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Comparative Analysis of Latest Technologies in Microscopic Endodontics: Diagnostic

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Abstract **Background:** Modern developments in microscopic endodontics have included Dental Operating Microscope (DOM), ultrasonics, piezo technology, CBCT, digital imaging and scanning, laser endodontics, and nanotechnology. Aim: This narrative review also assesses the diagnostic efficiency, treatment outcomes, patients' outcomes and cost-effectiveness of these technologies. **Methods:** The literature search was done in PubMed, MEDLINE, Scopus, Web of Science, and Cochrane library by searching for English language, peer-reviewed articles published in the last 15 years. **Results:** According to this review, DOMs and CBCT both considerably increase diagnostic accuracy and therapeutic potential, which enhances treatment outcomes and raises patients' quality of life. Ultrasonics and laser endodontics can be used to produce minimally invasive treatments, and there is little to no pain following surgery. Nanotechnology and digital imaging are two instances of new technologies that still need to be developed. These technologies need significant capital investments from an economic perspective, but the investment pays for itself in returns. **Conclusion:** This review established that improvements in microscopic endodontic are impressive in diagnostic and therapeutic result while the initial costs are high. Arguments including increased accuracy in treatment, decreased patient discomfort, and better therapeutic outcomes serve as strong arguments for the continued application and advancement of endodontic tactics.

Key Words antioxidants, pharmacology, ethnomedicine, traditional knowledge, herbal medicine

1. Introduction

Endodontics is a science of treatment in dentistry that addresses diagnosing and curing diseases of the pulp and periradicular tissues of the teeth [1]. This field is very important to oral health, due to its focus on saving teeth that could otherwise be lost due to caries, diseases, or traumas. To put into perspective the importance of endodontics, one needs to consider the contribution of dentistry in improving the general well-being of the mouth and the head. In this way endodontics contributes to the stability of the dental arch, preserving teeth that are important for proper mastication, speech, and maintaining an attractive smile, as well as supporting oral health in the long term [2]. Specifically, endodontic procedures such as root canal treatments are intended to disinfect and seal off the pulp chamber and root canals from the rest of the tooth and anaerobic bacterial population to avoid further extension of the infection. Severing the affected pulp tissue followed by canal scraping and uncontaminated canal space refilling to avoid any further inflammations [3], [4]. This not only reduces pain and discomfort but also assists in preserving the natural tooth, which is considered the optimal solution by various studies other than extraction and dental implants [5].

Concerning the aspects of dental health, endodontics plays a certain significant role in the preservation of teeth and the prevention of their loss [6]. Replacement of a missing tooth results in other issues such as shifting of adjacent teeth, changes in bite relationship, or periodontal problems. Furthermore, it may lead to low self-esteem and therefore poor performance in social functions and activities shows the significance of the humanitarian impact that was extended to dental health [7].

The most significant innovation that has contributed to improved endodontics, however, has been the incorporation of microscopic endodontics [8]. A Dental Operating Microscope (DOM) was described to have taken endodontic treatments to another level. DOMs offer variable magnification of 3x to 30x and bright light illumination to offer the viewer optimal visual access to the root canal system [9]. This improved topography enables endodontists to easily detect and work on features of the root canal that are otherwise undetectable or barely visible without enhanced vision or with simple loupes [10].

Microsurgical endodontics has advanced the practice of better and finer control in endodontics. Looking down the root canal allows for effective negotiation of the anatomy and efficient instrumentation cleaning and shaping therefore avoiding canal and infection remnants. They've led to better success rates as well as longer patient recoveries than traditional treatments have offered in the past [11].

A. Research problem

One of the most important areas of development is the progress of micro technologies in endodontology Interestingly, the diagnostics and treatment options in endodontics have advanced rapidly, primarily due to the development of the microscope as the main tool. Still, the mentioned technologies differ in their performance and there is no special study which would compare the efficiency of these technologies, their advantages, and drawbacks. However, the use of these tools is expensive and technically demanding and this hinders the widespread application of the tools. As it is, further research into these technologies is necessary including their cost – efficacy and clinical implications or effectiveness in the dental practice.

B. Research Focus

This narrative review of the current literature reviews the particular application of recent advanced technology in microscopic endodontics; specifically, DOMs, ultrasonics, CBCT, digital imaging/scanners, laser endodontics, and nanotechnology. The review will seek to establish the strengths and weaknesses of these technologies in as far as diagnostic effectiveness is concerned, therapeutic effectiveness, patients' response and the cost-benefit analysis is concerned. So, it is aimed at offering the systematic view of the current and clinical researches in relation to the influence of these technologies on the endodontic practice.

