Medical Devices: Evidence and Research

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REVIEW

Dental Ultrasonography for Visualizing Osteoimmune Conditions and Assessing Jaw Bone Density: A Narrative Review

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Video abstract

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Abstract: Despite the widespread use of ultrasonography (US) in medical diagnostics, there is no similar US device available for visualizing jawbone density. This study is a narrative review of the possible applications of US in dentistry. This review is divided as follows: (a) Pulse–echo ultrasonography: the applications offer new perspectives for periodontal and peri-implant assessment. (b) Through-transmission alveolar US (TTAU): this technique was a novel imaging modality until 2004, when TTAU devices were last available. Quantitative US scaling made the device useful for diagnosing chronic inflammatory conditions in the jaw. (c) Ultrasound transmission velocity (UTV): in 2008, this technique was introduced in German university dental clinics to analyze the mechanical properties of the jawbone without translating the scientific findings into a practical device. (d) Trans-alveolar US device (TAU): the growing importance of "osteoimmune focal bone marrow defects" has led practitioners to develop a new TAU device. The attenuation of US was used for imaging of jawbone density. (e) Patients who benefit from TAU-guided jawbone surgery: research has shown remarkable results in specific disease cases. This review concludes that US has been undervalued as a diagnostic tool in dentistry. The new TAU-n unit offers the opportunity to change this in the future.

Keywords: ultrasonography, dentistry, jawbone density, osteonecrosis, trans-alveolar ultrasound, radiation protection

Introduction

The noninvasive use of ultrasonography (US) deserves greater attention, especially in light of the increased attention being given to the immunological sustainability of medical interventions and the growing critical awareness in environmental medicine.[1] At the same time, it is noticeable that in the vast market for medical diagnostic ultrasound (US) equipment, one specialty is completely neglected: dentistry.[2] However, the use of US in dentistry has been widely discussed in the past, and there have been many scientific studies on this subject.[3] US devices have also been developed with different techniques.[4,5] This review provides a retrospective look at the use of US in dentistry and describes the benefits for patients, as a newly developed US device enables insight into chronic inflammatory pathologies of the jawbone.

Is there any justification for a critical attitude towards the widespread use of diagnostic X-rays and thus the need for an alternative diagnostic use of US in dentistry? Despite radiation protection regulations, approximately 130 million X-ray examinations are performed in Germany every year, nearly 40% of which are performed in dentistry.[6] This means that dentistry is one of the leading sources of diagnostic X-ray exposure per patient worldwide.[6]

In Germany, the average natural radiation exposure of the population is approximately 2 mSv to 3 mSv.[6] In contrast, the radiation exposure of the population due to diagnostic X-ray and nuclear medicine examinations in 2004 was approximately "1.9 mSv per inhabitant and year", of which "0.7 mSv was already attributable to computed tomography in 2000", with a steadily increasing trend.[7,8] Regarding the medically induced collective dose, Germany is "in the upper range in a European comparison".[7,8] Due to the high number of X-ray examinations, the average effective dose per inhabitant in Germany from

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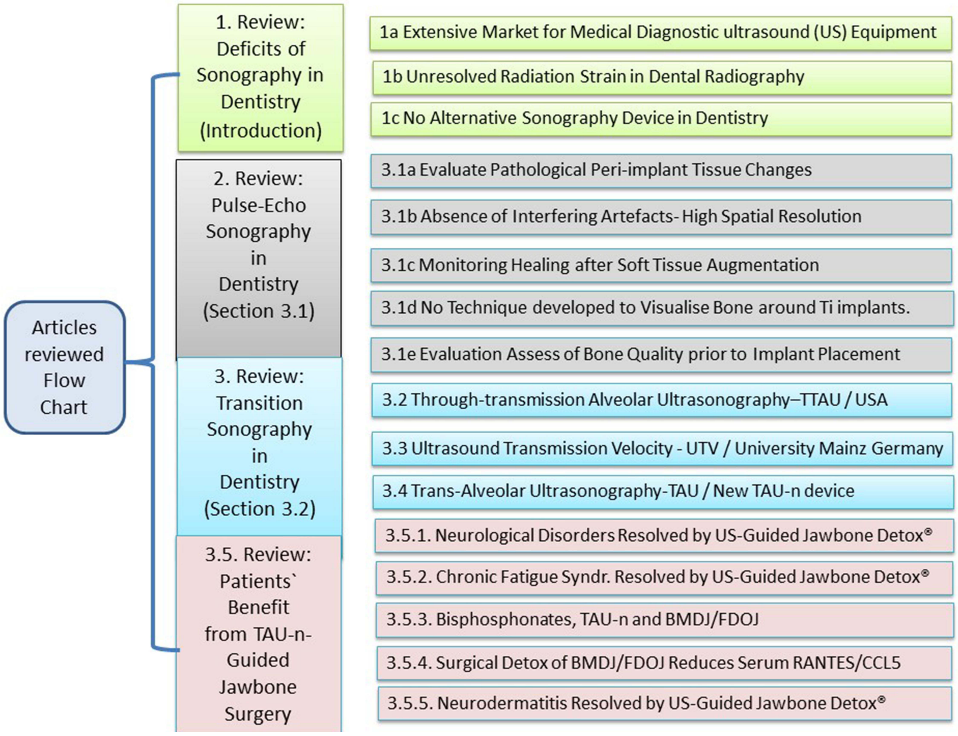
Graphical Abstract



X-ray diagnostics alone is two millisieverts per year (mSv/a); this value is four times higher than that in the USA and twice as high as that in France and Switzerland, which rank behind Germany statistically.[9–11] Although the authors` research brought up relatively high radiation dosages, dental radiation exposure is negligible in comparison to medical X-ray radiation.

