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Ultrasounds in Odontology: A Literature Review

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Abstract

Introduction: This project was a crucial step in exploring the use of ultrasound in odontology, focusing specifically on its effectiveness in scaling and decontaminating dental surfaces. **Materials and Methods:** The literature search was carried out using a combination of keywords and Boolean equations to optimize the accuracy and relevance of the results obtained. **Results:** The results obtained provided important insights into the advantages of this innovative approach. **Discussion:** Analysis of the data clearly showed that ultrasound was significantly effective in removing plaque and bacterial biofilms. Another key aspect of the use of ultrasound in dentistry was its positive impact on the preservation of surrounding tissues. Unlike some more traditional methods, ultrasound enabled more targeted action, minimizing damage to surrounding healthy tissues. **Conclusion:** Despite the promising results obtained in this article, it was clear that further research was needed to deepen our understanding of the effectiveness of ultrasound in dentistry. Larger-scale clinical studies were required to validate the results obtained, focusing on various patient populations and assessing their long-term impact. Advancement, improving clinical outcomes and patient satisfaction. Continued research is essential to maximize its clinical potential.

Subject Areas

Dentistry

Keywords

Ultrasounds, Ultrasonic Scaling, Ultrasonic Debridement, Ultrasonic Biofilm Removal, Ultrasonic Plaque Removal, Ultrasonic Surface Decontamination

1. Introduction

Over the past 60 years, the use of ultrasound devices in dentistry has evolved significantly. Ultrasound was first discovered for its therapeutic use in the late 1940s, particularly to treat conditions such as chronic osteomyelitis and osteoradionecrosis, and in the 1980s clinicians began to be concerned with its ability to influence bone repair. The "Cavitron" (see **Figure 1**) was created in the 1950s, and is crucial in the treatment of periodontal disease for the gross removal of supragingival calculus. [1] [2]

Figure 1. Cavitron plus ultrasonic scaler.

The treatment of choice for periodontitis is the removal of subgingival biofilm and pathogens. (See **Figure 2**) Subsequent studies have shown that ultrasonic devices remove plaque and calculus in the same way as manual instruments, with a comparable healing response. Sonic/ultrasonic debridement also has the advantage of effectively dislodging biofilm and deposits, as well as residual calculus in areas of limited access, such as furcation lesions, deep vertical defects and multi-rooted teeth. To remove deposits, the active end of the tip is positioned towards the tooth. [4]

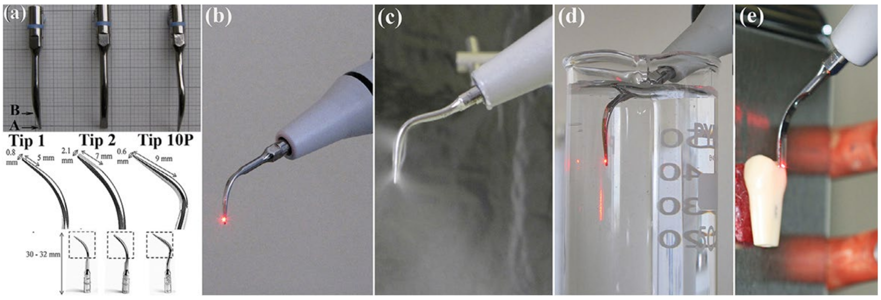

Figure 2. (a) Design of selective tips 1, 2 and 10P; the free end of the tip (position A) is placed on the opposite side of the tooth during treatment. Tip vibrations are measured in air (b), underwater (c), in a water tank (d) and under load (e). [3]

The strongest vibrations are produced by fine tips and high-power settings. Tip performance is affected by water irrigation and loads, which reduce tip vibration as the volume of water increases. [5]

Cavitation in the cooling water around the tip has been shown *in vitro* to play a role in the cleaning process. Cavitation is the formation, growth and collapse of microscopic bubbles in liquids when the local pressure falls below the saturated vapour pressure of the liquid. [6]-[8]

The main aim of this study is to analyze the physical basis of ultrasound in dentistry, to investigate its effectiveness and safety, and to study the specific applications of ultrasound in scaling and decontamination of dental surfaces.

To do so, the following research question was addressed:

"How effective is ultrasound in odontology for scaling and decontaminating dental surfaces?"

2. Materials and Methods

2.1. Search Strategies

To identify relevant literature in the field of ultrasound use in dentistry, an extensive search was conducted in several reputable electronic databases.