C. Research Aim and Research Questions

To the best of this narrative review's purposes, this study aims to investigate the efficiency of the most recent technologies applied to microscopic endodontics; to compare the diagnostic and treatment outcomes of the innovations against existing technologies, as well as the effects on patients 'experiences and hospitals' expenses. The objective is to deliver information that will assist practitioners of dentistry to make appropriate choices pertaining to utilization of these technologies.

1) How do modern micro-technologies used in endodontics like DOMs and CBCT vary in the diagnosis and treatment accuracy?
2) Are positive clinical results and high levels of patient satisfaction obtained by application of ultrasonics, laser-assisted endodontics, and nanotechnology in endodontic treatments?
3) What are the costs of using new technologies at the microscopic level in clinical endodontics and what are the advantages compared to the costs?
4) When are these technologies not implemented and what strategies or solutions can be suggested for their implementation that would be beneficial for clinicians and patients?

The advancements in technology utilized in endodontic treatment not only increase the correct rate of treatment but also increase the patient's comfort. Several significant technologies have provided critical initiatives in this transformation. In this clinical setting, Cone-Beam Computed Tomography (CBCT) has turned into a significant diagnostic tool in endodontics. CBCT differs from conventional two-dimensional radiology in that it delivers three-dimensional images of teeth and organs around them which helps visualize the structure of root canals and surrounding tissues.

2. Literature Review

A. Historical Overview

Conventional methods of endodontic have for a long time been considered very vital in the treatment of patient's dental treatment having as their main aim the treatment of diseases of the dental pulp and tissues surrounding it such as root canal treatment [12], [13]. These conventional procedures generally concerned the application of simple hand equipment and standard emitting radiographs for the identification and management of infections within the tooth. This involved the initial phase of the removal of carious tooth tissue and the infected pulp, as well as the subsequent phases that involved the cleaning, shaping, and sealing of the root canal space to prevent further infection [14]. These methods relied mainly on the practitioner's feelings and vision, although, these could to a certain extent be quite useful though they were characterized by several difficulties and shortcomings [15].

In the past, generalized endodontic procedures were the backbone for most root canal treatment procedures; however, one of the major disadvantages related to these approaches was the inability to provide higher visualization. As for now, there were no improved imaging methods, so, a dentist could only employ two-dimension images, x-rays that only give them a restricted look into the internal structure of a tooth. This often complicated the understanding of the morphology of the root canals and, thus, the treatment of various C-shaped canals or of multiple or accessory canals that could contain residual infection if not removed [16]. Further, limited visibility of the root canal system also posed challenges to the procedure as it made it difficult to avoid serious complications like perforations or bypassing some canals during the process, which in turn influenced the success of the treatment [17].

Another major hurdle was the lack of efficacy, specifically in the process of cleaning and shaping the root canals. Previous techniques employing hand files and solutions remained unable to effectively clear out all the infected tissue and debris from the complex work canal network. Its long-term application could also lead to infections which would require repetitive treatments. Additionally, the tactile sensation of stones used in Endodontics was not sufficient to clean the curved and narrow canals keeping in mind the contour of the root canal system leaving behind un-cleaned canals and the possibility of treatment failures [18], [19].

B. Introduction of Microscopic Endodontics

Microscopic endodontics can be defined as a paradigm shift in endodontic practice as it has scaled down the instrumentation of periodontal endodontics and enhanced the accuracy and efficacy of endodontic procedures [20]. Three of them can be described as significant milestones in the evolution of microscopic endodontics: The last major development is the use of the DOM. This technology was revolutionary in changing anticipation due to its capacity to produce higher magnification and light on the area being operated by the practitioner, thus meaning that the practitioner was able to see better the details of the root canal system [21], [22].

The dental operating microscope provided a magnifying lens with a magnification range of 3X to 30X together with a fiber optic light source permitting dentists to view anatomy that was inconceivable to view using the naked eye. These details remained critical in the assessment of other features such as the presence of accessory canals, fractures, and other defects within the tooth. The improved visualization additionally augmented the accuracy of diagnoses and better instrument visibility allowing for better and safer cleaning and shaping of the root canal orphans with the reduction of the chance of leaving infection or technical mistakes. The first impressions and early implementation experiences with MIE by dentists were primarily favorable. Dentists also understood that this innovative technology provided better results in treatment and enhanced the care of patients [23]. Endodontic treatment programs for both basic microscopic endodontics and continuing education courses on applying the technology were progressively offered to update the knowledge of practitioners and assimilate the technology into their practice [24]. The application of DOMs was adopted as standard in many advanced endodontic treatment procedures and established a new era for advocates of precise and high-quality endodontic treatment. It also made the evolution and improvement of other technologically sophisticated approaches and instrumentation possible. For example, dendospace integration with a dental operating microscope with ultrasonics and laser-aided technologies added more efficiency to endodontic therapies [25]. Ultrasonics enhanced cleaning within the root canals, as shown by the reduction in debris and biofilm removal capability of the instrument, while lasers' disinfection potential exceeded that of ultrasonics. Such integrative approaches are productive and have led to better outcomes in patients compared to single-modality treatment [26].

