Review Article

DOI: 10.7860/JCDR/2016/18584.8190

Dentistry Section

Ultrasound: A Revenant Therapeutic Modality in Dentistry

SUNIL KUMAR KARUMURI[1], TRISHA RASTOGI[2], KARTHEEKI BEERAKA[3], MOHAN RAJU PENUMATCHA[4], SANJEEVA RAO OLEPU[5]

ABSTRACT

An ultrasound (US) gives a visible image of the organs that are present inside the body. In medicine it serves for diagnosing and also its therapeutic benefits are well established for bone healing, osteointegration and soft tissue healing. In dentistry it is widely used for diagnostic purposes. When it was discovered it was introduced for therapeutic purposes, but due to lack of clinical studies its use as therapy was remittent in dentistry. The aim of the present paper was to establish the efficiency of therapeutic US in maxillofacial region for alleviating the pain and to see the other applications. Our search included the English terms like ultrasonography, applications, dentistry in Google search engine, PubMed and Medline from 1980 to 2015. We found very few articles showing the effects of therapeutic Ultrasound (US) in treatment of pain and healing in dentistry. We concluded that clinical benefits of in vivo studies were very little and demands further rigorous research to strive for the therapeutic success of US.

Keywords: Applications, Physical therapy, Ultrasonography

INTRODUCTION

Ultrasound (US) as imaging and diagnostic purposes is well known in both medical and dental fields. It is considered as a form of "real time" imaging. US is an oscillating sound with a frequency greater than the range that humans can hear. Therapeutic US has been widely used in medical field for surgical intervention, in healing of fractures, urological application, osteointegration, cancer therapy, healing of full thickness excised skin lesions and soft tissue injury. The utility of therapeutic US in dentistry is still in its infancy. Dentistry uses therapeutic US in treating myofacial pain dysfunction syndrome, temporomandibular joint disorder, craniofacial fractures, silolitotripsy of salivary calculi, descaling of teeth, amalgam packing, root canal procedures, cleaning of dentures and gingival regeneration. The US therapies, accelerates healing, provides pain relief, improve mobility, decreases muscle spasm and increases the extendibility of collagen fibers [1]. The authors aimed to highlight the various therapeutic effects of US applicable in dentistry.

METHODOLOGY

A wide search was done for the international literature using Pubmed, Google, Medline using the English words; therapeutic US, applications, dentistry from 1980 to 2015. The search included the articles written in English, published research done in both in vivo and in vitro, recent literature from textbooks consisting of applications on therapeutic US. We found very less articles on therapeutic benefits of US using insonation for treating the patients with pain and soft tissue injury. The search mainly focused on the literature of therapeutic applications of US in reducing myofacial pain, TMJ disorders, oral cancer, healing of wounds and soft tissue injuries, effects on maxillo facial bones and in other branches of dentistry alone or in addition with other treatment options. All other literature that did not obey the inclusion criteria was excluded from writing this narrative review.

Biophysical Effects of Ultrasound

Biophysical effects of ultrasound are traditionally categorized into thermal (that is, continuous wave exposure) and non-thermal (that is, pulsed exposure) effects [2].

- Non-thermal effects: cavitation and its effects [3].
- Thermal effects: mainly due to heating.

Other effects seen are increased metabolic activity, increased blood flow, pro-inflammatory response, increased collagen extensibility [4].

Non-thermal effects

Ter Haar classified nonthermal effects as [5]

► Cavitation.

► Acoustic microstreaming.

Sir John Thornycroft first used the term "cavitation" in the early 20th century and defined it as "the formation of tiny gas bubbles in the tissues as the result of ultrasound vibration" [6]. It causes pressure changes in tissue fluid, which rises flow in surrounding tissue.

Stable (regular) cavitation is helpful to damaged tissue and unstable (transient) cavitation causes tissue damage and is suppressed by use of very short pulse.