There is an increased incidence of cancer in patients who underwent CT scans as children or adolescents between 1985 and 2005. According to a study published in the *British Medical Journal*, the cancer incidence is approximately 25% greater than that in people who were not exposed.[12] At risk are the red bone marrow of the facial skull and the surface of the skin, where malignant melanoma can develop. As early as 1991, the nuclear medicine specialist Dr. Horst Kuni predicted that approximately 40,000 carcinomas would be induced each year in Germany as a result of all medical X-ray diagnostics.[13] According to recent estimates by researchers at the US National Cancer Institute, more than 70 million CT scans alone led to approximately 29,000 new cases of cancer in 2007.[14] In modern dentistry after 2008 the newly developed CBCT technique was able to lower the radiation exposure and health risks in the head and neck region, compared to medical CT.

The International Commission on Radiological Protection (ICRP) has warned against using the effective dose for epidemiological studies or for estimating individual risks.[15] According to a risk assessment model, any radiation exposure in a population can lead to cancer due to the stochastic biological effects of ionizing radiation. Scientists have investigated the origin of a dose–response model and the utility of the model for global cancer risk assessment[16] which is generally used to estimate cancer risk from exposure to low-level radiation. In addition, there is some limited evidence of an increase in radiation-induced tumors in the brain and thyroid.[17] These obvious limitations of radiographic techniques necessitate the use of radiation-free US technology in dentistry in the interest of a diagnostic approach that is not harmful to patients.

Purpose

This study aimed to review the applications of ultrasonography in dentistry and to provide a description of a current generation of US devices and their possible use in this field.

Materials and Methods

Pulse–echo ultrasound is widely used in medicine for all types of tissue imaging. In principle, images of structures in the body are produced by analyzing the reflection of US waves. Since 2015, there has been growing support in the literature for the increased use of echo US in dentistry.

On the other hand, cone beam computed tomography (CBCT) has become increasingly common in dentistry over the past decade. As the only type of clinical cross-sectional imaging tool available, CBCT provides clinically accurate hard tissue imaging. However, because it relies on ionizing radiation, it should be used sparingly. According to the American Academy of Oral and Maxillofacial Radiology, routine use of CBCT for peri-implant health assessment is not recommended due to radiation accumulation.[18] Limited soft tissue contrast, increased cost and less-than-ideal image quality due to interference artefacts from metal objects are other drawbacks. As a result, CBCT is useful prior to implant placement or during the implant planning phase. However, once an implant is in place and functioning, CBCT is not as useful in identifying problems.[19] As a noninvasive, non ionizing, chairside and cross-sectional imaging modality, US offers new advantages and overcomes some of the disadvantages of other imaging modalities.[19] US imaging has been a useful adjunct to 2D radiography, CBCT and direct clinical examination over the past decade. Real-time, low-cost, non ionizing US has the potential to become another useful cross-sectional imaging modality for peri-implant tissue assessment.[20,21]

Pulse–Echo Ultrasonography in Dentistry

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An overview of the many applications of US in dentistry has been provided in a detailed review.[22] These strong findings led to the idea that future efforts should focus on transforming US from a research tool to a clinical tool. To ultimately improve the standard of patient care, a concerted effort is needed to integrate ultrasonography into dental education and the dental community. The proposed applications offer new perspectives on how to differentiate between different disease subtypes and create effective treatment plans.

1. An evidence-based diagnostic system for peri-implant disease is being developed based on the potential of US to evaluate pathological peri-implant tissue changes at a preclinical level.[23] The evidence observed in these studies suggests that US transducers may be used in the future for periodontal and peri-implant assessment in humans.[24]

2. The major advantage of US is the absence of interfering artefacts in the presence of metals, eg, implants and abutments, and the ability to provide high spatial resolution and image contrast.[25] To date, no technique has been developed to visualize and verify whether bone or soft tissue is actually present around Ti implants.[26]
3. Recent studies have shown that US is a reliable and reproducible method for monitoring healing after soft tissue augmentation around implants for a period of up to one year.[27,28]
4. To promote uneventful healing, flap mobilization is followed by biomaterial placement and an attempt at primary wound closure. According to the available data, achieving early wound stability is essential for a favorable outcome.[29–31]
5. Preimplant evaluation studies can also assess bone quality before implant placement to predict treatment outcomes.[32]
6. Evaluation of intra bony lesions in the jaw.[33]
7. Studies have reported the high sensitivity and specificity of US in the diagnosis of periapical cysts and granulomas.[34,35]
8. US has been used in numerous preclinical and in vitro studies to measure the buccal bone around implants, peri-implant tissue dimensions, bone–implant interfaces and bone quality.[36,37]
9. The American Institute of the US in Medicine (AIUM), among others, continues to evaluate the safety of US. For example, the AIUM Bioeffects Committee issues statements on the appropriate and safe use of US.[38]

Despite the wide range of potential applications in the diagnosis and imaging of dental disease, no device that can establish echo sonography in widespread daily dental practice has yet been commercialized.