The databases searched included PubMed, Scopus, Web of Science and Google Scholar. The literature search was carried out using a combination of keywords and Boolean equations to optimize the accuracy and relevance of the results obtained. This approach made it possible to specifically target articles relevant to the use of ultrasound in dentistry.

Keywords used:

- Ultrasounds
- Dentistry
- Ultrasonics Dentistry
- Ultrasonic scaling
- Ultrasonic debridement
- Ultrasonic biofilm removal
- Ultrasonic plaque removal
- Ultrasonic surface decontamination

To ensure the inclusion of the most recent and relevant studies, searches were limited to articles published in English within the last ten years. Each database was searched independently, and results were carefully reviewed to avoid duplication.

2.2. Keywords and Boolean Equations

The words used were either [MeSH Tems] with the sign (*) or [Free Text] keywords with the sign (♯). - Ultrasound(*) - Dental scaling(*) - biofilm(*) - Dental scalers(*) - plaque(♯)

The Boolean equations selected in our electronic search were:

—Ultrasonic scaling AND *dental plaque removal*

—Dental calculus removal *AND ultrasonic debridement*

—Dental biofilm removal* AND ultrasonics♯

We included in our search articles and works that met the following conditions.

—Articles meeting the objectives of our research area.

—Only publications in French and English were retained. During our bibliographic search, we admitted experimental studies, original articles, review articles, theses and literature reviews.

And we excluded any criteria opposing this selection.