C. Latest Technologies in Microscopic Endodontics

1) Dental Operating Microscopes (DOMs)

Features and Advancements in DOMs: DOMs are essential devices in present-day endodontics, where they facilitate up to 30 times magnification and intense light source. Some of these application features make it possible for endodontists to view structures within the root canal system that are not visible to the naked eye. Recent developments include ergonomic solutions to decrease operators' fatigue, incorporation of high-definition cameras for documentation and more practical purposes such as education of the patient, and better lighting for optimal visualization of the root canal in its deepest and narrowest part [27].

D. Impact on Visualization and Precision During Procedures

By using DOMs, the visualization process becomes more precise, and very important given the sensitivity of endodontic procedures. Using a high level of magnification, it is also easier to identify and address other structures like accessory canals and microfractures on the root. This decreases the chances of missing infections and procedural due to staff shortages. The distinct perception also helps in; a cleaner and precise form of root canal shaping and filling; increased chances of a successful treatment and ultimate positive result for the patient [28].

E. Ultrasonic

1) Description and Applications in Endodontics

This technique uses high-frequency vibrations greatly in raising the efficiency of the endodontic instruments. These are effective instruments in cleaning and shaping of canals, especially the root canal. Irrigates that can be activated by ultrasonic belong to the strategy of debris, biofilm, and smear layer identification from the root canal system.

2) Efficiency in Cleaning and Shaping Root Canals

For cleaning and shaping root canals, ultrasonic instruments are decidedly more effective. The movements at higher frequencies enable greater penetration of the irrigants into the anatomy of the root canal system, thereby enabling effective debridement. Research has tended to find that ultrasonics can be more effective at removing debris and bacteria when compared to conventional protocols which can in turn minimize the likelihood of post-treatment infection and thus increase the success of endodontic therapies.

F. Cone-Beam Computed Tomography (CBCT)

1) Role of CBCT in Diagnosis and Treatment Planning

CBCT gives a three-dimensional overview of the dental structures which helps in enhancing understanding of the root canal morphology as well as the surrounding tissues. They also stressed how beneficial this technology can be in diagnosing different clinical scenarios, for instance, additional canals, root fractures, and periapical lesions [29]. CBCT has the advantage of highly detailed anatomical information, which cannot only help to plan the treatments but also cannot be observed from the two-dimensional radiography [30].

2) Advantages Over Traditional Radiography

CBCT offers several advantages over traditional radiography. It provides high-resolution, three-dimensional images that allow for better visualization of the tooth's internal structures. This leads to more accurate diagnoses and more effective treatment plans. Additionally, CBCT reduces the likelihood of diagnostic errors and can reveal pathologies that might be missed on standard radiographs [31]. Despite its higher cost and radiation exposure compared to traditional X-rays, the diagnostic benefits of CBCT often justify its use in complex endodontic cases.

G. Digital Imaging and Scanning

1) Use of Digital Sensors and Intraoral Scanners

The use of digital imaging and intraoral scanners has greatly enhanced the endodontic diagnosis and documentation processes [32]. Digital sensors are used instead of film to deliver high-resolution images with increased efficiency and lower emission of radiation. Intraoral scanners are applications that capture high-quality three-dimensional images of the teeth that can be utilized for diagnosis, treatment planning, and related restorations [33].

2) Impact on Diagnostic Accuracy and Documentation

Most of the procedures of the diagnostic field currently remove traditional image types from digital imaging, which have enhanced accuracy. The features of digital radiographs can be optimized, and images can be altered to provide a better understanding of the underlying root structures, open canal spaces, and pathological changes in the periapical area [29]. The intraoral scanner offers high-quality images of the morphology of the tooth and of the surface, which aids health care consultation with the patient as well as with specialists. The convenience of storing and sharing digital images is highly beneficial to documentation and other forms of inter-professional communication, hence improving patient care and coordination [34].

H. Laser-Assisted Endodontics

1) Types of Lasers Used and Their Applications

In laser endodontics, different kinds of lasers are used whereas common ones include diode, Er, and Nd. lasers to disinfection work, root canal preparation, and apicoectomy, respectively. These lasers can easily and deeply penetrate and kill bacteria inside the root canal system and provide a very high degree of sterilization [35].