Through-Transmission Alveolar US—TTAU

Since 2000, through-transmission alveolar ultrasonography (TTAU) has been a novel imaging modality in dentistry that has been developed and extensively clinically tested. In February 2002, a through-transmission alveolar ultrasonic device (Cavitat 4000, Cavitat Medical Technologies, Inc., Aurora, CO) was approved by the US Food and Drug Administration and Health Canada for the detection of low bone density and bone desiccation, both of which are features of BMDJ and chronic ischemic bone disease [34]. According to the manufacturer of CaviTAT®, this device can only be used in conjunction with other methods to detect jaw abnormalities. Accompanying 3D X-ray diagnostics, if possible, was a prerequisite for converting the results of the bone density measurements into a medical diagnosis. The sale or use of this device as the sole method of examination was considered an unapproved use under the terms of the FDA approval. These restrictions are also included in the US Food and Drug Administration, Center for Devices and Radiology Health approval: Cavitat US Bone Densitometer ("Cavitat"); 510(k) No. KO11147; Rockville, MD: FDA: 15 February 2002. Nevertheless, TTAU is a safe and useful imaging modality that can be used both for the clinical evaluation of alveolar cancellous bone pathologies related to ischemia and low bone density and for research.[39] The importance of early detection and treatment of oral cancellous bone pathologies associated with low bone density (LBD), such as regional ischemic osteoporosis, chronic nonsuppurative osteomyelitis, bone marrow oedema and cavitational ischemic osteonecrosis (osteocavitation), has been highlighted.[39] With the increase in the use of TTAU in the USA and Canada, the impact of osteoporosis on maxillofacial bone has become increasingly recognized. It has been suggested that there should be an increased focus on skeletal health, particularly in individuals with chronic immune conditions known to be associated with inflammatory pathology in the jawbone.[40–42]

TTAU for the Diagnosis of Bone Marrow Defects

As the medullary pathologies in the jawbone described above are—usually—not visible on X-rays, the US device "CAVITAT®" was developed in the USA in 2000 to diagnose these pathologies reliably. According to Bouquot et al[43] imaging techniques typically yield false-negative results for ischemic osteonecrosis. After a pilot study confirmed the diagnostic potential of the Cavitat® device,[40] the procedure was validated by comparing radiographs and TAU images of 170 jaw sites in 72 patients with a microscopically confirmed diagnosis.[41,42] Cavitat® is a unique device that uses US to visualize the bone density of the maxilla and mandible in 2 or 3 dimensions. It very quickly provides a multicolored graph of bone density, which is important for the detection of chronic fatty degenerative osteonecrosis of the jaw (FDOJ).

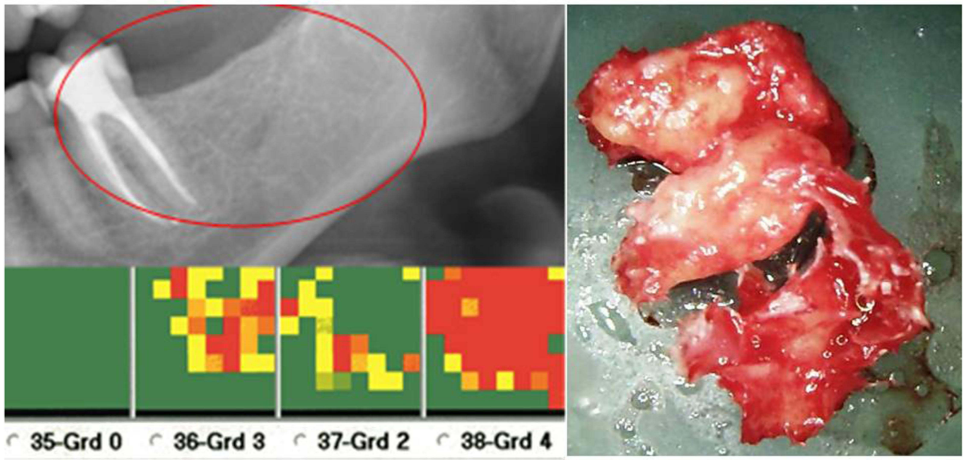

Figure 1 Left window: areas of osteonecrosis on TAU-n measurement depicted in green (healthy) and red (inflamed medullary space), with normal radiographs. "Grd-0 to Grd-4" display the grading of the US attenuation by fatty degenerative tissue inside the bone marrow. 35 to 38 describes the alveolar areas of US transmission in the left lower jawbone (European scaling). Red circle describes the inflamed alveolar area and corresponds to the TAU-n scaling. Right window: example of characteristic osteonecrosis in the jawbone, also known in the literature as a bone marrow defect in the jawbone (BMDJ/FDOJ). Adapted from Lechner J, Von Baehr V. Silent inflammation in the jaw and neurological dysregulation – case study linking RANTES/CCL5 overexpression in jawbone with chemokine receptors in the central nervous system. *J Dent Oral Health*. 2017;3:68. Creative Commons.[45]