3. Results (See Figure 3)

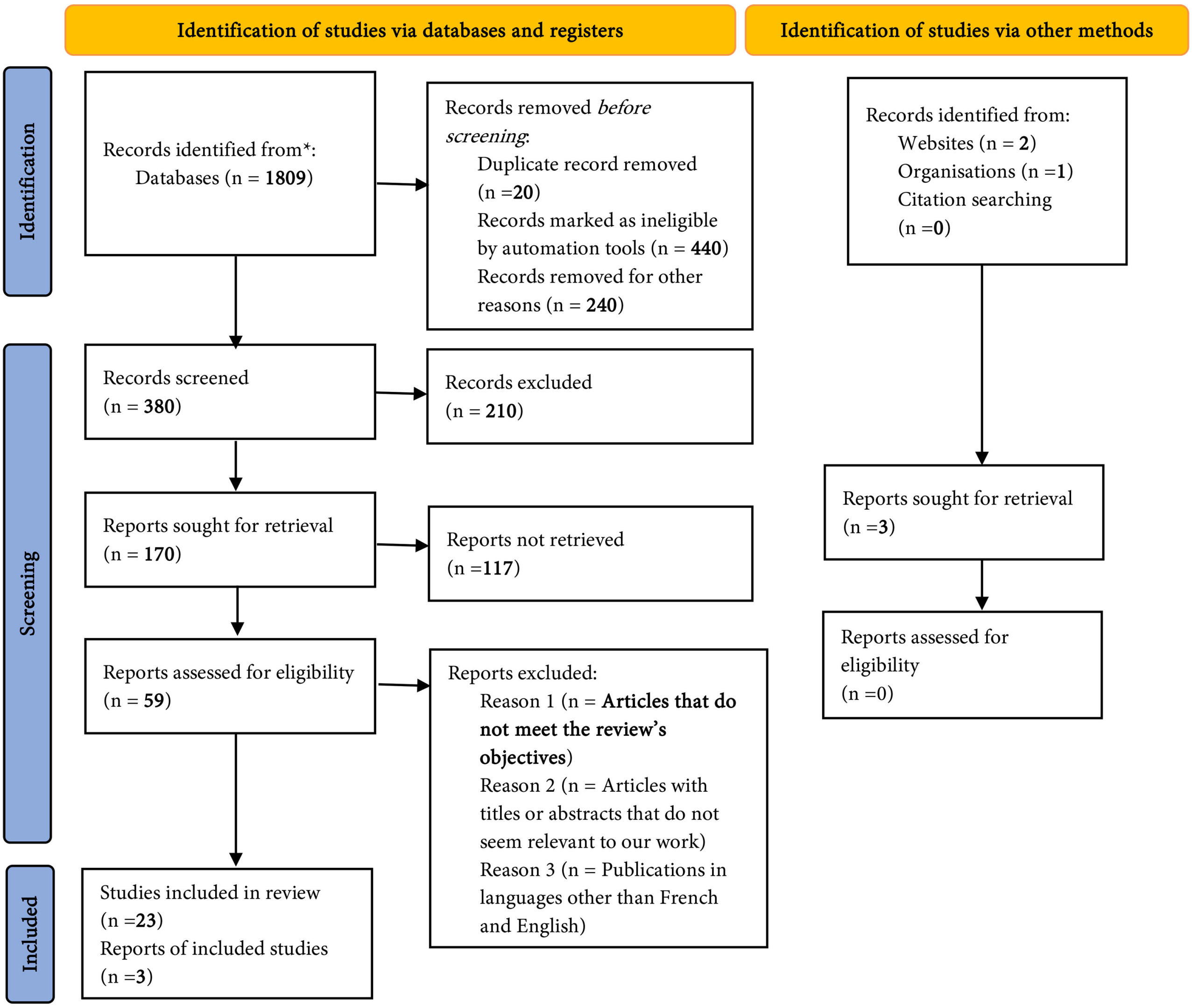

Figure 3. The results of our research were presented in the form of a "PRISMA" flow chart.

Selection of Articles

The remaining 23 articles formed the basis of our work. (See Table 1)

Table 1. List of selected articles.

Article title	Authors	Year	Reference
Dental hygienist's perception of preparation and the use for ultrasonic instrumentation	Asadoorian J., Botbyl D., Goulding M. J.	2014	[1]
Ultrasonography—A boon in dentistry	Alok A., Singh S., Kishore M., Shukla A. K.	2019	[2]
The performance characteristics of a piezoelectric ultrasonic dental scaler.	Pecheva E., Sammons R. L., Wamsley A. D.	2016	[3]
Influence of ultrasonic tip distance and orientation on biofilm removal.	Gartenmann S. J., Thurnheer T., Attin T., Schmidlin P. R.	2016	[4]

Continued

Ultrasonic vs hand instrumentation in periodontal therapy.	Krishna R., Jamie A. de Stefano	**2016**	[5]
High speed imaging of cavitation around dental scaler tips.	Vyas N., Pecheva E., Dehghani H., Sammon, Wang X., Leppinen Q.	**2016**	[6]
The application of ultrasound, and ultrasonography in dentistry: a scoping review of the literature.	Elbarbary M., Sgro A., Khazaei S., Goldberg M., Tenenbaum H. C., Azarpazhooh A.	**2022**	[7]
Static biofilm removal around ultrasonic tips *in vitro*.	Thurnheer T., Rohrer E., Belibasakis G. N., Attin T., Schmidlin P. R.	**2013**	[8]
Mechanized scaling with ultrasonics: Perils and proactive measures.	Paramashivaiah R., Prabhuli M. L. V.	**2013**	[9]
Ultrasonics in dentistry.	Wamsley A. D.	**2015**	[10]
Ultrasound devices and dental care.	Blanc G.	**2008**	[11]
Comparison between sonic/ultrasonic instruments for periodontal treatment: Systematic review with meta-analysis.	Gomes Muniz F. W. M., Haubman Pereira D., Pimentel R.	**2020**	[12]
Numerical investigation of cavitation in periodontal pockets: Insights for enhancing cleaning efficiency.	Yu Y., Smith W. R., Wang Q., Wamsley A. D.	**2023**	[13]
Clinical evaluation of ultrasonic subgingival debridement versus ultrasonic subgingival saling combined with manual root planing in the treatment of periodontitis.	Yan Y., Zhan Y., Wang X., Hou J.	**2020**	[14]
Current concepts in management of periodontitis.	Kwon T., Lamster I. B., Levin L.	**2020**	[15]
Subgingival Instrumentation for treatment of Periodontitis: systematic review.	Suvan J., Leira Y., Moreno F., Graziani F., Derks J., Tomasi C.	**2020**	[16]
Numerical investigation of cavitation generated by an ultrasonic dental scaler tip vibrating in a compressible liquid	Manmi K. M. A., Wu W. B., Vyas N., Smith W. R., Wang Q. X., Walmsley A. D.	**2020**	[17]
Subgingival Debridement: endpoint, methods and how often?	Lalemen I., Cortellini S., De Winter S., Herrero E. R., Dekeyser C., Quirynen M., Teughels W.	**2017**	[18]
Removal of stimulated biofilm: an evaluation of the effect on root surfaces roughness after scaling.	Graetz Ch., Plaumann A., Wittich R., Springer C., Kahl M., Dorfer C. E., El Sayed K. F.	**2016**	[19]
The effect of dental ultrasonic scaler on dental restorations.	Kamal D. M. Shukri, Saudi J.	**2022**	[20]
Complications and treatment errors in non chirurgical periodontal therapy.	Graziani F., Tinto M., Orsolini C., Izzetti R., Tomasi C.	**2023**	[21]
Sonochemical characterisation of ultrasonic dental scalers	Price G. J., Tiong T. J., King D. C.	**2013**	[22]
The clinical efficacy of subgingival debridement by ultrasonic instrumentation compared with subgingival air polishing during periodontal maintenance: systematic review	Zhand J., MDS, Liu J., Li J., Chen D., Li H., Yan A. F.	**2019**	[23]