2) Benefits in Disinfection and Minimally Invasive Procedures

Lasers have been used in endodontic treatments with many advantages. The ways it disinfects bacteria are more effective than conventional methods as it reaches bacteria that other methods cannot easily access the accuracy and detail of a laser are beneficial in dentistry because lasers cut and shape material with little abrasion to the rest of the tooth and much less discomfort for the patient [36]. Moreover, the surgeries using laser lead to reduced operations and recovery pain, hence, improving satisfaction and recovery among the patients [37].

I. Nanotechnology and Advanced Materials

1) Introduction of Nanomaterials in Endodontic Treatments

New materials of endodontics have evolved with the advancement of nanotechnology in the form of nanocomposites, nanoparticle-based sealers, and bioactive materials [38]. The properties of these nanomaterials have more advantages than the conventional material namely high mechanical strength, ability to kill bacteria and viruses, and biocompatibility [39].

2) Enhanced Properties and Outcomes

Nanomaterials in endodontic treatments are advantageous because of the following factors. Nanocomposites, as well as nanoparticle-based sealers, offer enhanced sealing properties thus minimizing chances of bacterial seepage and reinfection. Biological materials help in the revascularization and regeneration of tissues in the root canal thereby enhancing the prognosis of endodontic treatment. These superior materials enable higher and more long-lasting outcomes which help patients avoid repeating treatments and foster better long-term oral hygiene (Table 1) [40].

J. Comparative Analysis

1) Comparing Traditional Diagnostic Tools with Advanced Technologies

In the traditional endodontic process of diagnostics, the diagnostic tools employed include two-dimensional X-rays and basic palpation procedures. Even so, they are somewhat restricted and can overlook details of the tooth's morphology. CBCT and digital imaging, on the other hand, are considered modern techniques that give a three-dimensional and clear picture of the dental structures enabling the identification of the exact cause of the problems. For example, CBCT visualizes the root canal morphology, apical area, the existence of extra canal, root crack, and periapical pathology that are not recognized by the conventional radiographs; As a result, a precise diagnosis and treatment plan are possible. The use of digital sensors and Intraoral scanners provides higher diagnostic accuracy by offering instant high-quality images that can be altered for interpretation purposes if needed.

2) Case Studies and Research Findings

Several studies have revealed the fact of greater effectiveness of the CBCT scheme in the diagnosis of endodontic pathologies and the presence of periapical lesions, as well as in identifying complex root structures. In a study conducted by Setzer et al. (2022) established that CBCT examination had higher diagnostic gains compared to the traditional radiography for the detection of vertical root fractures. Further,

Technique	Features and Advancements	Impact on Visualization and Precision	Advantages Over Traditional Methods
Dental Operating Microscopes (DOMs)	High magnification (up to 30x), high-intensity illumination, ergonomic designs, integrated HD cameras	Enhanced visibility of root canal details, precise identification of anatomical structures, reduced procedural errors	Better identification and treatment of complex canals, higher success rates
Ultrasonics	High-frequency vibrations, activation of irrigants, effective debris removal	Improved cleaning efficiency, thorough debridement, enhanced disinfection	More effective debris and biofilm removal, reduced infection risk
Cone-Beam Computed Tomography (CBCT)	Three-dimensional imaging, high-resolution, detailed anatomical views	Comprehensive view of dental structures, accurate diagnosis, better treatment planning	Higher diagnostic accuracy reveals pathologies missed by traditional X-rays
Digital Imaging and Scanning	Instant high-resolution images, digital sensors, intraoral scanners	Enhanced diagnostic accuracy, better communication and documentation	Immediate image acquisition, lower radiation exposure, easier storage and sharing
Laser-Assisted Endodontics	Diode, Er, Nd lasers, effective disinfection, minimally invasive	Superior disinfection, precise tissue removal, less post-operative pain	Less invasive, faster healing reduced patient discomfort
Nanotechnology and Advanced Materials	Nanocomposites, nanoparticle-based sealers, bioactive materials	Better sealing, antimicrobial properties, promotes tissue regeneration	Improved durability and effectiveness enhanced long-term outcomes

Table 1: Shows summary of technologies in microscopic endodontics

the case reports have also cited examples pointing towards the ability of sophisticated imaging solutions to uncover key diagnostic aspects that changed the treatment plan and therefore, presented improved patient care [27].

