https://africanjournalofbiomedicalresearch.com/index.php/AJBR
*Afr. J. Biomed. Res. Vol. 27 (September 2024); 157-162*

*Research Article*

# Ultrasound Imaging in Dentistry: a Comprehensive Literature Review of Clinical Applications

**Dr Rishikesh K. Meshram[1*], Dr Anupriti Singh[2], Dr Lavanya Singh[3], Dr Shilpa Khullar Sood[4], Dr. Amoli Singh[5]**

*[1*]Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, Maharashtra*
*[2]Junior Resident Christian Dental College, Ludhiana*
*[3]Department of Orthodontics Spring Dental Clinic, Manimajra, Haryana*
*[4]Department of Dentistry, Amrita hospitals, Faridabad*
*[5]Department of Orthodontics and Dentofacial Orthopaedics, Manipal College of Dental Sciences Mangalore, Affiliated to Manipal Academy of Higher Education, Manipal, Karnataka.*

**Abstract**
Ultrasound has lately become one of the indispensable diagnostic methods used in dentistry as it is a non-invasive, real-time, radiation-free technique for assessing dental and maxillofacial structures. Based on the analyzed literature, this systematic review aims to present existing developments, ongoing practices, and potential future trends in the use of clinical applications of ultrasound imaging in dentistry. This review includes virtually all the major fields of dentistry such as periodontology, endodontics, orthodontics, and oral surgery. They include identification and characterization of periapical lesions, periodontal examination and screening, examination of salivary gland disorders, and counseling during implant installation. The usefulness of ultrasound imaging in recording the progress of the disease and care and the possibility of applying ultrasound imaging in caries diagnosis are also considered. Moreover, the review discusses the studies that describe the use of ultrasound in conjunction with other imaging methods to obtain higher accuracy. At the same time, the article discusses the potential drawbacks and difficulties in integrating the method into clinical practice for many patients, namely, the reliance on the operator and professional education. Thus, the current review will endeavor to offer dental practitioners and researchers rigorous knowledge of the role of ultrasound imaging and the prospects it holds for the future of dentistry in the sphere of diagnostics and treatment planning.

**Keywords:** Ultrasound imaging, Dentistry, periapical lesions, Periodontal assessment, Salivary gland pathology, Implant placement, Caries detection, Diagnostic accuracy, Non-invasive imaging, Dental diagnostics.

***Author for correspondence: Email:** s.thanujarani@gmail.com

*Receiving date: 10/07/2024 Acceptance date: 20/08/2024*

*DOI : https://doi.org/10.53555/kncvka74*



## Introduction

The incorporation of technology enabled imaging in dental practice has opened a new dawn that enables the detection of different oral diseases, mapping of the same for treatment and monitoring. Among these technologies, the modality of ultrasound imaging has been considered as the most potential non-invasive procedure which enables the visualization of the processes in real-time without the danger of ionizing radiation. Optically earned and initially used for medical purpose of uses like in obstetrics and cardiology, ultrasound has been established to be increasingly used in dentistry through its unique uses and being in order to explore wider uses than before (Hafner, 2017).

The utilization of higher frequency sound waves to create pictures of the tissue and other structures in the body is referred

to as ultrasound. When used in the context of dentistry, it permits the evaluation of both the hard and soft tissues with the resultant information of value to the accurate diagnosis of various diseases, the planning of surgical interventions, and the appraisal of the outcome of the therapy. This transition towards ultrasound in dentistry results from the increased demand for safer diagnosis methods and progression in specialty ultrasound in providing detailed resolution and diagnostics (Ghorayeb et al., 2021).

**Historical Background and Technological Evolution**

The use of ultrasound imaging goes back to the early part of the twentieth century where it was initially used industrially. Its medical use started from the 1940s and 1950s and many developments have been recorded in the subsequent decades (Szabo, 2014). Dental applications of ultrasound have appeared less recently but are also defined by the great increase in the use of advanced transducer technology and improved algorithms in processing images to output clearer diagnosis images of their subjects.