4. Discussion

4.1. History of Ultrasounds in Dentistry

The creation of high-frequency sound waves in dentistry dates back to the late 19th century, when Jacques and Pierre Curie exposed certain crystals to an alternating current at their resonant frequency. Paul Langevin was the first to observe the biological effects of ultrasound in 1926. However, ultrasound was discovered for its therapeutic use in the late 1940s, in particular, to treat diseases such as chronic osteomyelitis and osteoradionecrosis. Over time, more and more studies examined the mechanism of action of ultrasound, and in the 1980s, clinicians began to be concerned with its ability to influence bone repair. Numerous studies were published in the 1990s on the potential therapeutic effects of ultrasound on maxillofacial bones, including its impact on implant success, early diagnosis of precancerous lesions, and reduction of swelling in the maxillofacial region and detection of lymph node metastases, among others. [1] [2]

4.2. The Physical Basis of Ultrasound in Odontology

Ultrasound, as an acoustic pressure wave, passes through the tissue and can induce a variety of changes in the biological system, including heat generation, acoustic microcirculation and radiation forces. [3] [4]

These ultrasound waves generate vibrations as they pass through tissue, transmitting biological signals to cells. The physiological effects of ultrasound include thermal and non-thermal responses. (See **Figure 4**) Thermal effects include an increase in tissue extensibility and vascularization in the targeted region, as well as a reduction in muscle spasm and joint stiffness. On the other hand, the non-thermal effects of ultrasound are of particular importance in the treatment of soft tissue injuries, mediated mainly by cavitation phenomena (stable and unstable) and acoustic microcirculation. [7]

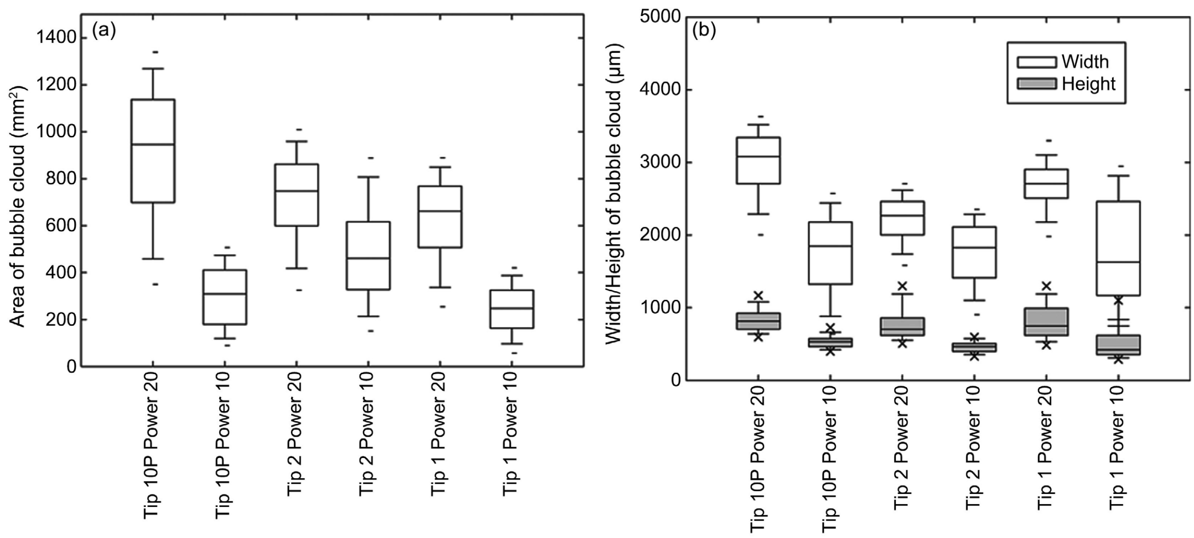

Figure 4. Box and curve plots (a) of the surface of the bubble clouds at the end of three different ultrasonic scalers operating at medium and high levels (b) of the height and width of the bubble cloud. [7]

