4% respectively.[20]

Christo et al, 2012, identified radiographically 15 patients with radiolucent lesions andsubjected them to an ultrasound study followed by histopathological evaluation. 86.7% of ultrasound diagnosis correlated with histopathological evaluation . One periapical cyst was misdiagnosed as a periapical granuloma by ultrasound because the content of the lesion showed high density resembling a solid lesion suggestive of a granuloma even though vascularity within the lesion was not detected. The other case was also a periapical cyst but was misdiagnosed as a periapical abscess because the ultrasound had revealed a mixedechogenic pattern with multiple scattered internal echo of varying densities suggestive of a periapical abscess.[22]

Parvathy et al, 2014, evaluated 20 patients with periapical lesions with ultrasound and color power Doppler. Ultrasound revealed 9 were periapical granulomas and 11 were periapical cysts and the findings correlated 100% with histopathology[23]. Similarly,Khambete et al, 2015, [19] evaluated 10 patients with lesions in anterior maxillary and mandibular teeth, to study the diagnostic efficacy of ultrasound. After radiographic assessment, an ultrasound study was performed followed by surgery to enable histopathology. Radiographs could identify the lesions, determine the size but a diagnosis could not be made with certainty. Though ultrasound underestimated the size of the lesion when compared to radiograph, the echo texture evaluation in all the 10 lesions correlated 100% with histopathological study.

Another application of ultrasound in endodontics is the evaluation of post treatment healing. In 2007,Rajendran et al followed up healing of 5 lesions managed by non-surgical endodontics through 6 months. All cases showed evidence of healing establishing the role of ultrasound as a monitoring tool for healing of periapical lesions.[24]Tikku et al, 2010selected 15 patients with lesions of endodontic origin indicated for surgery. Post surgical healing was evaluated by ultrasound with color power Doppler and conventional radiographs at 1 week and 6 months. At the end of one week post surgery, there were no significance in healing between the evaluation methods. 6 months, ultrasound,color power Doppler was able to detect healing significantly better than conventional radiography and could give information

on the nature of bone healing and vascularity. The callus was visible first in ultrasound thanin the radiographs, with a typical appearance as a hyperechoic or mixed hypoechoic- hyperechoic area.[25]In another study, Ipsita et al in 2011 selected 10 asymptomatic teeth with similar size lesions of endodontic origin. Preoperative evaluation with ultrasound and color power Doppler was made and a diagnosis was reached. Non surgical endodontics was performed and patients were followed up to monitor healing at 6weeks, 3months and 6months. Subjective feedback, radiographs, ultrasound and color power Doppler were used to assess healing trends.8 out of 10 cases showed healing as early as 6 weeks by ultrasound whereas radiographic healing was noted only at the third month. During the 3 month and 6 month follow up, both radiographs and ultrasound showed healing trends in the 8 cases except in 2 cases which failed. The study concluded that ultrasound could consistently predict healing 6 week onwards and could provide information on bone formation and vascularity.[26]

Another study included 8 patients who underwent root end surgery and were followedup using ultrasound imaging at 1 week, 1 month, 2 months, 3 months and 6 months after RES. In all cases, hypoechoic image became hyper echoic indicating gradual bone healing of the crypt. Compared to baseline, at 3 months, there were significant changes in the bony cryptsurface area and in some cases, the echographic follow up ended at 3 months because the ultrasound waves could no longer enter the bony crypt. Thus the study concluded that ultrasound imaging is a promising follow up tool and helps to understand the initial stages of bone healing and allows close healing monitoring and is radiation free.[27]

Cotti et al in 2018 assessed the possibility to detect early vascular changes in apical periodontitis using ultrasound examination with colour power Doppler and to establish a correlation between the early response of apical periodontitis to treatment and its potential healing. A total of 21 apical lesions were visualized with US-CPD before and after endodontic treatment and the results showed a decrease or a disappearance of vascular flow observed in apical periodontitis 4 weeks after root canal obturation significantly related to a healing trend of the lesions. So the study concluded the possibility to detect early vascular

change in apical periodontitis using US-CPD correlating them with a healing trend afterendodontic treatment.[21]