Although the Cavitat device has been at the centre of discussions about bone marrow defects and bone marrow oedema in the jaw, it has also been used to determine bone strength for implantation.[41,42]

TTAU and Quantitative US Scaling

Low bone density and ischemic bone marrow are major causes of implant failure and facial pain, yet they are among the most difficult conditions to diagnose before surgery. A completely new diagnostic imaging technique, quantitative US (QUS), appears to be able to identify such problems because the abnormal tissue interferes with optimal sound transmission through the bone. To correlate QUS scans with medullary histopathology in many patients and to determine the proportion of false positives of 3,522 alveolar sites scanned, 339 sites in 125 patients were biopsied after QUS scanning. The diagnoses were categorized into 5 broad disease types, which were then correlated with graded (4-point grading scale; Grade I to IV) QUS images of the biopsied sites. Osteoporotic and ischemic bone accounted for 61% of all microscopic diagnoses, and 79% of suspicious sites had high-grade QUS images, ie, Grade III or IV. The mean grade for these two types of disease was 3.5 (median: 4) compared with Grade 1.8 for normal bone (see Figure 1). The rate of false-positive QUS scans was approximately 2%. The researchers concluded that QUS imaging appears to be an excellent adjunctive tool for identifying ischemic and osteonecrotic alveolar bone, although only images graded as Grade III or IV are recommended for surgical exploration. However, the QUS test is sensitive to the technique used, and errors in technique could lead to false-positive results.[41,44]

Cavitat is a modern computerized US diagnostic device. It has regulatory approval from the FDA as a safe and harmless method for the diagnosis of ostitic interference field (NICO—neuralgia-inducing cavity-forming osteolysis). Cavitat US examination of the jaw reveals chronic inflammatory pathologies in the jawbone. With Cavitat®, ischemic sites (= prestige of chronic osteitis of the jaw), osteonecrotic areas (= dead and fatty degenerated jawbone) and cavities in the jawbone (= cavitations) can be visualized by using colours.[46] The color code is simply green for cavities and healthy jawbone and red for osteonecrotic areas. Orange and yellow are used for low-grade inflammation or anatomical structures such as the infra-alveolar nerve (Figure 1). The dark-red area corresponds to the characteristic bone marrow defect (BMDJ), referred to as "NICO" in these publications.

Further research revealed that 476 of the 500 medullary lesions (95.2%) were directly attributed to impaired blood flow in the jawbone, tooth or both, according to histopathological analysis and confirmatory Cavitat bone scans.[47] In another study, 100 biopsies were histologically examined and diagnosed as fatty osteonecrotic medullary degeneration based on consistent histological features. Until the introduction of TTAU by QUS, the only diagnostic criteria were radiographic evaluation and biopsy.[44] Due to various ambiguities in daily use and disputes with large insurance companies in the USA, the production and distribution of Cavitat was discontinued in 2010. A practical successor was neither planned nor in sight. Thus, for the time being, the use of TTAU-oral US is discontinued in dentistry.

Ultrasound Transmission Velocity—UTV

Because US is almost entirely reflected from the hard cortical bone of the jaw, the currently used impulse–echo US examination is not suitable for providing relevant and reliable information about the jawbone. Nevertheless, a reliable method for the preoperative assessment of bone quality is desirable because the mechanical properties of the bone at the implant site are critical to the overall long-term success of the procedure and therapeutic regimens.

As a result of these considerations, scientific tests on extraoral bone samples were carried out at the University Dental Clinic in Mainz, Germany, starting in 2008. Subsequently, the noninvasive technique of ultrasound transmission velocity (UTV) was introduced to analyze the mechanical properties of bone.[48] The in vivo measurement of US velocity in human cortical bone has been shown by researchers to be a rapid, reliable and noninvasive method for analyzing the mechanical properties of bone.[48] Cortical bone samples showed the highest values, followed by mixed bone samples and cancellous bone samples, with the latter showing the lowest values.[49]

In ex vivo mouse models, UTV measurements have been shown to be a reliable method for identifying critical bone quality prior to implantation. Measurement of ultrasound transmission velocity (UTV) has been shown to be a reliable and noninvasive technique for assessing the mechanical properties of bone.[49]

UTV Evaluation of Jawbone Quality in Research

Preoperative assessment of bone quality is critical to the long-term success of treatment in dental implantology. (a) Implant failure is more likely when implants are placed in areas where there is a significant amount of cancellous bone that is not well mineralized. (b) Assessment of the alveolar ridge UTV allows one to identify critical bone quality before implantation or to monitor bone healing (mineralization) after augmentation procedures.[50]