4.3. Description of the Different Frequencies and Powers Used

Ultrasonic instruments operating at frequencies of between 25 and 40 kHz were originally designed as drills before being reoriented as scaling tools to remove deposits such as bacterial biofilm from teeth. (See Figure 5 and Figure 6) Vibrations transmitted to a steel probe are used to physically detach these deposits from the tooth surface. In addition, the curved shapes of these probes facilitate access to hard-to-reach areas around or inside the tooth. However, incorrect use of the instrument carries the risk of damaging tooth structure. [9]-[11]

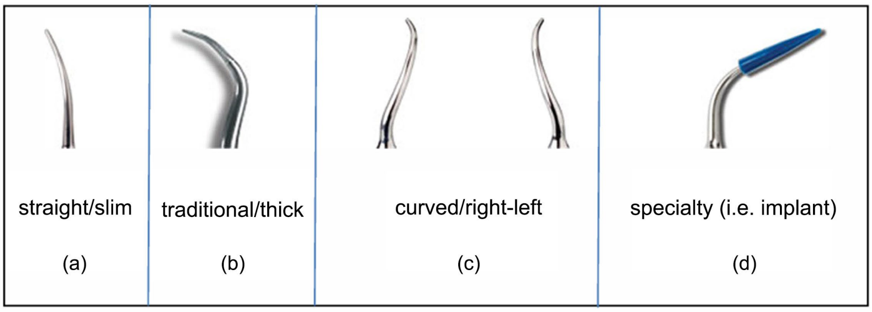

Figure 5. Different types of ultrasonic inserts. [9]

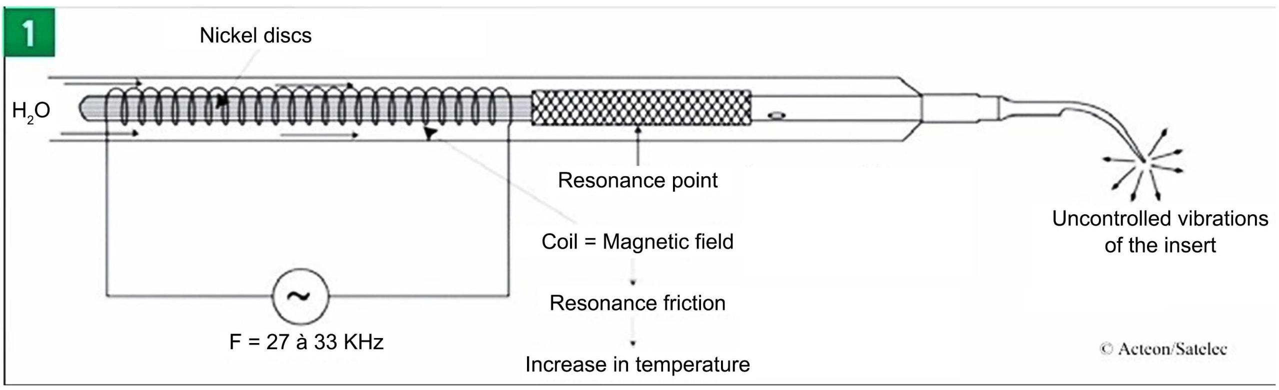

Figure 6. It refers to the property of ferromagnetic materials to deform under the effect of oscillating magnetic fields.

4.4. Working Instruments

4.4.1. Mechanical Action of the Ultrasonic Scaler

The ultrasonic scaler acts mainly by a "chiseling" movement, mechanically removing deposits from the teeth. This process results from the longitudinal chiseling movement and rapid oscillation of the tip, which is considered to be the main method of action. During use, a flow of cooling water is directed onto the tip to remove debris from the tooth surface while promoting biophysical effects such as cavitation and acoustic microcirculation. Recent studies have shown that the elliptical movement of scaling tips is observable regardless of the type of generator used, but variations may exist between classes of instruments due to a lack of standardisation.

Ultrasonic scalers have their own irrigation mechanism, mainly used to cool the heat generated by the rapid movement of the tip and to remove debris from the tooth surface.