K. Treatment Precision and Outcomes

1) Evaluation of Treatment Success Rates with Different Technologies

The specificity of treatment in endodontics has remarkably enhanced due to the increased use of modern technologies. Special instruments such as DOMs, for example, offer high magnification and enhanced illumination, therefore allowing endodontists to perform more refined tasks. This precision also helps avoid the possibility of cases where some canals are untreated or cases of residual infection hence higher chances of success in the treatments. The results produced by works that compared traditional methods with the ones that utilized DOMs and ultrasonics demonstrated a higher elevated percentage of success of the operations on the root canals. Through the advancement of these technologies, visibility is improved and hence thorough cleaning making chances of having treatment failures and having to do another round lesser. Also, laser-assisted endodontics hopefully have proved to have better disinfection than the conventional method hence the results will be satisfying to the patients.

2) Patient Outcomes and Satisfaction

Minimally invasive and high-technology treatment offers good results to the patients. Consequently, the treatments provided are more precise and efficient than conventional treatments, hence, less post-operative pains, shorter recovery time, and increased patient satisfaction. For instance, laser endodontics has been found to have less bacterial leakage, and cause less tissue irritation or inflammation, and therefore, treatment affects recovery time for patients. Furthermore, many of these technologies' uses are minimally invasive and decrease the need for appointments and subsequent treatments in several cases, which adds to the patient's comfort and satisfaction.

3) Minimally Invasive Techniques

This holds true for patients who benefit from treatments being offered by different technologies. The accuracy and efficacy of these treatments lead to reduced pain after the surgery and faster healing time and hence, a higher satisfaction level is achieved. For instance, laser dentistry, specifically those applied to endodontic therapy, checks lower bacterial load within the root canal, as well as reduced tissue damage, thus faster healing, and positive patient feedback [41]. Moreover, the refining of diagnosis and therapy with the help of such technologies implies that patients have fewer appointments and fewer treatments, which raises their satisfaction.

4) Benefits of Minimally Invasive Approaches Facilitated by New Technologies

That is why the application of new technologies, such as lasers, ultrasonics, and nanomaterials could be used as minimally invasive technologies in endodontics. These technologies support allowing more non-invasive treatment procedures that prevent unnecessary removal of tooth structure but achieve the treatment goal [42]. Lasers, for instance, are capable of selectively attacking the infected tissues without compromising adjacent healthy tissues thereby minimizing the amount of drilling and tooth structure that has to be removed [43].

5) Clinical Evidence Supporting Reduced Post-Operative Pain and Faster Healing

Supporting clinical outcomes for minimally invasive treatment methods enabled by these newer technologies are apparent. Clinical surveys suggest that patients treated with laser-assisted root canal therapies have considerably low levels of post-operative pain and discomfort as compared to those who have been treated with conventional methods. Furthermore, the detailed and pedantic preservation of personnel and tools in these techniques also enhances the rate of healing since tissue damage is minimal. Nanomaterials also have improved healing characteristics over cloth because they offer more secure sealing and anti-microbial characteristics to minimize reinfection while encouraging tissue rebuild.

L. Cost-Benefit Analysis

1) Economic Considerations for Practitioners and Patients

Although the complex technologies in endodontic cavity treatment are comparatively expensive to acquire for the practitioners, the return on investment usually offers more gains in the long run. When practitioners use appealing technologies like CBCT, DOMs, and lasers, they enhance the possibilities of attaining high treatment success rates, low retreatment rates, and highly satisfied patients, which, in turn, will help to improve their standing and attract more referrals from satisfied patients [44]. For patients, treatment costs utilizing new and highly developed technologies can be ultimately higher, but this should be compensated by better results, lower probabilities of requiring some extra interventions, and better perceptions of the procedure. Dealing with these treatments is more precise and efficient compared to the complications and follow-up doctor visits, which is time and money-saving in the process [45].

2) Long-Term Benefits Versus Initial Investment Costs
The cost of purchasing these technologies may be high in the beginning, but the returns, to both the practitioners and patients, are huge in the long run. This allows practitioners to expand the efficiency and accuracy of their diagnostic and treatment tools to enhance practice quality and profitability. Patients receive improved results, less determined discomfort, and faster rates of recovery. Therefore, the competence of the personnel also opens up the possibility of rendering qualitative care that will be compounded with the loyalty of the patient health population towards the practice [46].

3. Methods

A. General Background

It focused on presenting this narrative review to discuss the efficacy of the current technologies used in microscopic endodontics. It is a review of what is currently known about various state-of-the-art technologies used in endodontics concerning the diagnostic abilities, the custom that the technologies can offer to patients, and the cost implications involved.

1) Technology Focus
Scholarly that explores the application of enhanced techniques applicable in microscopic endodontics such as; DOMs, ultrasonic devices, CBCTs, digital imaging, laser endodontics, and nanotechnology.