UTV measurement has been shown to be a reliable and noninvasive technique for assessing the mechanical properties of bone. For example, guided US waves have been used to detect ischemic bone marrow disease, ie, focal osteoporotic defects or bone marrow defects in the jawbone.[51]

Although the use of a small UTV device in this study, following intensive research by the German University Clinic in Mainz, made it possible for the first time to record intraoral UTV values in a large and heterogeneous group of patients, it was not possible to develop a UTV device suitable for intraoral use based on the researchers' extraoral measurements. The scientific evidence for UTV and the researchers' diagnostic ideas were never translated into practice or into the construction of a suitable device. Further research was discontinued in 2012.[49]

New Transalveolar US Device: TAU-n

The general shift from acute to chronic immune diseases has re-emphasised the importance of "focal osteoporotic bone marrow defects" in the jaw (bone marrow defects in the jawbone—BMDJ). These bone pathologies have been the subject of ongoing scientific presentations and discussions.[51,52] Previous and existing research and experience with TTAU and UTV have led to the question of whether a newly developed transalveolar US (TAU) device can locate and detect BMDJ. In a new step starting in 2014, a development team of dentists and engineers in Munich, Germany, repeatedly evaluated the use of trans-alveolar ultrasonography with a new TAU device (TAU-n).[52] However, the intraoral equipment used in guided US must be minimized, as the area cannot be examined with conventional echo US equipment. Therefore, US has been of limited use in dentistry, although it has been used to detect "focal" bone defects in the jawbone ("focal osteoporotic marrow defects"), as described in previous scientific research.[53,54] The status of cancellous bone in the jaw can be of great clinical importance. Researchers have provided anatomical evidence that cancellous bone can be significantly degenerated, a phenomenon described as "ischemic osteonecrosis leading to cavitational lesions".[55]

Current Chairside Availability of TAU-n in Dentistry

A newly developed US TAU-n device (CaviTAU®) has been available on the medical device market since 2020 (www.cavitau.de). It is able to detect and locate the previously discussed BMDJ/FDOJ caused by the fatty degenerative dissolution of the medullary trabecular structures in the jawbone. As other studies have confirmed,[13,14] US is a cost-effective and efficient method for assessing jawbone health, and this finding has been replicated with the new TAU-n device. TAU-n provides a reliable indicator of poor bone quality and is a useful tool for treatment planning strategies in implant dentistry, as well as promoting collaboration between professionals in the assessment or management of osteoimmunological diseases and the association of such diseases with the immune system. TAU-n represents a novel imaging modality in dentistry and has the potential to noninvasively assess all types of "silent inflammation", such as the following:

1. Occult BMDJ/FDOJ areas in the human jawbone;
2. Reduced bone-to-implant contact due to lack of and neglect of preoperative assessments of bone structures for adequate bone health;
3. Bone density measurement of artificial bone grafts;
4. Postoperative monitoring of proper bone healing and restoration of noninflammatory jawbone health.

TAU-n is classified as a medical device under the Medical Device Directive 93/42/EEC and has been clinically evaluated in accordance with MEDDEV 2.7/1 Rev.4. CaviTAU® is a Class I medical device, but it cannot be used in isolation or alone and is therefore only an aid to medical diagnosis. EU medical approval: DIMDI VZ BS 914/2020-R. TAU-n is protected by international patents: Europe EP 3720382 (18826523.5); USA PCT/EP2018/084199; 5.3.3. China IF519453; Japan 7227981. For validation of TAU-n, scientifically based evidence has been provided in two PubMed searches of the ultrasound-related literature[47,51] and in a book: *Visualisation of Cavitational Osteonecrosis in the Jawbone with Sonography: Radiation-free imaging for Maxillo-mandibular Osteoimmunology* (ISBN 978-3-931351-43-4).

US-Guided Bone Density Imaging with TAU-n

The attenuation of the US wave amplitude is an indication of pathological changes in the jawbone and depends on the properties of the medium through which the wave propagates.[56] The appropriate values are based on published data by Wells[57] and Njeh et al[58]. TAU-n generates a US wave that passes through the jawbone. This wave is generated by an extraoral transmitter and then detected and measured by an intraoral receiver. Both parts (ie, the transmitter and receiver) are fixed in a parallel position with a single handpiece (Figure 2). The size of the TAU-n receiver is designed to allow it to be easily placed in the patient's mouth.[59] The TAU device uses 91 piezoelectric elements arranged in a hexagonal pattern. The jawbone area of interest must be positioned between the two parts of the unit. For the parts of the unit that are to be placed in the patient's mouth, acoustic coupling between these parts and the alveolar ridge is achieved by means

