ORIGINAL RESEARCH

Assessing Microbial Dynamics in Carious Lesions: Exploring the Role of Er:YAG Laser in Conservative Dentistry

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ABSTRACT
Background:The objective of this study was to explore the impact of Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser therapy on the concentration of cariogenic species and the microbial load composition within therapeutic cavities. This investigation aimed to assess the potential reduction in microorganisms following Er:YAG laser treatment and make a comparative analysis with conventional manual and rotating therapies (CT).**Methods**:Conducting a clinical trial, adult participants presenting with active deep carious lesions on permanent teeth were divided into two groups: a control group undergoing conventional treatment (CT) and an intervention group receiving Er:YAG therapy. Before and after any conservative treatment, oral samples were collected using a sterile microbrush scrubbed within the base of the dentinal cavity tissue. The focus was on evaluating the percentage reduction and colony-forming units (CFUs) count for total microorganisms, including Candida spp., Streptococcus spp., and Lactobacillus spp., after Er:YAG and conventional treatments.**Results**: indicated a substantial microbial reduction ranging from 80.2% to 100%, notably observed for total microorganisms and Streptococcus spp. ($p < 0.05$) following Er:YAG laser therapy. This outcome underscored the potential clinical applications of Er:YAG laser treatment, particularly in cases involving pediatric and complicated patients. The minimally invasive properties of Er:YAG laser therapy, coupled with its demonstrated efficacy in reducing microbial load, suggest its viability as an alternative or adjunctive approach in conservative dental treatments.**Conclusion**: These findings contribute valuable insights into the potential benefits of incorporating Er:YAG laser therapy into clinical practice, offering a promising avenue for improving treatment outcomes, especially in challenging cases.
Keywords:Er:YAG laser; conservative dentistry; oral microbiome; cariogenic species

INTRODUCTION

Caries, a prevalent chronic disease with an infectious origin, manifests as the deterioration of hard and mineralized dental tissues. This complex condition arises from a convergence of various contributing factors, including bacterial metabolism, dietary choices rich in sugars, inadequate oral hygiene practices, and intrinsic susceptibility influenced by socio-cultural elements.[1] Factors such as the patient's education level and employment status play a role in shaping the individual's susceptibility to caries.The destructive process at the heart of caries is fueled by the metabolic activities of commensal bacteria within the oral biofilm. These microorganisms release acid metabolites, which, over time, lead to the demineralization of tooth surfaces and the formation of carious cavities. The insidious nature of caries emphasizes the need for a comprehensive understanding of the interplay between microbial, dietary, and behavioral elements.[2]Current theories on the microbial etiology of caries, such as the "Specific Theory" and the "Ecological Plaque Theory," shed light on the importance of certain bacterial species in the disease's progression. Notably, Streptococcus mutans and Streptococcus sobrinus have been identified as primary pathogens associated with caries, contributing to the dysbiosis of commensal microbiota. This dysregulation disrupts the delicate balance of microbial communities in the oral environment, further exacerbating the risk of carious lesions.Addressing the multifactorial nature of caries requires a holistic approach to oral health. Effective prevention and treatment strategies must extend beyond targeting the presence of cariogenic bacteria and consider lifestyle factors, dietary habits, and oral hygiene practices.[3,4] This broader perspective is instrumental in managing and mitigating the impact of caries, offering a comprehensive framework for oral health care that goes beyond the traditional focus on individual pathogens. As an ever-present oral health concern, understanding the intricate dynamics of caries is essential for developing tailored interventions and promoting overall dental well-being.Conventional methods of caries removal, including manual and mechanical rotating instruments such as dentine spoons, turbines, or drills, have long been associated with patient discomfort.[5,6] While local anesthesia can alleviate pain, issues such as noise, vibration, and fear of needles may persist. Furthermore, the mechanical techniques involved in these methods pose the risk of removing significant amounts of healthy tissue and may inadvertently damage the pulp by increasing temperature due to thermal stimulation.In response to these challenges, alternative treatments have been proposed to preserve tooth structure and adopt a more conservative approach. Chemo-mechanical methods, ozone therapy, and laser technology represent some of these alternatives. These methods aim to selectively remove damaged tissue, minimizing the loss of healthy tooth structure and reducing patient discomfort.[7]Ozone therapy, despite having various applications in dentistry, still carries risks, particularly concerning upper airway issues and contraindications in fragile subjects. On the other hand, lasers present a promising alternative with a dual effect—both mechanical and thermal. Lasers have the potential to disorganize microbial biofilms effectively. This is particularly significant as carious lesions can progress and reach the pulp if pathogenic microorganisms are not adequately eliminated from the cavity. Residual microorganisms also pose a potential risk for recurrent caries in conservative dental treatments.The exploration of alternative caries removal methods reflects a commitment to patient comfort, preservation of healthy tooth structure, and enhanced efficacy in eliminating pathogenic microorganisms. As technology continues to advance, these alternative approaches contribute to the evolution of conservative dental treatments, striving to optimize outcomes and minimize potential risks associated with traditional methods.