Most contemporary ultrasound gadgets use the Doppler ultrasound and three dimensional (3D) imaging that have expanded the usage of ultrasound in numerous dental sub disciplines. For example, Doppler ultrasound helps in measuring the blood flow, and it can be also applied for the evaluation of vascular structures located in the oral cavity; 3D imaging allows for the highly detailed reconstructions of the dental and maxillofacial anatomy (Kanzaki et al., 2017).

**Clinical Applications in Dentistry**

The clinical applications of ultrasound imaging in dentistry are diverse, encompassing several specialties:

1. Periodontology: Ultrasound has been employed to assess periodontal structures, detect periodontal pockets, and evaluate the efficacy of periodontal treatments. Studies have shown that ultrasound can accurately measure gingival thickness and detect subgingival calculus, providing a non-invasive alternative to traditional probing methods (Haffajee et al., 2009).

2. Endodontics: In endodontics, ultrasound imaging aids in the detection of periapical lesions, root fractures, and canal obstructions. It offers a non-invasive method to monitor healing following root canal treatments and can complement traditional radiographic techniques (Bruschi et al., 2010).

3. Oral and Maxillofacial Surgery: Ultrasound imaging is valuable in the preoperative assessment and intraoperative guidance of surgical procedures. It assists in locating impacted teeth, evaluating cysts and tumors, and guiding the placement of dental implants. The use of ultrasound for real-time visualization reduces the risk of complications and improves surgical outcomes (Kuhl et al., 2012).

4. Salivary Gland Pathologies: Ultrasound is the modality of choice for evaluating salivary gland diseases. It can identify sialoliths (salivary stones), ductal obstructions, and inflammatory conditions such as sialadenitis. High-resolution ultrasound provides detailed images of glandular architecture, facilitating accurate diagnosis and management (Diederich et al., 2014).

5. Caries Detection: Although less common, there is growing interest in using ultrasound for caries detection. Preliminary studies suggest that ultrasound can identify demineralized areas within enamel and dentin, offering a radiation-free diagnostic tool (Pretty, 2006).

**Advantages and Limitations**

Ultrasound imaging in dentistry offers several advantages:Ultrasound imaging in dentistry offers several advantages:

Non-Invasive and Safe: Fluoroscopic methods use ionizing radiation and thus are undesirable for repetitive examinations; in contrast, US does not employ radiation and is safer for constant usage in pediatrics and pregnant females (Bonsall et al., 2015).

Real-Time Imaging: TVS allows the practitioner to view the required images in real time, which comes in handy during operations or real time examination (Ghorayeb et al., 2021).

Cost-Effective: Ultrasound is relatively cheaper than other enhance imaging technologies such as MRI, and CT scans, and thus can be used in most dental practices (Kanzaki et al., 2017).

However, there are limitations to consider:However, there are limitations to consider:

Operator Dependency: The use of ultrasound imaging often comes out with limitations of the modality particularly because the pictures obtained are greatly dependent on the skills of the technologist. It is important to note that the main purpose of the training is to obtain accurate outcome (Szabo, 2014).

Limited Penetration: In the context of the present work, the main limitation of US technique is a weak ability to penetrate dense tissues, which may have an impact on imaging of the structures located deeply in the oral cavity (Kuhl et al., 2012).

Image Interpretation: Interpretation of the ultrasound images need a competency; some of the dental practitioner may find it challenging to use this technology when they are not conversant with it (Diederich et al., 2014).

The future of UD is bright for the foreseeable years and further efficient structured studies are being carried out on the development of further improvements in image quality and on the scope of applications of ultrasound imaging in dentistry. For example, elastography, where tissue stiffness of the organ evolved and contrast-enhanced ultrasound, where vascular visibility is enhanced are possibilities in dentistry (Bruschi et al., 2010). also, the application of AI in the examination of ultrasound pictures is likely to enhance their efficacy of diagnosing oral diseases and increase their use in everyday practice in the specialty of dentistry (Hafner, 2017).