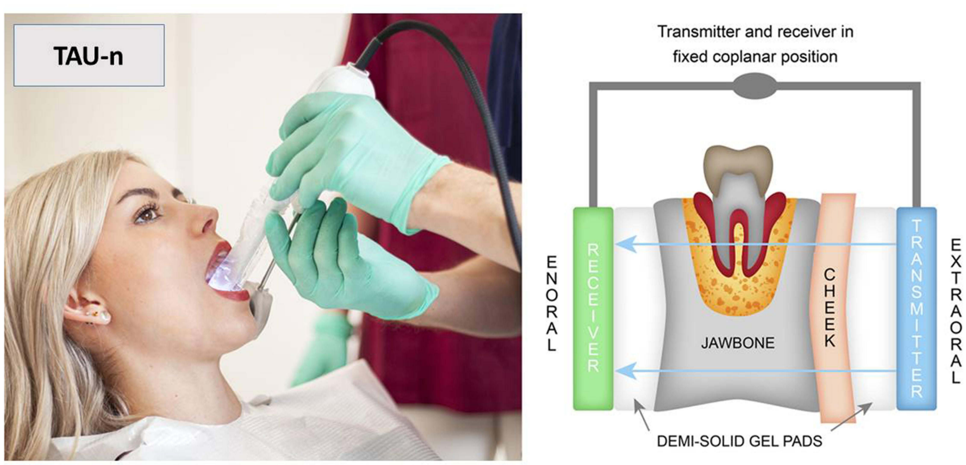

Figure 2 Left window: The TAU-n transmitter and receiver are fixed in a parallel coplanar position with a single handpiece. The size of the TAU-n receiver is such that it can be easily placed in the patient's mouth. The jawbone must be positioned between the two parts of the unit, sender outside and receiver inside the oral cavity. Right window: Acoustic coupling between the extraoral US transmitter and the intraoral US receiver is optimized and personalized with special demi-solid US gel pads for the parts of the unit to be placed inside and outside of the patient's mouth. Adapted from Lechner J, Zimmermann B, Schmidt M. Focal bone-marrow defects in the jawbone determined by ultrasonography-validation of new trans-alveolar ultrasound technique for measuring jawbone density in 210 participants. Ultrasound Med Biol. 2021;47:3135–3146. https://creativecommons.org/licenses/by-nc-nd/4.0/.[59]

of a semisolid gel.[59] The contact between the jawbone and both the extraoral US emitter and the intraoral US receiver (Figure 2) is optimized and customized by using a specially developed US gel cushion. For hygienic reasons, a semisolid disposable gel pad is used around the receiver.

TAU-n Displays a Color Scale Associated with the TAU-n Attenuation Coefficients

The TAU-n display is capable of capturing the following physical structures in the dentoalveolar region with corresponding color variations of 91 color columns per cm2: (a) solid bone in the marginal cortical area (green or white/light blue); (b) healthy cancellous bone (green or white/light blue); (c) chronically inflammatory cancellous bone with fatty degenerative components (red or black/dark blue); (d) fatty nerve structures (yellow/light blue); and (e) extremely dense and complex structures such as teeth, implants and crowns (green or white/light blue) (Figure 3).[59] The results are displayed on a color monitor that shows different colors depending on the level of attenuation. Figure 3 shows the color scheme associated with the TAU-n attenuation coefficients. This scheme corresponds to a color scale indicating the different degrees of bone density (upper bar). This color scale shows that the colors used to indicate different densities each represent a small part of the total signal range.[59]

Numerical Evaluation of Local Attenuation Coefficients in TAU-n

While radiography provides an algorithm for the conversion of grey levels (Hounsfield units—HUs),[56] the TAU-n device provides an exact numerical value of the attenuation coefficients of the TAU-n measurement area in a separate numerical evaluation, the so-called CT unit (CT). By clicking on 1 of the 91 sensor fields of a given measurement, the software marks the field and displays the measured value in a logarithmic evaluation.[59] Sensor patches with the highest attenuation values defined by TAU-n are marked in either red or black, indicating the bone density of an area of the BMDJ. TAU-n calculates the logarithmic average of the sum of the sensor elements with the lowest density unit as “Average(log)”, shown in red (Figure 4, left panel). Similarly, the logarithmic average of the sensor elements with the highest density, corresponding to reduced attenuation by solid structures, is shown in green (Figure 4, right panel).[59]

Patients Benefit from TAU-n-Guided Jawbone Surgery

In several studies, researchers have reported how “silent inflammation”, a chronic stage that develops after wisdom tooth surgery with etiologies ranging from acute local inflammation to hidden chronic oral risk factors such as FDOJ,