The introduction of laser therapy in dental procedures has not only demonstrated efficacy in reducing microbial load but has also shown a significant impact on bacterial adhesion to dental surfaces.[8] Among the various laser systems, Erbium:Yttrium-Aluminum-Garnet (Er:YAG) therapy is frequently employed for hard dental tissue ablation. This wavelength coincides with the absorption peaks of water and hydroxyapatite, facilitating the removal of mineralized dental substances through micro-explosions.Carious tissues, compared to healthy ones, contain higher water content, enhancing the absorption of Er:YAG laser chromophores in infected areas. Consequently, Er:YAG laser therapy proves to be a selective and conservative approach for caries removal, allowing for the creation of therapeutic cavities without excessive extension into healthy tissues beneath the lesion.[9] The Er:YAG laser combines photoablative and decontaminating properties with minimally invasive characteristics, offering benefits beyond conventional therapy (CT).In contrast to CT, Er:YAG laser therapy minimizes vibrations and noise, providing a more comfortable experience for patients. Importantly, the high temperatures developed during laser irradiation contribute to bactericidal and bacteriostatic properties. The photothermal effect generated during ablation can effectively disinfect residual bacteria in the cavities without causing thermal damage to the dental pulp.Furthermore, laser irradiation, particularly with Er:YAG, has the potential to melt inorganic components of dentin and induce remineralization. This unique feature allows for the sealing of treated dentinal surfaces and enhances resistance to recurrent caries.[10] By combining efficient caries removal, disinfection, and remineralization, Er:YAG laser therapy emerges as a comprehensive and advantageous approach in modern dentistry.In summary, the utilization of Er:YAG laser therapy represents a significant advancement in dental care, offering a host of benefits including selective caries removal, bacterial disinfection, and remineralization. These features contribute to a more patient-friendly and effective approach to managing carious lesions, highlighting the continued evolution of dental technology and treatment modalities.

MATERIALS AND METHODS

In alignment with recent articles and methodological considerations, the study evaluated an appropriate sample size, determining a capacity to recruit 66 patients while accounting for a 10% dropout to maintain statistical significance. The patient cohort was randomly assigned to two groups: group A, the control group, undergoing treatment with conventional therapy (CT); and group B, the intervention group, receiving treatment with Erbium:Yttrium-Aluminum-Garnet (Er:YAG) therapy. Randomization was achieved by associating each treatment (group A or group B) with individual participants through a randomized sequence maintained in numbered opaque envelopes. This ensured the preservation of a randomization sequence and minimized selection bias.

