Thai Moogambigai Journal Of Periodontics and Dental Science, 2024; Volume No: 5, Issue No: 3

Review Article | ISSN (O): 2582 6794

EFFECT OF LOW-INTENSITY PULSED ULTRASOUND ON DENTAL IMPLANTS

Sabarimani[1*], Balaji[1], Manikandan[1]

[1]Department of Periodontics & Implant Dentistry, CSI College of Dental Sciences and Research, Madurai. *Corresponding Author's Email: drsabarims@gmail.com

Abstract

Low-Intensity Pulsed Ultrasound (LIPUS) has gained attention as a non-invasive therapeutic modality with potential applications in regenerative medicine, orthopedics, and dentistry. This review explores the current evidence regarding the impact of LIPUS on osseointegration, bone healing, and the overall clinical outcomes of dental implants. Additionally, it examines the historical development of LIPUS, its biological mechanisms, its effects on osseointegration and peri-implant tissue healing, and its potential clinical applications. Furthermore, the limitations of existing studies are discussed, along with recommendations for future research to optimize the integration of LIPUS in dental implantology.

Keywords:

INTRODUCTION:

The concept of osseointegration, introduced in 1969 by Professor **Per-Ingvar Brånemark** at the University of Gothenburg, revolutionized dental implantology, offering new treatment possibilities for partially and fully edentulous patients. Titanium endosseous implants have since been widely adopted due to their success in achieving osseointegration—a direct interface between implant surfaces and living bone. Various approaches have been investigated to enhance implant osseointegration, including dual acid etching, biomimetic coatings, and the engineering of dental pulp cells on implant surfaces. [1]

Among the novel biophysical stimulation methods explored to improve bone healing around biomaterials, LIPUS has emerged as a promising tool. LIPUS is a non-invasive acoustic radiation therapy that plays a crucial role in osteogenesis. With intensities ranging from 30 mW/cm^2 to 100 mW/cm^2, it has shown significant potential in oral healthcare, particularly in periodontal regeneration, alveolar bone healing, orthodontic bone remodeling, temporomandibular joint cartilage regeneration, and dentin-pulp repair. [2]

HISTORY AND DEVELOPMENT OF ULTRASOUND:

Ultrasound has been utilized for therapeutic

and diagnostic purposes for over 50 years. Defined as sound waves with frequencies above the audible range of the human ear, ultrasound propagates through tissue, generating both thermal and nonthermal effects.

- **1950s:** Researchers explored high-intensity continuous ultrasound (HICU) for tissue repair and pain reduction.
- **1980s:** The breakthrough development of LIPUS demonstrated its ability to accelerate bone fracture healing.
- **1994:** The U.S. Food and Drug Administration (FDA) approved the first LIPUS device (Exogen bone healing system) for treating non-union fractures.

DIAGNOSTIC APPLICATION OF ULTRASOUND

Transthoracic ultrasound (US) can be used for evaluating:

1. Chest wall lesions
2. Pleural abnormalities (effusion, thickening, tumors)

3. Peridiaphragmatic lesions
4. Peripheral pulmonary lesions in contact with the pleura
5. Pulmonary lesions with accessible ultrasound windows
6. Mediastinal tumors adjacent to the chest wall

Additionally, diagnostic ultrasound is widely employed for imaging visceral organs (liver, pancreas, kidneys) at 3 MHz frequency, while higher frequencies (5–7 MHz) provide enhanced resolution for neck, breast, and pediatric examinations. [7]

THERAPEUTIC APPLICATIONS OF ULTRASOUND:

1. **Osteoradionecrosis:** Ultrasound has been shown to enhance blood supply and promote the replacement of necrotic bone with healthy callus. [7]
2. **Bone and Periodontal Regeneration:** LIPUS enhances bone healing by increasing intracellular calcium deposition, stimulating osteoblast activity, and promoting callus formation in experimental animal models. [2,7]
3. **Fracture Healing:** Randomized controlled trials (RCTs) have demonstrated the efficacy of LIPUS in accelerating fracture healing and providing pain relief. [4]

LIPUS IN DENTAL IMPLANTOLOGY:

A study by **Elaf Akram Abdulhameed et al.** reported that CBCT measurements of bone thickness and implant stability values (RFA) were significantly higher in LIPUS-treated groups compared to controls, indicating improved stability and osseointegration. [3]

MECHANISM OF ACTION OF LIPUS:

Padilla et al., and **Sato et al**. LIPUS generates mechanical energy through acoustic waves, resulting in minimal thermal but significant non-thermal effects, including cavitation, acoustic streaming, and mechanical stimulation. [6, 30] These effects trigger mechanotransduction pathways that enhance bone wound healing by activating integrin/MAPK signaling, intercellular gap-junction communication, COX-2/PGE2 and iNOS/NO pathways, and mechanosensitive receptors. [7, 9]

Kleinheinz J et al. suggested that LIPUS promotes both osteogenesis and angiogenesis, with angiogenesis being a prerequisite for new bone formation. [10]

ADVANTAGES OF LIPUS:

1. **Non-Invasive and Safe:** LIPUS provides a non-surgical alternative for enhancing bone healing with minimal side effects. [1,3,4,7]
2. **Faster Recovery:** It accelerates healing, facilitating earlier implant loading. [3]
3. **Enhanced Bone Quality:** LIPUS benefits patients with osteoporosis, diabetes, or smoking history by improving bone regeneration.
4. **Cost-Effectiveness:** While requiring specialized equipment, LIPUS may reduce overall treatment costs by preventing implant failures.
5. **Increased Implant Stability:** Studies confirm improved implant stability and higher marginal bone levels with LIPUS treatment. [3,7,5]
6. **Fracture and Non-Union Treatment:** LIPUS has been extensively studied for its role in healing fresh fractures and non-unions. [11]

CHALLENGES AND LIMITATIONS:

1. **Lack of Standardized Protocols:** Variability in ultrasound intensity, frequency, and treatment duration affects study comparability.
2. **Mixed Clinical Outcomes:** Some studies show no significant improvements, emphasizing the need for further research.
3. **High Equipment Cost:** Limited availability in dental practices may hinder widespread adoption.
4. **Patient-Specific Variability:** Treatment effectiveness may differ based on age, health status, and

bone quality.

RELEVANT CLINICAL STUDIES:

- **Yakup Ustun et al.** demonstrated increased bone area, volume, and bone-implant contact with LIPUS, though RFA score improvements were not statistically significant.[1]
- **Yingying Wang et al.** found LIPUS effective in promoting peri-implant osteogenesis in type II diabetic rats, suggesting potential benefits for diabetic patients. [3]
    - **Yixuan Jiang et al.** highlighted the role of LIPUS in inducing local neuronal production of αCGRP, enhancing peri-implant bone regeneration. [4]
    - **Julie Chauvel Picard et al.** confirmed accelerated bone formation in a porcine model, reinforcing LIPUS as a complementary treatment for implantology. [12]
    - **Gregory J Della Rocca** advocated further investigation of LIPUS for human fracture healing. [11]

FUTURE DIRECTIONS:

To maximize LIPUS potential in dental implantology, future research should focus on:

- Standardizing treatment parameters (intensity, frequency, duration)
- Conducting long-term clinical trials to assess implant survival
- Investigating patient-specific applications for personalized treatment plans
- Evaluating cost-effectiveness for widespread clinical use
- Exploring combination therapies, such as LIPUS with transcutaneous electrical nerve stimulation (TENS)

CONCLUSION:

LIPUS holds significant potential as an adjunctive therapy for improving osseointegration and bone healing in dental implantology. It enhances cellular activity, angiogenesis, and gene expression, contributing to accelerated healing and improved implant outcomes. However, challenges such as inconsistent treatment protocols, variable clinical results, and equipment costs must be addressed. Future research aimed at standardizing protocols, assessing long-term efficacy, and tailoring treatments for individual patients will be crucial for its broader clinical integration.

REFERENCES:

1. Ustun Y, Erdogan O, Kurkcu M, Akova T, Damlar I. Effects of low-intensity pulsed ultrasound on dental implant osseointegration: a preliminary report. Eur J Dent. 2008 Oct;2(4):254-62.
2. Wei Y, Guo Y. Clinical Applications of Low-Intensity Pulsed Ultrasound and Its Underlying Mechanisms in Dentistry. Applied Sciences. 2022; 12(23):11898.
3. Wang Y, Cao X, Shen Y, Zhong Q, Wu Z, Wu Y, Weng W, Xu C. Evaluate the effects of low-intensity pulsed ultrasound on dental implant osseointegration under type II diabetes. Front Bioeng Biotechnol. 2024 Feb 2;12:1356412.
4. Jiang Y, Yuan Y, Xiong Y, Wang B, Guo Y, Gong P, Zhang L. Low-intensity pulsed ultrasound improves osseointegration of dental implant in mice by inducing local neuronal production of αCGRP. Arch Oral Biol. 2020 Jul;115:104736.
5. Rego EB, Takata T, Tanne K, Tanaka E. Current status of low intensity pulsed ultrasound for dental purposes. Open Dent J. 2012;6:220-5.
6. Jiang X, Savchenko O, Li Y, Qi S, Yang T, Zhang W, Chen J. A Review of Low-Intensity Pulsed Ultrasound for Therapeutic Applications. IEEE Trans Biomed Eng. 2019 Oct;66(10):2704-2718.
7. Liang C, Liu X, Yan Y, Sun R, Li J, Geng W. Effectiveness and Mechanisms of Low-Intensity Pulsed Ultrasound on Osseointegration of Dental Implants and Biological Functions of Bone Marrow Mesenchymal Stem Cells. Stem Cells Int. 2022 Sep 26;2022:7397335.
8. Kleinheinz J, Stratmann U, Joos U, Wiesmann HP. VEGF-activated angiogenesis during bone regeneration. J Oral Maxillofac Surg. 2005 Sep;63(9):1310-6.
9. Sato M, Nagata K, Kuroda S, Horiuchi S, Nakamura T, Karima M, et al. Low- intensity pulsed ultrasound activates integrin-mediated mechanotransduction pathway in synovial cells. Annals of Biomedical Engineering. 2014;42(10):2156-216.
10. Kleinheinz J, Stratmann U, Joos U, Wiesmann H-P. VEGF-activated angiogenesis during bone regeneration. Journal of Oral and Maxillofacial Surgery. 2005;63(9):1310-1316.
11. Della Rocca GJ. The science of ultrasound therapy for fracture healing. Indian J Orthop. 2009;43(2):121-126.