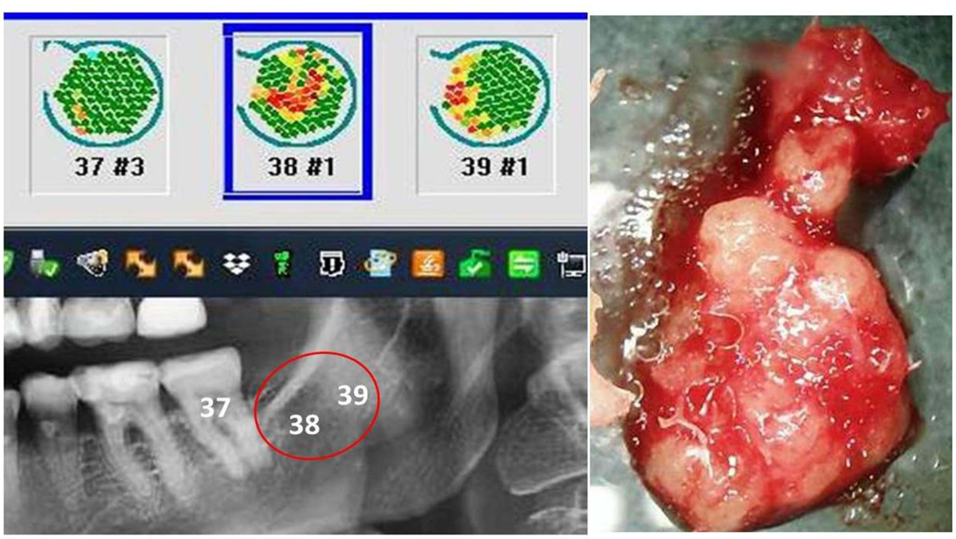

Figure 3 Left window, top bar: TAU-n displays the results in images with different colors depending on the degree of attenuation (green is high bone density, ie, healthy jawbone, and red is low bone density, ie, bone marrow oedema). Left window, lower part: OPG of corresponding areas 37 to 39 (European scaling). Red circle displays the bone marrow defect in the jawbone (BMDJ/FDOJ) corresponding to the TAU-n pictures at the top bar. In area 38 (EU scaling) the blue rectangle indicates specific area of TAU-n imaging. Note: Area 39 shows the edentulous retromolar jawbone. Right window: example of characteristic osteonecrosis in the jawbone, also referred to in the literature as a bone marrow defect in the jawbone (BMDJ/FDOJ).[45]

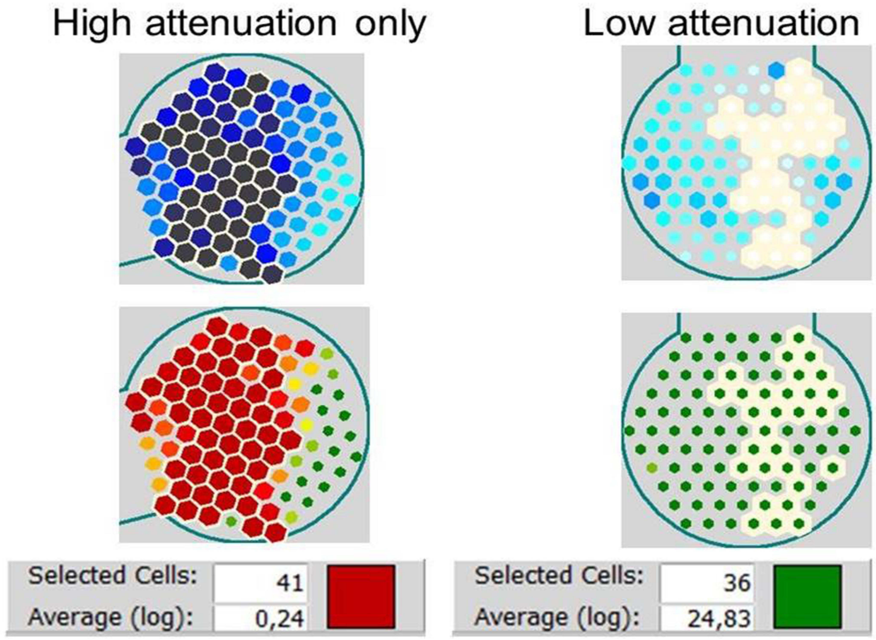

Figure 4 The CTU was measured by logarithmically averaging the sensor array values with the TAU instrument. Note: Numerical representation of TAU attenuation coefficients for reduced bone density (left panel) and dense material (right panel). Selected sensor cells (left panel: high attenuation; right panel: low attenuation) are indicated by a white outline. The evaluation is presented in the lower window for several selected sensor cells; the result is presented as a logarithmic mean value associated with a corresponding colour (ie, left panel: red corresponds to high attenuation; right panel: green corresponds to low attenuation). The TAU software allows the mean value to be calculated over a freely selected range of the 91 piezoelectric sensors. Reprinted from *Ultrasound Med Biol*, volume 47, Lechner J, Zimmermann B, Schmidt M. Focal bone-marrow defects in the jawbone determined by ultrasonography-validation of new trans-alveolar ultrasound technique for measuring jawbone density in 210 participants. 3135–3146, Copyright 2021. Creative Commons CC-BY-NC-ND.[59]

BMDJ and AIOJ, may be a neglected cause of unexplained medical conditions.[60] The term Jawbone Detox® is often used as a collective term for a local surgical procedure and for the removal of silent inflammation in the BMDJ/FDOJ jaw areas.