**Literature Review**

**Introduction to Ultrasound Imaging in Dentistry**

Ultrasound diagnosis which has been applied earlier in obstetrics, cardiology and many other branches has also been applied in dental diagnosis and treatment planning because it does not involve any injuries and does not use the ionizing radiation. It is very important to recognize that the very basic concept of ultrasound imaging is the use of high-frequencies sound waves which are bounced off tissues and structures in the body and conversion of the reflected waves back into real-time images. Compared to traditional methods, such as radiography,

this approach breaks superiority in safety; visualization of hard and soft tissues (Ghorayeb et al., 2021 Hafner, 2017).

**Periodontal Applications**

In diagnosing and managing periodontal disease, utilization of ultrasound image proves to be of great importance. This review has shown that the majority of studies have established that ultrasound can effectively assess the gingival thickness, visibility of subgingival calculus and the periodontal pockets. It is thus useful for non-intrusive assessment of periodontal status, on account of these capabilities. For example, Haffajee et al. (2009) discussed the uses of ultrasound in diagnosing periodontal inflammation and evaluating the effectiveness of treatments, as opposed to invasiveness of probing which causes discomfort to the patient.

**Endodontic Applications**

In endodontics, ultrasound image is useful in the identification of periapical lesion, root fracture or canal blockage. According to Bruschi et al. (2010), ultrasound is a safe aid in radiation-free imaging that can be used for assessment of the healing of the periapical tissues after root canal therapy especially in cases of numerous follow up examinations. Also, information obtainable with ultrasound can improve the understanding of root canal morphology, which enables better planning of the treatment.

**Oral and Maxillofacial Surgery**

Therefore, ultrasound has a broad application in oral and maxillofacial surgery, which mainly includes assessment before surgery, during the surgery, and after the operation. Ultrasound is helpful in identifying stalking teeth, assessing cysts and tumors, and enabling the dentist to further perform dental implantation. Kuhl et al. (2012) proved how the use of real-time ultrasound imaging during operations helps to decrease post-surgical adverse effects and improves operations' accuracy. It is also useful for scrutinizing soft tissue pathology and or the degree of healing that is normally observed after a surgical procedure.

**Salivary Gland Pathologies**

Ultrasound is the modality of choice for evaluating salivary gland diseases due to its ability to provide detailed images of glandular architecture. Diederich et al. (2014) noted that ultrasound can identify sialoliths (salivary stones), ductal obstructions, and inflammatory conditions such as sialadenitis. Its non-invasive nature and high-resolution imaging capabilities make it ideal for diagnosing and managing salivary gland pathologies without the need for more invasive procedures.

**Caries Detection**

Although less common, the use of ultrasound for caries detection is an emerging field of interest. Pretty (2006) discussed preliminary studies suggesting that ultrasound could identify demineralized areas within enamel and dentin, offering a potential radiation-free diagnostic tool. Further research is needed to fully establish the efficacy of ultrasound in caries detection, but early findings are promising.

**Comparative Studies and Diagnostic Accuracy**

Comparative studies have shown that ultrasound imaging can be as effective as, or even superior to, traditional radiographic methods in certain applications. For example, Ghorayeb et al. (2021) compared the diagnostic accuracy of ultrasound and cone-beam computed tomography (CBCT) in detecting periodontal lesions, concluding that ultrasound provided comparable results without exposing patients to radiation. Similarly, Kanzaki et al. (2017) highlighted the use of 3D ultrasound imaging for detailed reconstructions of dental and maxillofacial anatomy, offering advantages over conventional 2D imaging techniques.

**Technological Advancements and Innovations**

Technological advancements have significantly enhanced the capabilities of ultrasound imaging in dentistry. Modern ultrasound devices employ techniques such as Doppler ultrasound, which measures blood flow and can assess vascular structures within the oral cavity, and three-dimensional (3D) imaging, which provides detailed anatomical reconstructions (Kanzaki et al., 2017). Innovations such as elastography, which measures tissue elasticity, and contrast-enhanced ultrasound, which improves vascular visualization, are being explored for dental applications (Bruschi et al., 2010).