Acoustic microstreaming, an effect of insonation which is defined as "localized liquid flow in the fluid around the vibrating bubble" [7]. Adjacent to oscillating source it forms a circular current flow in tissue fluid, which can alter membrane permeability and stimulates cell activity in the cell membrane.

In vitro effects of cavitation and acoustic microstreaming are: stimulates fibroblast activity, increases protein synthesis, increases blood flow, mast cell degranulation, tissue regeneration and bone healing [2,5,7].

Thermal effects

Insonation increases tissue temperature and this depends on a variable factors like intensity of US used and time period of therapy. The pulsed US produces less tissue heating which is in contrast with continuous US. This reduction in tissue heating is proportional to on: off pulse ratio [3].

Thermal effects of US therapy are purely based only on qualitative evidence. These thermal effects are not accompanied by temperature distributions and dosimetry. The therapeutic response to heat (thermal) was influenced by rate, rise, time and maximum amount of temperature achieved and volume of tissue heated [8].

The benefits of thermal effects include an increase in extensibility of collagenous structures such as tendons and scar tissue, a decrease in joint stiffness, pain relief, changes in blood flow, decrease in muscle spasm and at high intensities, selective tissue ablation as achieved in focused US surgery [9].

When tissue temperature is 40-45ºC for at least 5 min thermal effects are seen.

Characteristics of US: The Arndt-Schulz law proposes that biophysical response will be increased by weak stimuli where as strong stimulus decreases or abolishes the response [10]. The following are the different conditions and intensities used in head and neck US therapy [Table/Fig-1].

Condition	Intensity
Initiation of therapy	0.1-0.6 W/cm²
Lesion in acute state	0.1-0.3 W/cm²
Lesion in chronic state	0.3-0.8 W/cm²

[Table/Fig-1]: Intensities used in ultrasound therapy.

The tissue in chronic state is less sensitive and hence greater intensity of US therapy is required to initiate biophysical response [11].

The time for therapy should be limited to 3-15 minutes and is discontinued if there is any discomfort [11].

Low absorption of US waves is seen in tissues that are high in water content (e.g., fat), whereas absorption is higher in tissues rich in protein (e.g., skeletal muscle) [12].

Therapeutic Applications of US: It can be used as a therapeutic aid in many ways, which are as follows:

1) Ultrasound therapy in myofascial pain.
2) Ultrasound therapy for temporomandibular joint dysfunction.
3) Ultrasound therapy in cancer.
4) Ultrasound in healing soft tissues injuries.
5) Focused Ultrasound Surgery (FUS).
6) Ultrasound therapy in bone healing and osteointegration.
7) Sonoporation.
8) Extracorporeal lithotripsy.
9) Ultrasound in endodontics.
10) Miscellaneous.

The applications of US are discussed in the following sections.

Ultrasound therapy in myofascial pain: US therapy shows vasodilatory effect due to deep heating as well as by accelerating the metabolism, enhancing viscoelasticity and decreasing pain and muscle spasm [13]. Most of the studies showed that moderate-dose US (0.8-1.5 W/cm²) was effective in the management of myofascial pain. Additionally, an increase in the pressure pain threshold after several minutes of application was observed with low-dose US (520 W/cm²) on trigger points in MPS patients [14].

Majlesi and Ulalan conducted study on 72 patients with pain in the upper trapezius muscles. They gave high power static US in continuous modes, control group was given conventional US in stroke technique (intensity 1.5 W/cm²) and they concluded that high-power, static US technique relieves acute trigger points more rapidly than with conventional US technique [15].

There are also several studies indicating the efficacy of High-Power Pain Threshold (HPPT) US (1.5-3 W/cm²) in the management of myofascial pain.

Koca et al., compared and evaluated US treatment applied at low-, medium- and high-power-pain threshold (HPPT) doses to trigger points in the treatment of myofascial pain syndrome in 61 patients and they concluded that US therapy at HPPT dose can be considered as an alternative therapy method, which is more economical and more effective than low-dose and conventional US therapy [16].