Neurological Disorders Resolved by US-Guided Jawbone Detox

This study discusses a unique case of recurrent syncope in a 19-year-old woman whose condition had not improved after a year of treatment in several clinics and the use of a variety of prescribed medications.[61] By eliminating local sources of R/C, staged surgical removal of FDOJ areas containing osteonecrotic medullary cavities that had not fully healed resulted in permanent cessation of her syncope episodes.[62] Two-dimensional radiography alone was not sufficient to make a valid diagnosis of FDOJ by exclusion.[63] First, in contrast to 2D-OPG, the TAU image was able to immediately show the pathogenic FDOJ in the wisdom tooth areas. TAU is useful in the diagnosis of FDOJ. Osteonecrotic and ischemic areas of the medullary alveolar bone can be targeted for detection and treatment with diagnosis via TAU.[40] In contrast to the unremarkable radiographs, there were large areas of softened and necrotic cancellous bone in the FDOJ region that were completely asymptomatic to the patient. Thus, the development of TAU for bone density imaging is a major advance in this controversial area.[63]

Chronic Fatigue Syndrome Resolved with US-Guided Jawbone Detox®

A clinical case report is presented to demonstrate the added value of US in the diagnosis of osteolysis and osteonecrosis (bone marrow defects) of the jaw.[64,65] A young man with chronic fatigue syndrome (CFS) presented with typical vague symptoms along with headaches and tinnitus. X-ray imaging techniques such as panoramic radiography (OPG) and cone beam computed tomography (DVT/CBCT) did not provide significant results regarding bone marrow defects (BMDJs) in the jaw.[65] However, a possible bone marrow defect in the left lower jawbone was demonstrated by measuring the bone density with trans-alveolar US (TAU).[66] The surgical site was conspicuous, as a black spot was visible there in addition to the softened, ischemic, fatty tissue. Surprisingly, histopathological examination of this area revealed aspergillosis.

Furthermore, the increased local RANTES/CCL5 expression in the affected region confirmed the need for surgical debridement and further TAU findings.[67] Complementary TAU imaging of the BMDJ demonstrated fungal colonization and chronic inflammatory signaling via the RANTES/CCL5 pathways, in contrast to radiography.[68] This case study demonstrates the value of additional diagnostic modalities beyond radiography to better understand how systemic disease manifests in bone.[69]

Bisphosphonates, TAU-n and BMDJ/FDOJ

Local effects of BP therapy are observed in the dentoalveolar region. As this condition affects only a small percentage of patients receiving intravenous BPs, this study[70] answers the following question: does defective bone remodeling—found in FDOJ and bone BMDJ—pose a risk for the development of bisphosphonate-related osteonecrosis of the jaw (BRONJ)?[71] An analysis of unexposed patients with BRONJ is provided in a case report. Prevention of BRONJ is of paramount importance and has been repeatedly emphasised.[72] Therefore, BPs should not be considered the sole cause of osteonecrosis. The results of this study suggest that unresolved areas of wound healing at extraction sites, especially around former wisdom teeth, may directly contribute to the pathogenesis of BRONJ. The study's conclusion recommends that patients should be screened for occult oral risk factors such as FDOJ and BMDJ. Therefore, the TAU-n can be used to measure bone density and fill this gap.

Surgical Debridement of BMDJ/FDOJ Reduces Serum RANTES/CCL5—Solved by US-Guided Jawbone Detox®

In a retrospective study, a clinical group of practitioners investigated whether BMDJ therapy reduced serum RANTES/CCL5 levels in BMDJ patients in a real-world setting.[73] Of the 113 BMDJ patients, 57 were untreated, 25 underwent BMDJ surgery, 20 underwent tooth extraction, and 11 underwent root canal therapy. Although there is a lack of systematic data, it has been suggested that a BMDJ may interfere with the immune system and cause chronic inflammation, which may lead to numerous chronic diseases.[74] Imaging techniques such as computed tomography, digital volume tomography or trans-alveolar ultrasonography (TAU) have been used to confirm the diagnosis of BMDJ.

Neurodermatitis Resolved by US-Guided Jawbone Detox®

A case report by Schick et al[75] highlights the importance of ultrasonographic measurements and immunological and toxicological diagnostics in addition to standard radiographic imaging techniques for the diagnosis of latent oral and maxillofacial infections. Do long-term toxic and inflammatory stressors from the oral region have an impact on a female patient's dermatological symptoms related to her skin? Oral surgery was used to rehabilitate a 52-year-old female patient with neurodermatitis who had been resistant to treatment for several years. After the healing period,[76] postoperative TAU control was performed to document the absence of inflammation in the jawbone.

Conclusions and Future Directions

This review provides a new perspective on the use of ultrasonography as a diagnostic tool in dentistry, which has been in development for decades and has been underestimated by the dental community due to the lack of availability of adequate commercial equipment. Thus, TAU-n offers a nonharmful alternative to the use of X-rays, which has received increasing criticism,[77,78] particularly in light of stricter protective legislation regarding radiation.[79,80] A newly developed US device, launched in 2020, offers dentists the benefits of US technology, with the future prospect of radiation-free assessment of osteoimmunological abnormalities in the jawbone.[81] For the reader`s information on commercial availability of an effective ultrasonography device specifically designed for dental applications and tailored for dental diagnostics the authors recommend the website www.cavitau.de. Further scientific and practical research is needed to establish a new objective US device in dentistry.

Institutional Review Board Statement

Ethical review and approval were waived for this review because it was a retrospective report that did not impact patient management.

Data Sharing Statement

The authors declare that all relevant data supporting the findings of this review are included in this article. For further requests, the corresponding author should be contacted.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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