4.4.2. Cavitation and Acoustic Microcirculation

The ultrasonic scaler generates biophysical forces around the oscillating tip, promoting cavitation when it interacts with the water. This creates tiny bubbles, which, when they implode, release energy that can disrupt the cell walls of bacteria, destroying them. Acoustic microcirculation, on the other hand, generates shear forces around the probe immersed in the water, contributing to the acoustic turbulence that eliminates deposits and breaks up the biofilm. Research efforts are underway to improve cavitation at the working tip in order to optimise the cleaning process. [8]

4.5. Presentation of the Different Tips and Devices Used (See Figures 7-9)

Figure 7. Two-tank appliance. [11]

Figure 8. Piezo electric scalers. [11]

Figure 9. Odontosonde goof. [11]

4.6. Scaling Dental Surfaces

According to the definition of the First European Periodontology Workshop, scaling can be included in basic periodontal therapy or cause-related therapy (See **Figure 10**). Supra- and sub-gingival biofilm and calculus are mechanically removed during initial cause-related therapy using a combination of debridement, scaling and root planning. When soft microbial deposits are removed from root surfaces under direct view during flap surgery, debridement may also be part of the surgical therapy. [12]

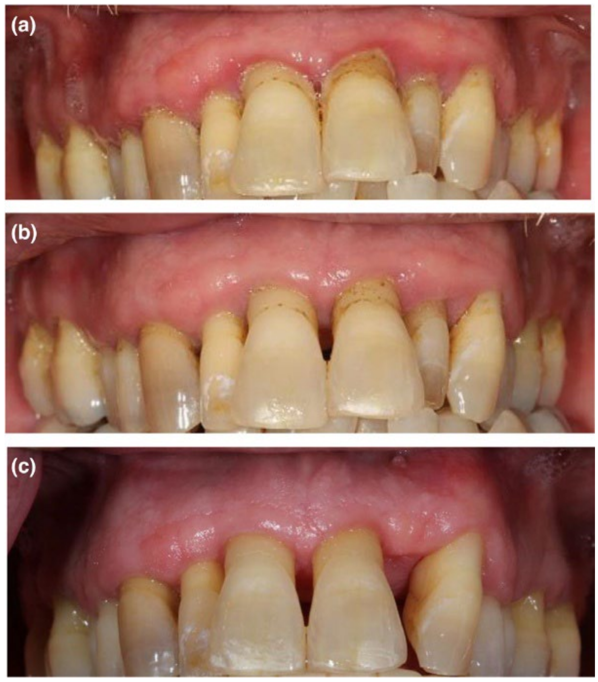

Figure 10. Evolution of the condition of teeth and mucosa after scaling. [13]

Although sonic and ultrasonic scalers were originally designed for scaling and removal of supragingival calculus, studies have shown that they can be used in a comparable way to manual instruments for subgingival instrumentation. [8]

4.6.1. Elimination of Plaque and Calculus

The use of ultrasonic devices for subgingival debridement offers a therapeutic approach that is less invasive and more comfortable for both patient and practitioner. [14]

To avoid infection at the point of communication between the root and the body, these biofilms can also form inside the tooth and must be removed. Such infection can lead to abscesses and other tissue inflammation. When ultrasonic vibrations are used, many tooth cleaning procedures can be carried out using manual instruments, but the process can be completed much more quickly and with less work. These are bacterial biofilms that may or may not be calcified. They are physically removed from the tooth using vibrations transmitted to a steel probe. (See **Figure 11**)

Figure 11. Evolution of the condition of teeth and mucosa after scaling. [10]

4.6.2. Reduction of Periodontal Inflammation

During routine periodontal therapy, subgingival instrumentation is an effective treatment for reducing inflammation, probing pocket depth and the number of affected sites in patients with periodontitis. This effect was constant, regardless of the choice of instrument (sonic/ultrasonic or manual) or mode of administration (whole mouth or quadrant). Thus, on shallow sites (4 - 6 mm), an average reduction in PD of 1.5 mm can be expected at 6/8 months, while on deeper sites (≥7 mm), the average reduction in PD has been estimated at 2.6 mm.

An overall pocket closure rate of 74% at 6/8 months was observed, combined with a mean BOP reduction of 62%. Considering the degree of disease resolution, measured in terms of pocket closure, it appears that well-performed, non-surgical periodontal treatment may limit the need for additional/alternative treatment approaches, which may result in higher costs for patients.