Min Jung et al, 2010, demonstrated another promising role of ultrasound in endodontics as a tool to determine pulp vitality. They assessed the difference in pulpal blood flow in vital teeth and root canal filled teeth in 11 patients. Significant differences in pulpal blood flow were noted. Various parameters were assessed such as maximum, average, minimum linear velocity, pulsation index and circulation resistance. The root filled teeth showed a linear non- pulsed waveform without pulsing sound, whereas, in vital teeth a pulsed waveform and pulsating sound characteristic of an arteriole was noted. The authors used a 20MHz probe which could detect blood flow as deep as 0.8 cm from tooth surface. This method is able to differentiate the origin of the signal (pulp origin or surrounding tissues) and does not need the use of a splint unlike laser Doppler flowmetry. Thus ultrasound shows promise in assessing pulp blood flow through intact enamel and dentin.[28]

Ahn et al in 2017 performed a study with 246 teeth from 78 patients to evaluate and compare the efficacy of ultrasound Doppler flowmetry (UDF) with that of electric pulp testing (EPT) in assessing pulp vitality in traumatized teeth. In control group, EPT alone was used whereas both UDF and EPT were used in UDF group. After propensity score matching, 69 teeth were included in each group. Pulp survival rates at 1 year were at 74% and 90 % in control and UDF groups respectively.In the UDF group, there was a significant difference between the UDF and EPT results at all follow up evaluations. ($p<0.001$). Thus, the study concluded that ultrasound Doppler flowmetry is more accurate than electric pulp testing in assessing pulp vitality of traumatized teeth.[29]

Ultrasound real time examination also helps to detect and trace non invasively, sinus tracts of endodontic origin. A study conducted by Cotti et al included 10 patients who had a lesion of apical periodontitis and sinus tract and 10 patients in control grop with apical periodontitis without a sinus tract. They also traced the pattern of the sinus tracts with a computer program. The data obtained were compared with the clinical and radiographic diagnosis of sinus tract. Inter observer agreement was high as there was diagnostic accuracy of ultrasound examination of sinus tracts. High sensitivity and a negative predictive value and 100% specificity and a positive predictive value were also obtained. The application of 3 dimensional mode further enabled reconstructions of more complex path and implementation with colour powered Doppler disclosed the vascularity surrounding the sinus tracts. Thus the study concluded that ultrasound examination is a technique feasible to describe and trace sinus tracts of endodontic origin.[30]

Ultrasound has also been used to investigate intraosseous lesions. Sumer, 2009,studied 20 patients with 22 intraosseous lesions both in the posterior mandible and anterior maxilla with ultrasound , colour power Doppler and compared the findings histologically. Ultrasound was able to provide accurate information on the contents of the lesions and vascularity but they concluded that was no correlation between the ultrasound findings and definitive histopathological diagnosis.[31]

Various other applications of ultrasound

Depending on the application and ultrasonic intensities it is divided into two-

1)Diagnostic ultrasound – useful in diagnosis of swellings in orofacial region, salivary glands disorders, periapical lesions, lymph nodes (benign/malignant), temporomandibular disorders, fractures of mandibular condyle, ramus and midfacial fracture, ultrasound guided core needle biopsy, submandibular gland injection of botulinum toxin for hypersalivation in cerebral palsy, basket retrieval of salivary stones.[32]

2.) Therapeutic ultrasound – for myofascial pain, temporomandibular joint dysfunction, ultrasound guided lithotripsy of salivary calculi using an electromagnetic lithotripter, bonehealing and osteointegration.[32]

Ultrasound also offers great potential in development of a noninvasive periodontal assessment tool that would offer great yield real time information, regarding clinical features such as pocket depth, attachment level, tissue thickness, histological change, calculus, bone morphology, as well as evaluation of tooth structure for fracture cracks.[33]Various studies havealso identified that tumour thickness and depth of invasion are prognostic indicators of oral cancer, especially with regional node metastasis. Ultrasound has a facility of onscreen nodal measurement and a study by Aggarwal et al shows the usefulness of grey scale ultrasound to assess suspicious nodes for metastasis and relation between the size of the node and echogenicity of the node. Thus the status of the lymph node can be successfully evaluated with ultrasound before extensive surgeries.[34]