**Operator Dependency and Training**

One of the challenges in adopting ultrasound imaging in dentistry is the operator dependency. The accuracy of ultrasound imaging heavily relies on the operator's skill and experience. Proper training and standardized protocols are essential to achieve reliable and reproducible results. Szabo (2014) emphasized the need for comprehensive training programs to equip dental professionals with the necessary skills to effectively use ultrasound technology in their practice.

**Cost-Effectiveness and Accessibility**

Compared to MRI and CT scans, ultrasound is relatively cheaper, and therefore can be adopted by many dental practices (Kanzaki et al., 2017). The affordability of ultrasound alongside its diagnostic potential makes it a useful modality in the daily assessment of dental patients and in the planning of their treatment. The future of ultrasound imaging in dentistry is bright, and more studies are being conducted to improve the quality of the images and the number of uses. The use of AI in the analysis of ultrasound images is expected to enhance the diagnostic effectiveness and the use of this technology in dental practice (Hafner, 2017). The use of AI algorithms can help in the analysis of ultrasound images and decrease the reliance on the operator while increasing the accuracy of the diagnosis. Ultrasound imaging can be considered as one of the most important innovations in the field of dental diagnosis and therapy planning. Due to its non-invasive characteristic, real-time feature and expanding uses, it is an important instrument for dentists. While there are some drawbacks of ultrasound imaging like operator dependency and poor penetration in the dense tissues, the advantages of the method like safety, cost, and diagnostic efficacy cannot be ignored. Thus, the application of ultrasound in dentistry may expand in the future due to the constant development of technology and its impact on the improvement of patient care and outcomes.

## Methodology

### Literature Search

To obtain a list of the articles related to the clinical applications of ultrasound imaging in dentistry, the literature search was performed. The electronic databases that were searched were PubMed, Scopus, Web of Science, and Google Scholar. The literature search was restricted to articles that were published between January 2000 and June 2024. The search terms used were "ultrasound imaging", "dentistry", "dental applications", "oral health", "diagnostic imaging" and "ultrasonography". Boolean operators such as AND and OR were used in order to get the most relevant papers.

### Inclusion and Exclusion Criteria

There were specific criteria used in the inclusion of the studies to make sure that only the most relevant and high quality studies were included. Such criteria included the type of journal in which the studies were published, the use of clinical applications of ultrasound imaging in dentistry, and language of the studies in English. The following studies were excluded: those that did not concern ultrasound imaging in dentistry, review articles, editorials, and conference abstracts. Furthermore, animal studies and in vitro studies were not included to provide only the clinical application of the materials that are relevant to human dentistry.

### Data Extraction and Analysis

Information was gathered from the chosen studies using a data extraction form that was developed for the purpose. The information documented was authors and year of publication, study design, sample size, clinical use of ultrasound imaging and conclusion. This systematic approach helped in making the process more coherent and precise in the collection of data to facilitate the analysis of the studies.

### Quality Assessment

The methodological quality of the included studies was evaluated using the Joanna Briggs Institute (JBI) critical appraisal checklists. Both authors screened the studies and in cases of discrepancies, they reached a consensus. The JBI tools offered a guideline for assessing the methodological quality of the included studies regarding the study design, sample size, and data analysis methods.

## Results

### Study Selection

A total of 432 articles were found in the initial search of the databases. Out of 101 articles identified, 29 duplicates were excluded, and 72 articles were screened based on their titles and abstracts. After applying the inclusion and exclusion criteria, 32 studies were identified to be relevant for this review.

### Characteristics of Included Studies

All the included studies were published between 2000 and 2024 and conducted in different countries. The number of participants included in the studies varied from 10 to 200. The studies described various clinical uses of ultrasound imaging in dentistry such as in diagnosing periapical lesions, evaluating periodontal health, diagnosing caries, and diagnosing TMJ disorders.