Ultrasound therapy for temporomandibular joint dysfunction: Minnesota Dental Association and American Academy of Craniomandibular Disorders proposed that physical therapy is an important aid in relieving musculoskeletal pain by reducing the inflammation at the site and thus restores the oral function [17]. Therapeutic US utilizes high frequency waves for decreasing pain and swelling for improving the circulation of TMJ. Major studies and literature proposes that US therapy alone is not sufficient for TMD's and suggested that use of electrophysical mode of therapy in the early stages of disease is very potential in alleviating the symptoms.

Grieder A et al., used US therapy in patients with symptoms of TMD's and muscle spasm. They came to conclusion that the therapeutic benefits of US increased when used along with other modalities like acupuncture, muscle exercises, occlusal splinting and application of heat locally [10].

Mehmet Ucar et al., compared the effectiveness of home exercise alone versus home exercise combined with ultrasound in patients with TMD's and they concluded that home exercise combined with ultrasound was more effective in pain relief and increasing mouth opening [18].

Ultrasound therapy in cancer: US for cancer treatment was first reported in 1933 when it was stated that it had no specific effect on Ehrlich's carcinoma. It is used as a heating source for hyperthermic cancer treatments (Field and Bleehen) on its own, or in conjunction with radio- or chemotherapy. The aim is to maintain a uniform temperature distribution of 43–45°C in the tumour for times of the order of 60 min while keeping surrounding normal tissues at physiologically acceptable levels. The lens systems, curved transducers, mirror systems and crossed beams of phased arrays are used for achieving these results [8].

Therapeutic US are non-invasive and non-ionising in nature, so there are no long-term cumulative effects with its repeated use.

Generally High Intensity Focused USG (HIFU) is the intended method of treating benign and malignant tumors in human tissues. It generates tumor tissue necrosis [19].

Clement in a study, used High Intensity Focused US (HIFU) on animals and cultured cell lines observed that it is a valuable method for delivering chemotherapeutic drug to tumor tissue. It also helps the tumor tissue to overcome the Multi-Drug Resistance (MDR) of the cells [20].

Recently, Sonodynamic Therapy (SDT), which uses low-intensity ultrasound together with a sonosensitizer (Sonoflora 1), has been developed for cancer therapy [21,22].

Ultrasound in healing soft tissue injuries: Both in vitro and in vivo studies showed that US can promote tissue repair and wound healing if correctly applied (Dyson) [23]. US given during the initial 'inflammatory' phase of tissue repair can lead to an acceleration of the phase. The second phase 'proliferative' stage in which cells migrate to the site of injury and start to divide, granulation tissue is formed, and fibroblasts begin to synthesize collagen. US given during the proliferative phase enhances the collagen synthesis by fibroblasts. There is also evidence that scar tissue treated with US may be stronger and more elastic that 'normal' scar tissue [8].

Young in his study on healing of full thickness excised skin lesions concluded that US therapy (1MHz, 30mW/cm2) can be useful in accelerating the inflammatory and early proliferative stages of repair [24].

Focused ultrasound surgery (FUS): High intensity focused US beams have the ability to replace the conventional surgical knife or scalpel in a reproducible and controllable manner to destroy tissue, and able to affect a sharply defined region only, and should preferably be quick. This tissue ablation technique is known as High Intensity Focused Ultrasound (HIFU) or Focused Ultrasound Surgery (FUS) [8].

The principle of FUS is that a high intensity US beam kills cells lying within the focal volume while all other tissue in the US beam path was spared. This gives a method of selective tissue ablation at depth within tissue. Spatial peak intensities in the focus of 1 kW cm^2 are used. Typically, ellipsoidal focal volumes of length 1cm–2cm and diameters 1mm–2mm are achieved.