2) Publication Date
Articles of the last 15 years' utilization to capture the most recent innovations and appropriate information only.

3) Language
Based on the language of publication: The number of articles and the distribution of publications in English languages.

B. Study Design

Published scientific research articles, review articles, meta-analyses, and clinical case reports at various levels of peer review.

1) Outcome Measures
Any research that involves the assessment of the efficiency and effectiveness of these technologies in diagnosis, treatment, precision of either diagnosis or treatment methods, outcome of treatment, use of less invasive procedures, or a comparison of the expenses incurred in the application of these technologies in endodontics with those of traditional techniques.

C. Exclusion Criteria

The following types of studies were excluded from the review:

1) Non-Scientific Publications
Editorials, opinion pieces, letters to the editor, and non-peer-reviewed articles.

2) Outdated Technologies
Research focusing solely on traditional endodontic methods without a comparison to advanced technologies.

3) Non-English Publications
Articles published in languages other than English due to language barrier constraints.

4) Irrelevant Focus
Studies that do not specifically address the efficiency or impact of advanced microscopic endodontic technologies. Insufficient Data: Studies lacking clear outcome measures or insufficient data for meaningful analysis.

D. Data Collection

For the present work, the first search provided many articles, and these were then filtered by their titles and abstracts. All articles identified within the pre-selected indexed databases that appeared to fit the inclusion criteria were retrieved in full for assessment. Screening was done by two reviewers who evaluated each article to determine its eligibility; in cases of disagreement, the reviewers discussed the discrepancies and came to a consensus or involved a third reviewer.

E. Descriptive Analysis

In descriptive analysis, the major emphasis was laid on the analysis of the efficiency and outcome of different advanced technologies in microscope endodontics treatment. In the analyzed sources, the following patterns and trends were highlighted: the diagnostic potential of modern equipment, such as CBCT, accuracy increases due to DOMs and ultrasonic instruments, minimally invasive interventions with laser and nanotechnologies, and the economic aspects that these tools entail. The study also elaborated on specific aspects of the patients who received these technologies, the outcomes, and satisfaction levels in which their utility and performance were best illustrated, concluding from the study's findings regarding actual applicability and relevance to endodontics.

4. Results

A systematic search was conducted, employing a specific search strategy to identify relevant literature. Initially, 1000 articles were retrieved. Following a screening of titles and abstracts, the selection was narrowed down to 200 articles for full-text evaluation. After thorough assessment, 50 articles were deemed relevant and utilized to inform and construct this review (Figure 1).

Alshargawi et al [47] investigated the impact of DOMs on the success rates of endodontic treatments. Modern improvements in dental tools include using loupes or surgical microscopes which have improved the precision of root

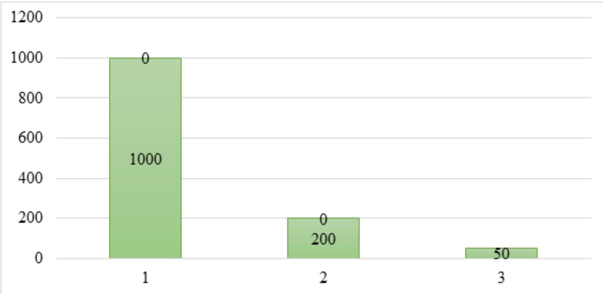

Figure 1: Summary of included studies

canal treatments. Currently, DOMs have become standard endodontic instruments as they enhance visibility and assist endodontists in locating specific structures such as anatomical references, canal orifices, and pulp remnants. DOMs' higher magnification and illumination aid in clearing bacteria and debris, as well as obtaining cleaner obturation, which is beneficial for treatment outcomes. This makes it possible for a competent endodontist to diagnose and treat the most minor canals and any other anatomical changes that may be present therefore using DOMs can significantly improve the overall success rates of endodontic treatments. Besides, DOMs enhance the ergonomics, communication with patients, as well as documentation processes in dental practice. Nevertheless, they have certain drawbacks, which include high costs and insufficient office areas that hamper their adoption. Reduced usage of the microscopes in endodontic work is attributed to poor education and understanding of the benefits that can accrue from the microscopes. Mittal et al [48] focused on the microscopic endodontics. They reported that optical magnification has also come a long way in promoting accurate visibility and has become a common tool in practicing endodontics. Some of the key benefits of an operating microscope include; Enhanced visibility and bright light, higher magnification, Iatrogenic accident prevention, comfortable working postures as well and documenting the treatment procedures. However, the beginning stages of the dental use of a surgical microscope have some difficulties that dentists meet with mouth mirror adjustments. Placed the rubber dam, it must be orientated so that the mirror is placed as close to the tooth as possible but outside the rubber dam at an angle of 45 °.