Cases classified as stage 1 or 2 are characterised by the presence of shallow pockets (≤5 mm), while stages 3 and 4 are characterised by deep probing and damage to the furcation. Although not perfectly aligned in terms of pocket depth thresholds, the present review showed that in more advanced cases, non-surgical treatment was more effective in terms of reducing PD, while disease resolution, as measured by pocket closure, was less likely. [13]

Future studies could use the biofilm model presented to investigate the non-contact effectiveness of ultrasonic instruments. [15]

4.6.3. Mechanism

In the present study, the same devices and techniques were used, and these earlier findings could also be reproduced in this biofilm model. However, the loads applied were higher in the latter case, ranging from 100 to 200g. (See **Figure 12**)

Future studies could use the biofilm model presented to investigate the non-contact effectiveness of ultrasonic instruments using different modes of action, power settings and geometries. However, it should be borne in mind that the arrangement of the samples, *i.e.*, the integration or attachment of the samples, can influence the transduction of vibrations and therefore, the effectiveness of the treatment. The disc material can also play a role. [16]

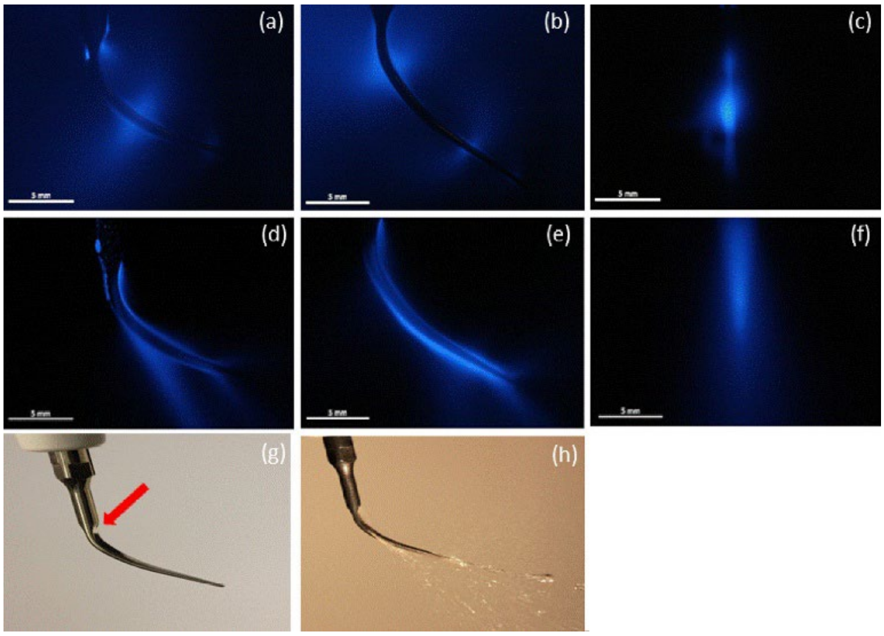

Figure 12. Mapping of an ultrasonic luminol insert; 30 s exposure at full power. Tips immersed in solution (a) A tip; (b) P tip; (c) PS tip; tips in the air with luminol irrigant flow (d) A tip; (e) P tip; (f) PS tip. The PS tip is shown in face-up orientation; (g) Showing the configuration of the tip in the air with the irrigant outlet indicated by the arrow; (h) Illustrates irrigant flow.

In this regard, it can also be assumed that a finer tip could cut the disc by projecting micrometer-sized particles, which could then add to a slurry increasing cavitation. In the present study, we used an HA artificial disc with a Knoop hardness index of 310, which is in the range of enamel, and no surface damage could be observed. However, this does not exclude the possibility of microscopic damage, and it would be interesting to evaluate this aspect on dentin or other biological surfaces and biomaterials in terms of biofilm removal in combination with surface damage in future studies.

Studies on ultrasonic devices provide valid documentation of their effectiveness, particularly when biofilm models are used, and this study provided the first insight into the microbiological aspects of the action of ultrasonic scalers. [17]

4.6.4. Elimination of Pathogenic Bacteria

One aim of non-surgical periodontal therapy is to reduce the amount of tooth-associated biofilms and their biological products, such as endotoxins, antigens, enzymes and other tissue-irritating substances.

This can be achieved by scaling and root planning or root debridement, with or without local administration of antimicrobials and/or antiseptics and/or the use of adjunctive systemic antimicrobials. Systemic colonies or microbial communities associated with other extracellular or intracellular mucosal niches in the mouth are not generally targeted by this initial therapy.

Research has shown that saliva, cheek, tongue, tonsillar crypts and the palatal surface are other sources of cross-contamination of the periodontium within and between individuals. However, to control reinfection, non-surgical therapy rarely involves treating the whole mouth or the whole body. The presence of disease is statistically linked to the quantity and bacterial composition of dental plaque. [5]

4.6.5. Effectiveness of Cleaning and Decontamination of Dental Surfaces

Every study that examined this outcome showed a significant improvement in this clinical factor "Efficacy". There were no statistical differences between the treatment groups, but it should be borne in mind that the majority of the studies included had a high risk of bias for several of the criteria assessed.