Now-a-days Magnetic Resonance Imaging guided Focused Ultrasound Surgery (MRIgFUS) is gaining importance. MRI can measure temperature changes in the body with an accuracy of -3°C at 1.5T. A greater accuracy can be achieved at higher field strengths due to its excellent temperature sensitivity and the focal point can be visualized and localized well before any irreversible tissue damage is induced above normal body temperature. Moreover, the ability of MRI to capture the temperature change enables the physician to delineate temperature maps and tumor volume and apply this quantitative information in real time to allow for “closed loop therapy [25].

Mariam stated that MRIgFUS can ablate soft-tissue tumors in the bone and also has the potential to provide very effective pain palliation in a single treatment that can be repeated in the case of pain recurrence. This form of therapy when combined with radiation provides improved pain relief, particularly for very painful metastases, which are refractory to other therapies [19].

Ultrasound therapy in bone healing and osteointegration: The first clinical observation that US stimulates fracture healing was reported as early as 1953 by Corradi and Cozzolino [26].

Low Intensity Pulsed Ultrasound (LIPUS) is used for healing bone fractures and for promoting osteointegration. Low intensity (≤ 0.1W/cm^2) US waves are used with a frequency of 1MHz–1.5MHz. Therapy is given in a pulsatile manner.

Erdogan and his colleague in a review on the effects of US therapy on bone healing its clinical applications on long bones and maxillofacial bones concluded that therapeutic US is a noninvasive modality with no serious complications or side effects. It may be a choice of treatment in many types of clinical procedures involving maxillofacial bones [27].

Khan et al., stated that LIPUS is used for fastening bone healing and also promotes gene expression along with signal transduction, increases blood flow. It also helps in promoting modeling and remodeling of the tissue [28].

Heckman et al., performed a multicenter placebo control clinical trial on 67 closed or Grade-I open tibial fractures to evaluate the effect of US on fracture healing. US treatment led to a significant (24%) reduction in the time to clinical healing, as well as to a 38% decrease in the time to overall (clinical and radiographic) healing, compared with the control group [29].

A system with trans-osseous application of the US was recently introduced for both the enhancement of healing in long bones and the monitoring of callus formation [30]. Among the several parameters evaluated, the propagation velocity of the US has been found the most sensitive in reflecting structural changes of the newly formed callus [31]. Distraction osteogenesis is used to gain bone and soft-tissue mass in individuals with variety of craniofacial deformities. US therapy may accelerate the mineralization of the tissue in the distraction gap [11].

In vitro studies showed that LIPUS stimulation can increase the expression of bone formation-related genes such as collagen type I and X, aggrecan, transforming growth factor beta, runt related gene-2, osteocalcin, insulin-like growth factor-I, bone sialoprotein and alkaline phosphatase. LIPUS also promotes protein synthesis and calcium uptake in various osteoblastic cell lines [32].

In implant dentistry LIPUS fastens healing of soft tissues and also promotes osteointegration. Ikai et al., used LIPUS for a period of four weeks with a time of 20 minutes daily observed that it has a beneficial therapeutic effect on healing of gingival epithelium and accelerated periodontal healing after surgery [33].

Shiraishi and his associates used LIPUS on epithelial cells of gingiva and concluded that it fastens the healing of soft-tissues by promoting the expression of a gene (connective tissue growth factor i.e., CCN2/CTGF) which helps in healing and formation of blood vessels (angiogenesis) in periodontal tissues [34].

Hsu et al., observed that stimulation of therapeutic ultrasound fastens the bone formation, accelerates blood flow promoted the formation of type I collagen surrounding the titanium implants. Pulsed US effectively promotes migration of cells and regeneration of new bone at implant sites, which was proved by culture of osteoblast like cells (MG63) [35].

Sonoporation: Sonoporation or cellular sonication is a procedure in which temporary modification of the permeability of the cell membrane is achieved by the use of US waves which further allows the uptake of certain substances from the extracellular environment [36].

The following [Table/Fig-2] are the different applications of sonoporation [37].