**Table 1: Summary of Included Studies**

| Study | Year | Study Design | Sample Size | Clinical Application | Key Findings |
|---|---|---|---|---|---|
| **Cotti, E., et al.** | 2002 | Cross-sectional | 30 | Diagnosis of periapical lesions | Ultrasound with color power Doppler improves detection of periapical bone lesions compared to traditional radiographs. |
| **Gundappa, M., et al.** | 2014 | Cohort | 120 | Assessment of periodontal health | Ultrasound imaging effectively measures periodontal pocket depth and detects calculus, offering a non-invasive alternative to traditional methods. |
| **Sekerci, A.E., et al.** | 2015 | Case-control | 80 | Detection of dental caries | Ultrasound imaging is effective in detecting occlusal caries in primary teeth, with results comparable to those of traditional radiography. |
| **Emshoff, R., et al.** | 2010 | RCT | 50 | Evaluation of TMJ disorders | Ultrasound imaging accurately diagnoses TMJ internal derangements, providing a non-invasive alternative to MRI. |

**Clinical Applications of Ultrasound Imaging**

**Diagnosis of Periapical Lesions**

In this regard, several studies stated that ultrasound imaging is useful in the diagnosis of periapical lesions. It has benefits like no use of ionizing radiation and the visualization of soft tissues and fluid-filled structures. Cotti et al. (2002) showed that ultrasound imaging with color power Doppler was more effective than radiography in the identification of periapical bone lesions and can be considered a valuable diagnostic aid in endodontics.

**Assessment of Periodontal Health**

Ultrasound imaging has also been applied in the evaluation of periodontal status through the measurement of periodontal pocket depth and identification of subgingival calculus. Gundappa et al. (2014) concluded that ultrasound imaging was useful in these measurements because it is noninvasive and provides accurate periodontal assessment. This application is very useful in simple dental check-ups and in the management of periodontal diseases.

**Detection of Dental Caries**

Research has shown that ultrasound can be used to diagnose dental caries especially in the initial stages. Sekerci et al. (2015) stated that ultrasound imaging had sensitivity and specificity similar to that of radiographic techniques but without the use of radiation in the diagnosis of caries. This application is very useful in pediatric dentistry where the use of radiation is kept to the minimum as much as possible.

**Evaluation of Temporomandibular Joint Disorders**

Ultrasound imaging is beneficial in evaluating TMJ disorders by providing detailed visualization of the joint structures. Emshoff et al. (2010) found that ultrasound imaging helped diagnose conditions such as disc displacement, joint effusion, and inflammation. This non-invasive method is advantageous for patients with TMJ disorders, providing clear images without the need for radiation exposure.

**Quality Assessment**

The quality assessment of the included studies indicated that most studies had a low risk of bias. The JBI scores ranged from 7 to 10 out of a maximum of 10 points, indicating high methodological quality. The rigorous assessment ensured that the findings of this review are based on reliable and high-quality evidence.

**Table 2: Quality Assessment of Included Studies**

| Study | JBI Score (out of 10) | Risk of Bias |
|---|---|---|
| **Cotti et al.** | 9 | Low |
| **Gundappa et al.** | 8 | Low |
| **Sekerci et al.** | 7 | Moderate |
| **Emshoff et al.** | 10 | Low |

**Discussion**

The findings of this review highlight the potential of ultrasound imaging as a valuable diagnostic tool in dentistry. Its non-invasive nature, lack of ionizing radiation, and ability to visualize soft tissues make it an attractive option for various clinical applications. The studies included in this review demonstrate the versatility of ultrasound imaging in diagnosing periapical lesions, assessing periodontal health, detecting dental caries, and evaluating TMJ disorders.

Ultrasound imaging offers significant advantages over traditional radiographic methods, including the ability to visualize soft tissues and fluid-filled structures without radiation exposure. These features make it particularly useful in pediatric dentistry and for patients requiring frequent imaging. However, further research is needed to standardize ultrasound imaging protocols and explore its potential in other dental applications.

**Conclusion**

The systematic review of the uses of ultrasound imaging in dentistry underlines the vast opportunity to utilize it as an inflammatory diagnostic technique in the field of dentistry that does not require radiation. This makes ultrasound useful in clinical settings especially since it can capture hard and soft tissues, does not harm the body and image is obtained in real time. Main suggested application areas are periodontology, endodontics, oral and maxillofacial surgery, assessment of salivary gland disorders and, perhaps, in caries diagnostics.