The treatments administered did not involve the routine use of anesthesia unless explicitly requested by the patient during the procedure or deemed necessary by the operator based on the patient's clinical conditions.The study's sample included adult patients of both sexes aged 18 years or older, each presenting with a cavitated non-destructive carious occlusal lesion on a permanent tooth. These lesions extended up to the middle third of the dentin, as confirmed by radiographic examination, without evidence of pulp involvement. Exclusion criteria encompassed patients who refused to provide informed consent, individuals under 18 years old, pregnant subjects, those with syndromes or chronic systemic diseases, recent use of antibiotics or pharmacological treatments, and those experiencing painful symptoms of irreversible pulpitis, tooth mobility, or destructive carious lesions extending beyond the middle third of the dentin. Additionally, patients with carious lesions exposing the dental pulp or associated with periodontitis were excluded, as were individuals with caries on deciduous teeth. During the course of the trial, patients who did not cooperate with radiographic examinations or treatment procedures were subsequently excluded.This rigorous inclusion and exclusion criteria framework ensures a focused study population, allowing for a more controlled investigation of the effects of Er:YAG therapy compared to conventional therapy in the management of carious lesions.

RESULTS

The research collected samples from a total of 66 patients, systematically distributed into two groups: group A with 30 participants and group B with 36 participants. The aim was to conduct microbiological analysis on these samples, representing a comprehensive investigation into the microbial dynamics associated with carious lesions in permanent dental elements. However, during the sample collection process, certain exclusions occurred. Specifically, samples from one participant in group A were excluded due to suboptimal storage conditions in the transport medium. Additionally, samples from two subjects in group B were excluded due to contamination of the transport medium. As a result, a meticulously examined dataset comprising a total of 112 samples, encompassing both pre- and post-treatment samples from 56 permanent dental elements (28 in each group), was considered for the final analysis, revealing the presence of microbial growth.

In delving into the demographic composition of the study participants, the gender distribution demonstrated that 43% of the patients were female (24 individuals), while 57% were male (32 individuals). Further exploration based on age categories showcased the diversity within the study population. Specifically, 18% of the patients were between 18 and 30 years old, 28% fell within the age range of 30 to 42 years, 29% were aged between 42 and 54 years, and 25% were in the age group of 54 to 66 years.This comprehensive microbial analysis, considering both pre- and post-treatment samples, provides a robust foundation for evaluating the efficacy of the different treatments administered—conventional therapy in group A and Erbium:Yttrium-Aluminum-Garnet therapy in group B. The demographic breakdown ensures a representative sample across various age groups and gender categories, enhancing the applicability and generalizability of the study's findings. The meticulous attention to the exclusion criteria and the subsequent detailed analysis contribute to the scientific rigor and reliability of the study, fostering a deeper understanding of the microbial response to different therapeutic interventions in the context of carious lesions.