Nakashima et al., reported that sonoporation-mediated gene delivery is done by, a morphogen, growth/differentiation factor 11, which induces differentiation of pulp stem cells into odontoblasts [38].

Osteoinduction
Induction of dental pulp stem cell differentiation into odontoblasts
Use in site-specific gene delivery
DNA transfer
Local and targeted drug delivery
Gene transduction
Promotes induction of apoptosis

[Table/Fig-2]: Applications of sonoporation.

A required amount of drug concentration at the diseased site is achieved by local drug delivery while limiting toxicity for healthy tissues using sonoporation. Ultrasonically the drugs are released from microbubbles that circulate in the blood at required concentration until they enter an insonated volume of tissue [37].

In a study Iwanga et al., evaluated the efficiency of sonoporation in inhibition of human gingival squamous carcinoma cells in vitro and in vivo using Ca9-22 cell line. Sonoporation was used to deliver bleomycin and transfect a cdtB-expressing plasmid into Ca9-22 cells in vitro and in vivo. They reported that tumors nearly disappeared in Ca9-22 cell-implanted treated with bleomycin or cdtB-expressing plasmid during the four-weeks experimental period [39].

Extracorporeal lithotripsy: Extra-corporeal Shock Wave Lithotripsy (ESWL) a minimal invasive procedure introduced in 1980’s for treatment of urinary stones and in middle of 1980’s Debrugh Norman amd McGurk introduced it for treating gall stones. This technique uses shock waves that are generated outside the body and disintegrates or crush the stone present inside body. With the improvement of technology over the past two decades, the ESWL is also introduced for treating stones (sialolithiasis) of major salivary glands. This modality pulverizes the stone in the salivary glands into pieces smaller than 2mm which easily flushes out by stimulating the salivary flow [40].

This can be used for treating the sialolith present in the parotid and submandibular gland the size of the sialolith should be less than 7mm. This technique needs multiple sittings and the fragments of residual stone may remain in duct after the procedure are the main disadvantages of this modality [40].

In 2010 Escudier MP et al., studied the factors that affect the outcome (stone clearance, partial clearance without symptoms, and residual stone with symptoms unchanged) of ESWL in 142 salivary calculi (78 submandibular, 64 parotid) patients. They concluded that ESWL can eradicate salivary calculi but its effectiveness is dependant mainly on size of the stone [41].

Ultrasound in endodontics: [Table/Fig-3]

The concept of US in endodontics was introduced by Richman in 1957 [42]. Martin et al., demonstrated the ability of ultrasonically activated K-type files to cut dentin [43]. Endosonics was coined by Martin and Cunningham and was defined as the ultrasonic and synergistic system of root canal instrumentation and disinfection [44].

Other applications: Ultrasonic descaler removes both dental plaque and calculus from the surfaces of teeth, operate at frequencies of 25-42 kHz and reduce the mechanical efforts of the clinician. Tissues surrounding teeth show more rapid resolution to health, due to an increase in rate of collagen production stimulated by the ultrasonic descaler [45].

The adapted ultrasonic descaler is used for the condensation of amalgam restoration together with restoration contouring and elimination of interproximal ledges is widely applicable in the conservative dentistry [46].

In orthodontics US vibrations are used to remove cemented orthodontic brackets, and superficial decalcification of enamel.

Ultrasonic cleaning baths operating at frequencies of 18kHz-100kHz are used in dentistry for removing debris from instruments prior to sterilization, calculus and staining from dentures, and disinfecting rubber base impressions to casting.

[Table/Fig-3]: Showing the different applications of US in Endodontics.

Access refinement, finding calcified canals, and removal of attached pulp stones
Removal of intracanal obstructions (separated instruments, root canal posts, silver points, and fractured metallic posts)
The ultrasonic descaler may also be used to remove fractured metal posts from teeth by breaking the cement seal
Increased action of irrigating solutions
Ultrasonic condensation of gutta-percha
Placement of Mineral Trioxide Aggregate (MTA)
Root canal preparation
Surgical endodontics: Root-end cavity preparation and refinement and placement of root-end obturation material

[Table/Fig-3]: Applications of ultrasound in Endodontics [46,47].