Conclusion

Ultrasound presents an easy,reproducible, low risk,nonionizing, noninvasive, lowcost alternative imaging technique with the potential to differentiate lesions of endodontic origin, detect blood flow in vital teeth, monitoring post treatment healing. However it must be said that some limitations of sonography include the need for expertise of operator in interpreting the results. Also anatomic landmarks such as roots of teeth are not specifically visualized so attributing the lesion to a specific area requires a radiograph to orient the lesion. The ultrasound probe is cumbersome to use for endodontic purposes and the presence of thick overlying bone can decrease the diagnostic validity. In spite of the limitations, ultrasound can be seen as a safe valuable imaging technique though more research with larger samples will help establish its usefulness in the field of endodontics.

References

1. Torabinejad M, Eby WC, Naidorf IJ. Inflammatory and immunological aspects of the pathogenesis of human periapical lesions. J Endod1985;11:479–84.

2. Metzger Z, Abramovitz I. Periapical lesions of endodontic origin. In: Ingle JI, Bakland LK, Baumgartner JC, editors. Ingle's endodontics. 6th edition. Hamilton (ON): BC Decker Inc; 2008. p. 494–519.

3. Elisabetta Cotti .Advanced Techniques for Detecting Lesions in Bone . Dent Clin N Am2010;54:215-235.

4. Nair PNR, Parajola G, Schroeder HE. Types and incidence of human periapical lesions obtained with extracted teeth. Oral Surg Oral Med Oral Pathol Oral RadiolEndod1996;81:93–102.

5. Nair PN.New perspectives on radicular cysts: do they heal? IntEndod J1998;31:155-60

6. M Gundappa, SY Ng, EJ Whaites. Comparison of ultrasound, digital and conventional radiography in differentiating periapical lesions.DentomaxillofacRadiol 2006;35:326-333.

7. Raghav N,ReddySS,GiridharAG,MurthyS,YashodadeviBK,Santana N etal.Comparision of the efficacy of conventional radiography,digital radiography and ultrasound in diagnosing periapical lesions.Oralsurg Oral med Oral pathol Oral RadiolEndod 2010;110:379-85

8. Patel S, Dawood A, Whaites E, Pitt Ford T. New dimensions in endodontic imaging: part 1. Conventional and alternative radiographic systems.IntEndod J. 2009;42:447-62

9. Dula K,MiniR,VanderStelt,LambrechtJT,SchneebergerP,BuserD.Hypothetical mortality risk associated with spiral computed tomography of the maxilla and mandible.Eur J Oral Sci1996;104:503-10

10. Cotti E. and Campisi G. Advanced radiographic techniques for the detection of lesions inbone. Endod Top 2004; 7: 52–72.

11. Rasmus TF, Williamson GF. Current Oral and Maxillofacial Imaging; 2006. p. 19-20.

12. Dib LL, Curi MM, Chammas MC, Pinto DS, Torloni H, Paulo S. Ultrasonography evaluation of bone lesions of the jaw. Oral Surg Oral Med Oral Pathol Oral RadiolEndod.1996;82:351–7.

13. Cotti E, Campisi G, Garau V, Puddu G. A new technique for the study of periapical bone lesions: Ultrasound real time imaging. IntEndod J. 2002;35:148–52.

14. Cotti E, Campisi G, Ambu R, Dettori C. Ultrasound real time imaging in the differential diagnosis of periapical lesions. IntEndod J. 2003;36:556–63.

15. Palmer PE.Basics of ultrasound.In:PalmerPE,editor Manual of diagnostic (New millennium edition)NewDelhi:AITBS Publishers;2004 p 3-5

16. Stuart C White, Micheal L Pharoah. Oral Radiology-Principals and interpretation .First South Asia Edition 2014.

17. Carol M, Rumack, Stephanie R,Wilson, J.WilliamCharboneau.Diagnostic Ultrasound Vol1;edition 3rd

18. Fleischer AC1, Andreotti RF. Color Doppler sonography in obstetrics and gynecology.Expert Rev Med Devices 2005; 9:605-11.