Table1: Distribution of patients in two groups

	No. of patients
Group A	30
Group B	36
Total	66

Figure1: Distribution of patients in two groups

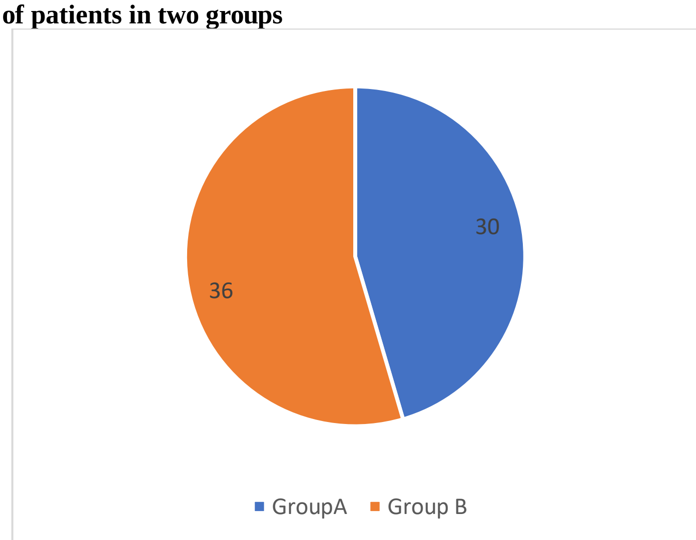


Figure2: Gender distribution

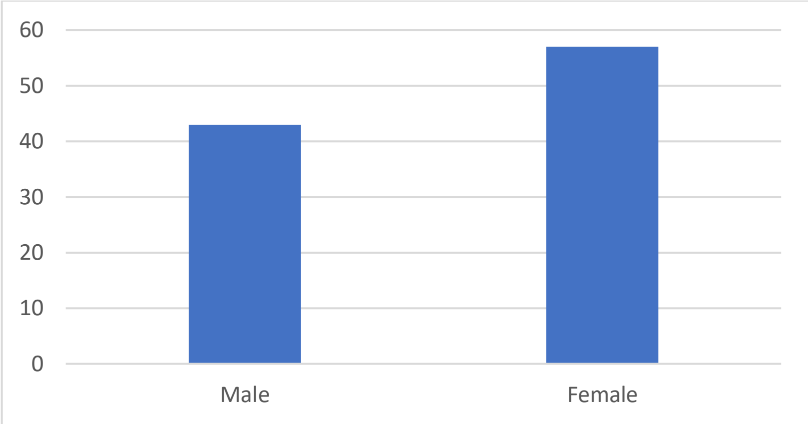
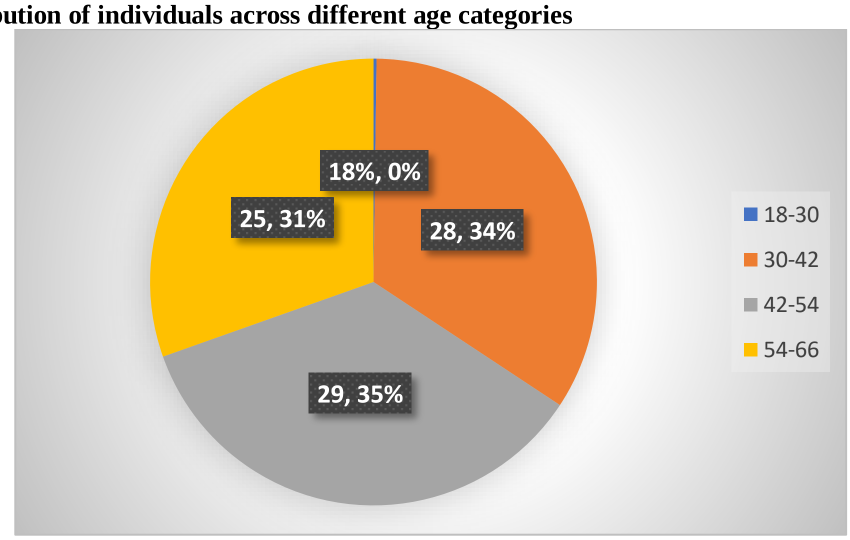


Table2: Gender distribution

Gender	% of individuals
Male	43%
Female	57%

Figure3:distribution of individuals across different age categories



DISCUSSION

In the realm of conservative dentistry, the Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser has emerged as a compelling alternative to traditional handpieces for the removal of dental carious lesions. This is attributed to its distinctive decontamination properties and strong affinity for mineralized tissues. Moreover, the Er:YAG laser offers notable advantages in terms of patient acceptability, making it an increasingly preferred choice in clinical practice.One significant aspect is the perceived reduction in patient discomfort associated with Er:YAG treatment compared to conventional therapy (CT).[11,12,13] The use of Er:YAG lasers is often characterized by being less painful and invasive, particularly in terms of minimizing noise and vibrations, thereby enhancing the overall patient experience. This patient-friendly attribute contributes to a positive perception of Er:YAG treatment, making it an appealing option for individuals undergoing dental procedures.Scientific research supports the notion that pediatric patients, in particular, exhibit higher compliance with laser therapy, underscoring the effectiveness of Er:YAG treatment in this demographic. The minimally invasive nature of Er:YAG lasers aligns well with the unique considerations of pediatric dental care, where managing patient comfort and cooperation is crucial. The reduced perception of pain and the absence of disruptive noise and vibrations associated with Er:YAG therapy make it a more acceptable and tolerable option, facilitating a smoother and more positive experience for young patients.In summary, the Er:YAG laser has gained recognition in conservative dentistry not only for its decontamination capabilities and strong affinity for mineralized tissues but also for its patient-friendly attributes. The reduced pain, invasiveness, and acceptability of Er:YAG treatment, especially in pediatric patients, contribute to its growing popularity as a viable and preferred tool for caries removal in contemporary dental practices.[14]