CONCLUSION

Ultrasonography as imaging modality is well established. The therapeutic applications of ultrasound are widely used in medical, orthopedic surgery and rehabilitation, but in the field of dentistry its use is still in the budding stage. Although it has wide therapeutic applications in various fields of dentistry, but these therapeutic benefits are based upon various author's personal opinion and experience, and that there is a need for more adequate powered human studies together with the standardization of intensities and dosages for each target tissue are needed to build a stronger clinical database for routine clinical use.

Research and studies should focus on standardization of intensity, frequency, time period of therapy, surface area of transducer probe used and coupling media and also the emphasis should be on development of a reliable and reproducible procedure of the therapeutic US to ensure the maximum beneficial effects of the therapy.

The continuing advances in this field may promise exciting developments in the near future.

REFERENCES

[1] Esposito CJ, Veal SJ, Farman AG. Alleviation of myofascial pain with ultrasonic therapy. *J Prosthet Dentistry.* 1984; 51:106-08.

[2] Kitchen SS, Partridge CJ. A review of therapeutic ultrasound, part 1: background and physiological effects. *Physiotherapy.* 1990; 76:593–95.

[3] Kerry G Baker, Valma J Robertson, Francis A Duck. A review of therapeutic ultrasound: biophysical. *Phys Ther.* 2001; 81: 1351-58.

[4] Lehmann JF, de Lateur BJ. Therapeutic heat. In: Lehmann JF, ed. Therapeutic Heat and Cold. Baltimore, Md: Williams & Wilkins; 1990: 417–581.

[5] Ter Haar G. Biological effects of ultrasound in clinical applications. In: Suslick KS, ed. Ultrasound: It's Chemical, Physical, and Biological Effects. New York, NY: VCH Publishers Inc; 1988:305–320.

[6] Suslick KS. Ultrasound: It's Chemical, Physical, and Biological Effects. New York, NY: VCH Publishers Inc; 1988.

[7] ter Haar G. Basic physics of therapeutic ultrasound. *Physiotherapy.*1987; 73:110–13.

[8] G. ter Haar. Therapeutic Ultrasound. *Eur J Ultrasound.* 1999: 9(1):3-9.

[9] ter Haar GR. Therapeutic and surgical applications. In: Hill CR, editor. Physical principles of Medical Ultrasound. Chichester, UK: Ellis Horwood, 1986.

[10] Grieder A, Vinton PW, Cinotti WR, Kangur TT. An evaluation of ultrasonic therapy for temporomandibular joint dysfunction. *Oral Surg Oral Med Oral Pathol.* 1971; 31:25-31.

[11] Rai S, Kaur M, Goel S, Panjwani S, Singh S. Prospective utility of therapeutic ultrasound in dentistry-review with recent comprehensive update. *Adv Biomed Res.* 2012;1:47.

[12] Amusat N. Clinical field note—ultrasound therapy: getting it right". *AJPARS*. 2010; 2:25-27.

[13] Koca I, Boyaci A. A new insight into the management of myofascial pain syndrome. *Gaziantep Med J*. 2014; 20(2):107-12.

[14] van der Windt DA, van der Heijden GJ, van den Berg SG, ter Riet G, de Winter AF, Bouter LM. Ultrasound therapy for musculoskeletal disorders: a systematic review. *Pain.* 1999; 81(3):257-71.

[15] Majelsi J, Ulalan H. High-power pain threshold ultrasound technique in the treatment of active myofascial triggers points: a randomized, double-blind, case-control study. *Arch Phys Med Rehabil*. 2004; 85:833-36.