19. Khambete N,KumarR.Ultrasound in differential diagnosis of periapical radiolucencies.A radio histopathological study J Conserv Dent 2015;18:39-43.

20. Sumit Goel, et al. Ultrasonography with color Doppler and power Doppler in the diagnosis of periapical lesions .Indian J Radiol Imaging. 2011; 21: 279–283.

21. Cotti E, Esposito SA, Meesu D, Campisi G, Shemesh H. Ultrasound examination with colour power Doppler to assess the early response of apical periodontitis to the endodontic treatment. Clin Oral Investig 2018 Jan;22(1):131-140.

22. Christo Naveen Prince, ChandrakalaShekarappa Annapurna, S. Sivaraj,and I. M. AliUltrasound imaging in the diagnosis of periapical lesions . J Pharm Bioallied Sci. 2012 ; 4:369–372.

23. Parvathy V, Kumar R, James EP, George S. Ultrasound imaging versus conventional histopathology in diagnosis of periapical lesions of endodontic origin: A comparative evaluation. Indian J Dent Res 2014;25:54-7.

24. Rajendran N,SundaresanB.Efficacy of ultrasound and color power Doppler as a monitoring tool in the healing of endodontic periapical lesions.JEndod 2007;33:181-6

25. Aseem P. Tikku, Sunil Kumar, KapilLoomba, Anil Chandra, PromilaVermaandRenuAggarwal. Use of ultrasound, color Doppler imaging and radiographyto monitor periapical healing after endodontic surgery. J of Oral Sci 2010;52: 411-416.

26. Ipsita Maity, AnithaKumari, Anil Kumar Shukla,HLUsha, and DN Naveen .Monitoring of healing by ultrasound with color power doppler after root canal treatment of maxillary anterior teeth with periapical lesions .J Conserv Dent 2011 ; 14: 252–257.

27. Curvers ZF, Meschi N, Vanhoenacker A, Strijbos O, Mierla MV, Lambrechts P. Ultrasound of bone healing after root end surgery: Echoes back to patient's safety. Journal of Endodontics 2017;44(1):33-37.

28. Min-Jung Yoon ,Euiseong Kim, Seoung-Jong Lee , Young- Min Bae, Sergey Kim, Sung- Ho Park .Pulpal Blood Flow Measurement with Ultrasound Doppler Imaging .J Endod 2010;36:419-422

29. Ahn SY, Kim D, Park SH, So-Yeon Ahn, Dohyun Kim, Sung Ho Park. Efficacy of ultrasound Doppler flowmetry in assessing pulp vitality of traumatized teeth- A propensity score matching analysis. J Endod 2018 Mar;44(3):379-3833.

30. Cotti E, Musu D, Goddi A, Dettori C, Campisi G, Shemesh H. Ultrasound examination to visualize and trace sinus tracts of endodontic origin. J Endod 2019 Oct;45(10): 1184-1191

31. Sumer AP, Danaci M, OzenSandikçi E, Sumer M, Celenk P. Ultrasonography and Doppler ultrasonography in the evaluation intraosseous lesions of the jaws.DentomaxillofacRadiol 2009; 38:23–7.

32. Shubham Sharma, Deepali Rasila, Mohit Singh, Mansha Mohan. "Ultrasound as a diagnostic boon in Dentistry-A Review". Int J Sci Stud. 2014;2(2):70-76.

33. Vivek K B, Ranjana Mohan, Rhythm Bains.Application of ultrasound in periodontics:Part II.J Indian SocPeriodontol. 2008 Sep-Dec; 12(3): 55–61.

34. Aggarwal A, Daqniel MJ, Shrinivasan SV, Sargouname CP. Greyscale ultrasonography in assessment of regional lymph nodes in oral cancer and its correlation with TNM staging and FNAC. JIAOMR 2011;23:104-107.