The primary objective of this research was to investigate the viability of Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser treatment as a safe and effective alternative to conventional therapy (CT) for the removal of caries and conservative cavity preparation. The study aimed to delve into the decontaminating properties of Er:YAG and its impact on microbial load, encompassing a comprehensive analysis of various microbial species.Examining microbial growth in permanent teeth affected by caries, the research revealed a substantial reduction of 91% following Er:YAG treatments, while CT achieved a microbial clearance rate of 80.6%. This significant microbial reduction following Er:YAG treatments led to the rejection of the first null hypothesis, signifying the elimination of cariogenic microorganisms and the establishment of a decontaminated therapeutic cavity.[15]Building on prior research by Schwass et al., the study underscored that Erbium laser irradiation not only facilitates the complete removal of demineralized tissue but also enables a minimally invasive preparation. The mechanism involves the promotion of water absorption, initiating dental ablative processes characterized by micro-explosions, water evaporation, and dental tissue expansion and expulsion. Protocols for Er:YAG caries removal on permanent teeth were meticulously designed with pre-set parameters, ensuring a standardized effect and predictable cut level, thereby minimizing operator-dependent variations in the amount of removed dental tissue.[16] In an effort to preserve pulp vitality, working times were strategically reduced, resulting in lower heat doses. The decontaminating properties of Er:YAG were leveraged to optimize residual tissues, facilitating a minimally invasive approach with a reduced risk of pulpal exposure. However, the study acknowledged the necessity for further investigations to assess the amount of residual healthy dentin accurately.Notably, Er:YAG lasers exhibited a preference for deciduous tooth structures due to their lower thickness, more porous surface, and higher water and chromophores content, resulting in a higher cutting power. The potential variations in tissue mineralization, even within different areas of the same tooth, such as recently erupted permanent teeth with thicker enamel, emphasized the importance of additional research to comprehensively understand the effects of Er:YAG on different regions of dental elements.[17] Such insights would contribute valuable knowledge into the nuanced responses of various dental structures to Er:YAG laser treatment, further enhancing the understanding of its clinical implications.

The rejection of the second null hypothesis is supported by robust evidence demonstrating the significant reduction in microbial load achieved with the Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser, thereby affirming its noteworthy antimicrobial properties. A detailed examination of the average colony-forming units (CFUs) reduction reveals the efficacy of the Er:YAG laser compared to conventional therapy (CT), with particularly remarkable results for active and demineralized carious lesions, showing reductions of 91% and 80.6%, respectively.These findings harmonize with existing literature, where the thermal effect induced by laser ablation is acknowledged for its pivotal role in influencing the viability of microorganisms.[18] The elevation in temperature generated by the Er:YAG laser induces modifications in the cellular structure of microorganisms, leading to their elimination. This is especially relevant for bacteria implicated in the carious process. While the Er:YAG laser may not impart sterilizing power, the residual microorganisms that persist seem to have minimal relevance for the progression of recurrent or secondary caries beneath dental restorations.This comprehensive assessment accentuates the Er:YAGlaser's efficacy in significantly diminishing microbial load, positioning it as a potent antimicrobial tool in the realm of caries removal and conservative cavity preparation. The substantial reduction in CFUs observed following Er:YAG treatment, particularly in active and demineralized carious lesions, not only substantiates the study's findings but also contributes to the accumulating body of scientific literature recognizing the antimicrobial prowess of Er:YAG lasers in various dental applications.[19] This supports the growing acknowledgment of the Er:YAG laser's potential as a valuable asset in enhancing the microbial management aspect of dental interventions, offering a promising avenue for the advancement of minimally invasive and effective dental procedures.