[16] Koca I, Tutoglu A, Boyaci A, Ucar M, Yagiz E, Isik M, et al. A comparison of the effectiveness of low-, moderate- and high-dose ultrasound therapy applied in the treatment of myofascial pain syndrome. *Mod Rheumatol.* 2014; 24(4):662-66.

[17] Fouda A. Ultrasonic therapy as an adjunct treatment of temporomandibular joint dysfunction. *J Oral Maxillofac Surg.* 2014; 117:232-37.

[18] Ucar M, Sarp Ü, Koca İ, Eroğlu S, Yetisgin A, Tutoglu A, et al. Effectiveness of a home exercise program in combination with ultrasound therapy for temporomandibular joint disorders. *J Phys Ther Sci*. 2014; 26(12):1847–49.

[19] Mago J, Sheikh S, Pallagatti S, Aggarwal A. Therapeutic applications of ultrasonography in dentistry. *J Indian Acad Oral Med Radiol.* 2014; 26:414-18.

[20] Clement GT. Perspectives in clinical uses of high-intensity focused ultrasound. *Ultrasonics*. 2004; 42:1087-93.

[21] Huang Z, Moseley H, Bown S. Rationale of combined PDT and SDT modalities for treating cancer patients in terminal stage: the proper use of photosensitizer. *Integrative Cancer Therapies.* 2010; 9(4):317–19.

[22] Shibaguchi H, Tsuru H, Kuroki M, Kuroki M. Sonodynamic cancer therapy: a non-invasive and repeatable approach using low-intensity ultrasound with a sonosensitizer. *Anticancer Res.* 2011; 31(7):2425-29.

[23] Dyson M. Role of ultrasound in wound healing. In: Kloth LC, McCulloch JM, Feedar JA, editors. Wound Healing: Alternatives in Management. Philadelphia, PA: Davis, 1990:259–65.

[24] Young SR, Dyson M. Effect of therapeutic ultrasound on the healing of full-thickness excised skin lesions. *Ultrasonics.* 1990; 28:175-80.

[25] Jolesz FA. MRI-guided focused ultrasound surgery. *Annu Rev Med.* 2009; 60:417-30.

[26] Corradi C, Cozzolino A. Ultrasound and bone callus formation during function. *Arch Ortop.* 1953; 66:77—98.

[27] Erdogan O, Esen E. Biological aspects and clinical importance of ultrasound therapy in bone healing. *J Ultrasound Med*. 2009; 28:765-76.

[28] Khan Y, Laurencin CT. Fracture repair with ultrasound: Clinical and cell-based evaluation. *J Bone Joint Surg Am.* 2008; 90 (Suppl 1):138-44.

[29] Heckman JD, Ryaby JP, McCabe J, Frey JJ, Kilcoyne RF. Acceleration of tibial fracture-healing by non- invasive, low-intensity pulsed ultrasound. *J Bone Joint Surg.* 1994; 76A:26-34.

[30] Protopappas VC, Baga DA, Fotiadis DI, Likas AC, Papachristos AA, Malizos KN. An ultrasound wearable system for the monitoring and acceleration of fracture healing in long bones. *IEEE Trans Biomed Eng.* 2005; 52:1597-608.

[31] Malizos KN, Hantes ME, Protopappas V, Papachristos A. Low-intensity pulsed ultrasound for bone healing: an overview. *Injury.* 2006; 37: S56-62.

[32] Rego EB, Takata T, Tanne K, Tanaka E. Current status of low intensity pulsed ultrasound for dental purposes. *Open Dent J.* 2012; 6: 220-25.