Putting the mirror in front of the tooth makes adjustments and focusing of the microscope constant and thus causes many inconveniences in the operation. Furthermore, a slight shake from the operator or assistant holding the mirror also interferes with its steadiness and consequently the focus and quality of the treatment. Another study aimed to compare DOMs with a high-resolution video scope (VS) in terms of depth of field (DOF), resolution, and their effects on fine motor skills [49]. This was done by two observers who used test targets to establish the amount of resolution and DOF of both the DOM and VS. Further, 18 participants, of which, 12 were dental students and 6 were endodontic residents, conducted an accuracy test on a manikin head using DOM, VS, or loupes. After each of the devices was returned, the participant was administered a post-test questionnaire to get their opinions of each device. The results indicated that the DOM, at its three magnifications, had higher resolutions (32, 40. 3, and 50. 8-line pairs/mm) and DOF (15, 10, and 6 mm) compared to the VS (resolution: 20. 1-line /mm; DOB 5 mm. The analysis of accuracy tests showed that DOM yielded higher scores than the VS for residents and students (P <. 001), while the VS did not differ from loupes. Also, regarding both facilities DOM and VS, merged results have shown that residents did better than students with a significant value of P <. 001. Overall, it was observed that on average the students spent 1. It took the subjects three times as long as the residents to complete the accuracy test, irrespective of the type of magnifying device utilized. The DOM and VS needed 1. 9 and 2. This application is 8 times more effective than loupes, and the respective longevity is 8 times longer. In the area of visualization, and the aspect of easiness in its usage, the majority of participants stated their preference for the DOM. The comments also indicated that the VS should serve to be valuable in diagnosis and magnification in endodontics.

5. Discussion

In this type of review paper, we reviewed the current literature regarding the efficiency of the latest technologies in microscopic endodontics. At the same time, the present study reveals breakthroughs that have revolutionized modern endodontic care. The use of modern optical magnification techniques has particularly boosted imaging during operations, providing levels of magnification and light previously unimaginable. It has also helped in increasing accuracy, especially in critical areas like identification of the canal orifices and maneuvering through the pulp canal. In addition, the use of digital imaging and the integration of software improved the diagnostic capacity and treatment planning. Moreover, the visualization provided by these technologies has allowed clarifying the morphology of the root canal and choosing the proper treatment plan. Their smooth implementation into clinical practice revealed that processes have been made more efficient and treatment plans more predictable. The advancement of instruments suitable for microscopic methods of endodontics has equally improved procedural time as well as patient care. Technological advances in file designs particularly nickel-titanium files with increased flexibility and resistance levels to cyclic fatigue have helped instream advancements in cleaning and shaping activities hence reducing procedural time and improving treatment outcomes. Nevertheless, several issues and limitations are still present even in today's society. The implementation of the latter technologies may be hindered in some environments by a lack of funds or physical infrastructure. Furthermore, variations in efficiency due to new technologies and increased training time for operators can also affect procedural performance in the short term.

Rashed et al [49] aimed to evaluate the effects of root-end resection, ultrasonic root-end preparation, and root-end filling on dentinal crack formation detected with digital microscopy (DM) and optical coherence tomography (OCT). In total, thirty extracted lower incisors received classic endodontic treatment, and further manipulations, OCT, and DM observations were performed right after the treatment and at intermittent for two months. The study showed that 47 of the samples had instrumented cracks after root-end resection and 87% after ultrasonic preparation was done. Peculiarly, the case was that new cracks appeared after ultrasonic treatment, but the existing ones did not expand further. These findings suggest that the material used to fill the crack, either MTA or super-EBA, did not affect the formation of the crack. Thus, the researchers found that OCT and DM have a rather low inter-observer agreement in quite a sensitive range when comparing crack detection (Spearman coefficient of 0. 186; p-value = 0. 015). In measure against control, OCT once again had a sensitivity and specificity of 0. 50 and 0. make the following HSI-to-micro-CT juxtapositions: HH = 29, LF = 55, relative to micro-CT, while DM was conversely characterized by high sensitivity (1. The study also engaged McNemar's test in the analysis of the results and concluded a significant difference in the ability of OCT and DM to detect cracks with p < 0.