The rejection of the third null hypothesis signifies a compelling and nuanced exploration of the superior antimicrobial effects associated with Erbium:Yttrium-Aluminum-Garnet (Er:YAG) therapy, particularly demonstrating advantages in addressing both the total microbial load and the streptococcal population. The meticulous analysis revealed a noteworthy 90.2% reduction in Streptococcus spp. following Er:YAG treatments, surpassing the 72.4% reduction observed with conventional therapy (CT).[20] Moreover, the genus Lactobacillus spp. exhibited complete reduction (100%) with both Er:YAG therapy and CT, while Candida spp. experienced a 94.4% reduction in lesions treated with Er:YAG and an 89.5% reduction with CT.These findings align seamlessly with established scientific literature, reinforcing the efficacy of Er:YAG protocols in significantly reducing the overall microbial load, particularly characterized by the genera Streptococcus, Lactobacillus, and Candida.[21] These microbial macrogroups, being among the most frequently investigated in dental microbial management, underscore the clinical relevance and applicability of Er:YAG therapy in addressing diverse microbial populations associated with carious lesions.The study thoughtfully brought attention to certain challenges associated with Er:YAG laser instrumentation, including issues related to assuming a correct working position for accessing carious lesions, attributed to the presence of a fiber-optical transport system. Furthermore, challenges in maintaining precise focus and localizing cutting points were highlighted. The study also acknowledged the economic considerations associated with laser instrumentation, noting its higher cost compared to traditional tools. Despite this, the potential for technological advancements and the ability of preventive, minimally invasive, and early treatments to mitigate the need for complex dental therapies were recognized as factors that could contribute to reducing overall costs.[22]It is essential to note a limitation of the research related to the chosen methodology for microbial culture, which relies on standard culture media. The study acknowledges the restricted spectrum of microbial species capable of thriving under these conditions and suggests the need for future research employing more advanced technologies, such as Next-Generation Sequencing (NGS) 16S rRNA sequencing. This advanced approach holds promise for offering a comprehensive understanding of the microbial landscape, ensuring that valuable data are not overlooked and facilitating a deeper exploration into the intricacies of microbial dynamics within dental lesions.

CONCLUSION

The study's findings illuminate the promising potential of Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser therapy in revolutionizing key aspects of dental care. Notably, the laser's ability to accomplish minimally invasive removal of carious lesions stands out, offering a conservative therapeutic cavity preparation that enhances resistance to acid dissolution. The transformative impact extends to the ultrastructure of enamel surfaces, where Er:YAG laser treatment brings about modifications conducive to micro-retentive surfaces, ideal for adhesive restorations.Furthermore, the research underscores the significant divergence in microbial load reduction between Er:YAG therapy and conventional treatment (CT). The distinctive antimicrobial efficacy of Er:YAG laser therapy becomes evident, marking a departure from traditional approaches.The study's nuanced analysis of microbial populations reveals differential reductions post-treatment. Notably, the statistically significant reduction in the Streptococcus spp. genus highlights the laser's targeted antimicrobial effects. Despite acknowledged limitations, these findings position Er:YAG laser therapy as a promising tool, not only for its conservative and restorative benefits but also for its specific impact on key microbial populations associated with caries.In conclusion, this research adds valuable insights to the ongoing evolution of dental interventions, accentuating the multifaceted advantages offered by Er:YAG laser therapy. As the dental landscape continues to embrace innovative technologies, this study contributes to the growing body of evidence supporting the integration of laser technology for conservative, minimally invasive, and microbiologically impactful approaches in the management of dental caries.

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