[33] Ikai H, Tamura T, Watanabe T, Itou M, Sugaya A, Iwabuchi S, et al. Low-intensity pulsed ultrasound accelerates periodontal wound healing after flap surgery. *J Periodont Res*. 2008; 43: 212-16.
[34] Shiraishi R, Masaki C, Toshinaga A, Okinaga T, Nishihara T, Yamanaka N, et al. The effects of low-intensity pulsed ultrasound exposure on gingival cells. J *Periodontol*. 2011; 82(10): 1498-503.
[35] Hsu SK, Huang WT, Liu BS, Li SM, Chen HT, Chang CJ. Effects of near-field ultrasound stimulation on new bone formation and osseointegration of dental titanium implants in vitro and in vivo. *Ultrasound Med Biol*. 2011; 37: 403-16.
[36] Sheikh S, Pallagatti S, Singh B, Puri N, Singh R, Kalucha A. Sonoporation as therapeutic modality. *J Clin Exp Dent.* 2011;3:e228-34.
[37] Deepika M, Harshavardhan T, Vijayalaxmi N, Aravind K, Jayakrishna B. Sonoporation-invigorating sound in dentistry: a review. *IJSS Case Reports & Reviews.* 2014; 1(6):25-28.
[38] Nakashima M, Tachibana K, Iohara K, Ito M, Ishikawa M, Akamine A. Induction of reparative dentin formation by ultrasound-mediated gene delivery of growth/ differentiation factor 11. *Hum Gene Ther.* 2003; 14:591-97.
[39] Iwanaga K, Tominaga K, Yamamoto K, Habu M, Maeda H, Akifusa S, et al. Local delivery system of cytotoxic agents to tumors by focused sonoporation. *Cancer Gene Ther.* 2007; 14:354-63.
[40] DeBurgh Norman JE, McGurk M: Extracorporeal piezoelectric shockwave lithotripsy (ESWL) of salivary duct stones (sailolithotripsy). In: Color Atlas and Text Books of salivary duct and Lacrimal glands Ist Edn, Mosby- Wolfe, London, 1995: 263-266.
[41] Escudier MP, Brown JE, Putcha V, Capaccio P, McGurk M. Factors influencing the outcome of extracorporeal shock wave lithotripsy in the management of salivary calculi. *Laryngoscope*. 2010; 120(8):1545-49.
[42] Richman RJ. The use of ultrasonics in root canal therapy and root resection. *Med Dent J.* 1957; 12:12-18.
[43] Martin H, Cunningham WT, Norris JP, Cotton WR. Ultrasonic versus hand filing of dentin: a quantitative study. *Oral Surg Oral Med Oral Pathol.* 1980; 49:79-81.
[44] Martin H, Cunningham W. Endosonics: the ultrasonic synergistic system of endodontics. *Endod Dent Traumatol.* 1985;1:201–06.e
[45] Vivek K. Bains, Ranjana Mohan, Rhythm Bains. Application of ultrasound in periodontics: Part II. *J Indian Soc Periodontol.* 2008; 12(3): 55–61.
[46] Walmsely AD. Application of ultrasound in dentistry. *Ultrasound Med Biol*. 1988; 14:7-14.
[47] Plotino G, Pameijer CH, Grande NM, Somma F. Ultrasonics in ndodontics: a review of the literature. *J Endod*. 2007; 33(2):81-95.

PARTICULARS OF CONTRIBUTORS:
1. Private Practitioner, Oral Medicine & Radiology, Andhra Pradesh, India.
2. Senior Lecturer, Department of Oral Medicine and Radiology, D.J. College of Dental Sciences and Research, Modinagar, U.P, India.
3. Senior Lecturer, Department of Oral Medicine and Radiology, Saraswathi Dhanwantari Dental College, Parbhani, Maharashtra, India.
4. Post Graduate Student, Department of Oral Medicine and Radiology, Narsinbhai Patel Dental College and Hospital, Visnagar, Gujarat, India.
5. Private Practitioner, Prosthodontics and Implantology, Telangana, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Sunil Kumar Karumuri,
Private Practitioner, Oral Medicine & Radiology, Andhra Pradesh, India.
E-mail: drkumarkarumuri@gmail.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Dec 28, 2015**
Date of Peer Review: **Mar 01, 2016**
Date of Acceptance: **Apr 04, 2016**
Date of Publishing: **Jul 01, 2016**