Non-surgical periodontal treatment mainly involves the use of manual or motorized instruments, such as sonic or ultrasonic scalers, with the choice of instrumentation depending on the operator's preference.

Recent clinical studies have examined the differences between sonic/ultrasonic and manual debridement in the treatment of chronic periodontitis, but there is a need to continue to update the evidence base for manual and sonic/ultrasonic techniques in periodontal therapy. [18]

4.6.6. Minimization of Damage to Healthy Tissues

Scaling is a common buccal treatment method, and thermoelectric instruments have become popular for cleaning central teeth and alveolar regions. However, these procedures can cause rough areas such as scratches and fractures on enamel biomaterials. Ultrasonic scalers used along the cervical margin can easily damage restorative surfaces, which can lead to tooth enamel hypersensitivity and oral complications.

In the frontal areas of teeth, plaque and sediment accumulate excessively, exposing restorations to gingival treatment. Side effects associated with these friction treatments include increased roughness of fibrous tooth tissue and wound dressings. External divergences dramatically increase the available surface area by 3 to 4 times, providing an area of interest for pathogens to adhere and grow, resulting in more rapid plaque hardening. Bacterial adhesion has been shown to be equivalent to implant surface quality.

The ultrasonic equipment did not reduce the module of traction for less than 10 minutes, but after 20 minutes, it decreased considerably. The difference in temperature dependency characteristics between the dental components, the cement and the metal base leads to discrete movements of these components, resulting in the disintegration of the two superimposed components and, consequently, a loss of interfacial adhesion in compression. [19]

4.6.7. Limitations, Considerations

Periodontitis recommend sonic scaling every 6 to 12 months. The side effects of these friction treatments include an increase in the overall roughness of the fibrous dental tissue and wound dressings.

The passage of the ultrasonic insert over the tooth surface must be carried out very carefully, and polishing the scraped surfaces can help to attenuate the changes in roughness, thus minimizing additional cavities, discoloration of the upper layers, plaque hardening and subsequent aggravation of the gums. [20]

Of all the elements used, we can observe that ionomer lenses had a greater chance of impact. They are more likely to increase roughness, certainly more than any other element tested to date. Therefore, it is fair to say that modified ionomeric lenses work better in this respect. The *in vitro* design is the main limitation of this study. The effects of saliva-accumulated chewing and the aging of ceramic materials may influence the results under real clinical conditions. Further clinical studies are required to confirm the results of this study. In addition, further studies should evaluate the polishing method for removing discoloration from ceramic restorations after ultrasonic scaling procedures and the possible side effects of polishing. [20]

4.6.8. Complications

The procedure may cause damage to soft tissue or teeth, as well as restorations. Even in patients on medication, the risk of bleeding associated with non-surgical therapy is low and easily controlled by local hemostatic measures. Cervicofacial subcutaneous emphysema is not a common extra-oral intraoperative complication that occurs with the use of air polishing. [16]-[19]

In addition, the side effects of non-surgical periodontal therapy, such as pain, fever and dentine hypersensitivity, are frequently reported and can have a significant impact on the patient's perception of the treatment they receive. The types of instruments used the characteristics of the tips and the patient's individual tolerance can have an impact on the level of intraoperative pain. Procedural errors can also cause unexpected damage to teeth or restorations. [21]

5. Conclusions

The findings of this detailed research convincingly demonstrate that ultrasound is a remarkably effective modality, providing significant diagnostic and therapeutic benefits. Studies have shown that saliva, cheek, tongue, tonsillar crypts and the palatal surface are other sources of cross-contamination of the periodontium within an individual or between individuals. However, to control reinfection, non-surgical rarely involves treating the whole mouth or the whole body. [5]-[22]

Regarding scaling, the ultrasonic vibrations produced by specialized devices enable efficient detachment of these deposits, significantly reducing bacterial load. This proactive approach plays a crucial role in preventing oral diseases, particularly caries and gingival conditions. The inherent advantages of ultrasonic instrumentation extend beyond clinical efficacy, a key feature is its adaptability, facilitating synergistic use with other dental treatments, thereby contributing to improved overall outcomes.

Although significant progress has been made in the use of ultrasound in dentistry, questions remain, requiring further research to deepen our understanding of its effectiveness. These promising advances pave the way for modern dental practice focused on therapeutic efficacy and patient well-being, with positive implications for the future of dental care. [23]

Conflicts of Interest

The authors declare no conflicts of interest.

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