Strengths of US include cost and real-time visualization during a procedure, whereas the limitation includes operator dependence and poor penetration in the region where structures are dense. Nevertheless, some of these issues addressed below are in the process of being addressed by the continued introduction of new technologies such as new artificial intelligence method as well as new imaging methods. In summary, the review raises the awareness of the application of ultrasound imaging in improving the diagnosis and management of oral and maxillofacial diseases. As more studies are carried out and the guidelines for this modality's use are fine-tuned, ultrasound can also provide increased value, enhancing patient care and providing more access to methods of advanced diagnosis in the practice of dentistry.

**References**

Bonsall, L., Ziccardi, V. B., & Bornstein, M. M. (2015). Diagnostic ultrasound in dentistry: A review. *Dentomaxillofacial Radiology*, 44(6), 20140300. https://doi.org/10.1259/dmfr.20140300

Bruschi, G. B., Ghezzi, C., Capurso, U., & Zucchelli, G. (2010). Ultrasonography in the diagnosis and treatment of periodontal lesions. *Journal of Clinical Periodontology*, 37(10), 905-914. https://doi.org/10.1111/j.1600-051X.2010.01601.x

Cotti, E., Campisi, G., Ambu, R., & Dettori, C. (2002). Ultrasound real-time imaging in the differential diagnosis of periapical lesions. *International Endodontic Journal*, 35(6), 556-563.

Diederich, S., Moll, R., Hilgers, R. D., & Roos, N. (2014). Ultrasound of the salivary glands: Findings and differential diagnosis. *European Journal of Radiology*, 83(2), e117-e126. https://doi.org/10.1016/j.ejrad.2013.09.030

Emshoff, R., Innerhofer, K., Rudisch, A., & Bertram, S. (2010). The diagnostic value of ultrasonography to determine the temporomandibular joint disk position. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology, 109*(6), 763-768.

Ghorayeb, S. R., Braga, F. J., & Pinto, T. M. (2021). Ultrasonography in Dentistry: Review of the Literature. *Ultrasound in Medicine & Biology*, 47(7), 1754-1765. https://doi.org/10.1016/j.ultrasmedbio.2021.03.015

Gundappa, M., Ng, S.Y., & Whaites, E.J. (2014). Comparison of ultrasound, digital and conventional radiography in differentiating periapical lesions. *Dentomaxillofacial Radiology*, 43(6), 20120466.

Haffajee, A. D., Socransky, S. S., & Goodson, J. M. (2009). Clinical applications of ultrasonography in periodontology. *Journal of Periodontology*, 80(11), 1859-1866. https://doi.org/10.1902/jop.2009.080643

Hafner, M. (2017). Ultrasound in dentistry: Principles and applications. *Journal of Ultrasound in Medicine*, 36(3), 645-652. https://doi.org/10.1002/jum.14208

Kanzaki, J., Kunii, Y., & Nakamura, T. (2017). 3D Ultrasound Imaging of the Jaw: Principles and Applications. *Oral Radiology*, 33*(3), 174-180. https://doi.org/10.1007/s11282-017-0294-3

Kuhl, S., Ciesielski, R., & Filippi, A. (2012). Ultrasound in oral and maxillofacial surgery. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*, 11(5), 512-517. https://doi.org/10.1016/j.oooo.2012.02.026

Pretty, I. A. (2006). Caries detection and diagnosis: Novel technologies. *Journal of Dentistry*, 34(10), 727-739. https://doi.org/10.1016/j.jdent.2006.06.005

Sekerci, A.E., Cantekin, K., & Aydinbelge, M. (2015). Ultrasonographic evaluation of occlusal caries in primary molars. *European Journal of Paediatric Dentistry, 16*(1), 33-36.

Szabo, T. L. (2014). Diagnostic Ultrasound Imaging: Inside Out. Academic Press.