Another study [50] evaluated the sealing efficiency and marginal adhesion of various root canal sealers to dentine. Sixty extracted human lower premolars were employed, duly cleaned for removing the pail deposits and calculus, and then accessed through a straight cut at the CEJ level. After cleaning and shaping the canals, the teeth were randomly divided into three groups based on the sealer used: Endosequence BC bioceramic sealer, Endorez resin-based sealer, and Pro root MTA-based sealer were used in this study. Seventy molars received root canal fillings with AH Plus sealer, and SEM with 5000 x magnification was used to assess the marginal gaps at the root dentin and sealer interface in the middle and lower thirds of the root canal. The present study revealed that evaluated materials in different groups were significantly different from each other and EndoSequence BC sealer had the highest marginal seal effect with a score of 5. 60 ± 0. 12, ProRoot MTA sealer score was 4. 48 ± 0. 12 and EndoREZ sealer score was 2. 10 ± 0. 54. Results obtained from the statistical analysis proved that EndoSequence BC sealer and ProRoot MTA, have significantly variably marginal adaptation both at apical and coronal regions revealed by 'p = 0. 001'. At the coronal level, the EndoSequence BC and EndoREZ sealers showed a significantly (p < 0. 05) different sealing ability meanwhile the apical level presented a significantly (p < 0. 05) lower sealing ability for the EndoSequence BC compared with EndoREZ and ProRoot MTA sealers. The objective of the study by Wang et al [51] was to evaluate the results of endodontic microsurgical procedures and assess the predictive variables that affect these results. In this prospective clinical trial, 98 teeth from 81 patients were included and all the surgical procedures were carried out by an endodontist using microsurgical techniques. The treated teeth were clinically and radiographically re-examined at least one year after the surgery. Radiographic healing was classified into four categories: fulfilled, unfulfilled, ambiguous, and inadequate. Multivariate logistic regression analysis was used to determine the prognostic factors. Of the 98 teeth, 74 (75. 5%) were recalled and assessed 12 to 30 months after the surgery. Of these, 71 were evaluated clinically and radiographically, and 3 had been removed. The results of the periapical radiographs are presented in Table 2; 55 teeth (74. 3%) were completely healed and 12 teeth (16. 2%) were partially healed. To sum up, the complete and incomplete healing rate was 90%. 5% (67/74) of all the teeth in the 67 analysed were considered clinically normal. Some 3 teeth (4. 1%) had uncertain healing, one of which had symptoms of pain, sinus tract, and swelling while the other two had no symptoms at all. One tooth (1. 4%) did not heal satisfactorily but was non-tender. The presence of the treated tooth as an abutment was established as a determinant that negatively affects patient outcomes (P < 05; odds ratio = 22; confidence interval = 20. 47-23. 53).

6. Conclusion

This narrative review aims to highlight the vast influence of microscopic technologies in various contemporary endodontic procedures. Modern Operating microscopes, fiber-optic technology, digital imaging modalities, and other innovative technological aids have enhanced the diagnostic accuracy and efficiency of root canal treatment planning and execution. Despite the above challenges which include costs at the end of stage one and training costs these technologies have helped to increase the predictability of treatments and reduce invasive procedures. In the future, subsequent research and implementations of these developments are expected to enhance the existing professional guidelines, resulting in better outcomes for patients while contributing towards the progress of the field of endodontics.

7. Future Research and Recommendation

Future research on microscopic endodontics should concern the long-term results of modern technologies applied and how they influence patient satisfaction and oral hygiene. Further comparative research based on larger samples and more diverse patients is needed to confirm the cost-effectiveness of these sophisticated instruments. Exploring the potential of applying digital imaging techniques, nanotechnology, and artificial intelligence in endodontic practice could reveal novel opportunities for increasing accuracy and productivity. Further, it may be argued that miniaturization and the development of cheaper versions of these technologies may help in the spread of these technologies in more resource-limited environments. It is also advised to improve the availability of educational courses presented to dental specialists regarding the advantages and use of superior microscopic endodontic procedures. This will ensure that practitioners are in a better position to capitalize on these innovations in their handling of patient cases.

Data availability

Data are available upon contacting any of the authors.

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Author Contributions

Conceptualization: Larysa Dereyko, Bohdan Hudyma; Data curation: Maryana Paladovska; Formal analysis: Andriy Kolba; Research: Oleksandra Kolba; Methodology: Larysa Dereyko, Maryana Paladovska; Project management: Bohdan Hudyma; Resources: Andriy Kolba; Software: Oleksandra Kolba; Supervision: Larysa Dereyko; Visualization: Andriy Kolba; Writing - original draft: Maryana Paladovska, Oleksandra Kolba; Writing - review & editing: Larysa Dereyko, Bohdan Hudyma.

Conflict of interest

The authors declare no conflict of interests. All authors read and approved final version of the paper.

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