OPEN ACCESS

Volume: 12

Special Issue: 2

Month: October

Year: 2024

P-ISSN: 2321-788X

E-ISSN: 2582-0397

Received: 24.09.2024

Accepted: 10.10.2024

Published: 22.10.2024

Citation:
Anukraha, K., Arun Suji, A., Theshma Vishalini, SA., & Nivashini. (2024). The Role of Dental Operating Microscopes and Digital Technologies in Endodontics and Conservation Dentistry: A Comprehensive Review. *Shanlax International Journal of Arts, Science and Humanities*, *12*(S2), 27-32.

DOI:
https://doi.org/10.34293/sijash.v12iS2-Oct.8510

The Role of Dental Operating Microscopes and Digital Technologies in Endodontics and Conservative Dentistry: A Comprehensive Review

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Abstract

The integration of dental operating microscopes (DOM) and digital technologies in endodontics and conservative dentistry has transformed the precision and quality of dental care. DOMs offer enhanced visualization, allowing clinicians to address complex procedures with greater accuracy, such as identifying calcified canals, detecting microcracks, and removing fractured instruments. This review explores the historical evolution of DOMs, their structural design, and the technological milestones that have contributed to their widespread use. By improving ergonomics and clinical outcomes, DOMs have become invaluable in various applications, from caries detection and conservative access openings to endodontic microsurgery. Additionally, the incorporation of digital imaging aids in documentation and postoperative evaluations, contributing to better patient follow-up and long-term monitoring. Although limitations like high cost and illumination challenges remain, continuous advancements in DOM design and function suggest a promising future. DOMs are set to further influence patient care standards, making them a cornerstone in modern dental practice.

Introduction

The last few decades have seen advances in digital technology, which have altered diagnostics and treatments in dentistry. These innovations have replaced traditional manual and mechanical methods with computer-controlled systems, significantly enhancing accuracy, efficiency, and accessibility to dental care. Digital dentistry refers to the use of devices or technologies that include digital or computer-controlled components, providing the means for more advanced tools in diagnoses, planning, and execution (Dhawan et al., 2022). Of the various technologies used, it is the dental operating microscope (DOM) that has proven really revolutionary.

The DOM-mounted digital cameras allow clinicians to take detailed images and videos of the treatment field for diagnostic purposes, patient education, and treatment planning. This synergy shows how digital technology amplifies the capabilities of DOMs, transforming them from simple magnification tools into comprehensive diagnostic and procedural aids (Dhawan et al., 2022; Wynne, 2014). This review focuses on the historical development and current impact of digital technologies in dentistry, with special emphasis on DOM. We would outline applications, evolution in usage, and scope to possibly revolutionize patient care in both endodontic and conservative dental procedures.

Historical Development of Dental Operating Microscopes

The development of the dental magnification system, which evolved into the launch of the DOM, must surely have been linearly a step in more precision and functionality.

- 1850 The starting point : With the invention of the magnifying glass, which gave the first primitive form of magnification of 2 times for viewing through dental structures
- 1870: Surgical loupes were developed that gave magnifications between 2x to 6x, which facilitated an in-depth view of the oral structures (Wynne, 2014).
- 1900: Binocular loupes put over spectacles allowed dentists to view with both eyes via magnifying lenses, which provided better ergonomics and a clearer view (Wynne, 2014).
- 1978: Apotheker and Jako designed the very first dental surgical microscope that soon spread in the dental practice for magnification (Das & Das, 2013).
- 1979: The rod lens endoscope was designed which offered a better visual presentation of surgical and dental treatments (Pradeep & Vinoddhine, 2014).
- 1981: The first commercially available surgical microscope was marketed and gained popularity among clinicians (Selden, 2002).
- 1999: Orascope - A fiber optic endoscope designed specifically for intracanal visualization was released, thus facilitating higher visibility than ever before within the root canals (Pradeep & Vinoddhine, 2014).

These technological advancements form a continuous effort toward better magnification, illumination and ergonomic designs to improve the accuracy and effectiveness of dental treatments

With advances in digital technologies, dental operating microscopes along with other instruments became part of the clinical care system. Some of the most important milestones:

- 1989, Dr. Howard Selden, DOM was first used to identify calcified canals based on nonsurgical perspectives, changing the face of endodontic procedures.
- 1997, CODA mandated that U.S. dental schools incorporate DOMs into the endodontic curriculum. That way, future endodontists understood how to apply DOMs.
- DOMs are part and parcel of both academic and clinical settings. These instruments assist practitioners in offering precise and efficient practices leading to successfully executed dental treatments
- Another aspect of endodontic practice that is enhanced by the magnification is documentation. When magnification instruments are used in dentistry, it becomes necessary to record the diagnosis and treatment in pictures or videos for forensic reasons and dentist's own documentation purposes.
- A small sensor size is used for the depth of field and larger pixels cameras are used for detail documentation. JPEG is small, and in most cases does not need any editing and is immediately available (Druttman & Finn, 2014).

Structure and Working Principle of Operating Microscope

The operating microscope consists of three basic components (Singla et al., 2018).

- The supporting structure
- The body of microscope
- The light source

Magnification Progression from the Naked Eye to the Need of Microscope

Using the naked eye in dental procedures has significant limitations including limited magnification, reduced accuracy and increased eye strain. A Magnifying glass works by creating a magnified virtual image of an object behind The lens. This happens only when the distance between the lens and the object is shorter than the focal length of the lens. It has a focal length of 25 cm^3. Loupes have an array of convergent multiple lenses. There are air spaces in between these lenses which gives an additional refracting power, magnification, working distance, and depth of field. Their only disadvantages are limited magnification (2.5- or 3.5- fold) and a blurry peripheral border of the visual field. To overcome these limitations advanced dental operating microscope introduced. The microscope provides better magnification from 3× to 30× and better illumination. The focal length ranges from 100 mm to 400 mm. Ideally through a microscope, the light reaching the left and right eyes appears to be essentially parallel which reduces strain on eye muscles, fatigue, and soreness compared to loupes. Achieving the effect of far distance observation and avoiding short accommodation stress as with the naked eye (Arora et al., 2021).

Role and Advancements of Dental Operating Microscopes in Dentistry

Among many digital advances in dentistry, DOM stands out because it can magnify visual fields up to 25x or more, which allows a clinician to see minute details inside a patient's tooth that would not have been perceived otherwise. Such improved visualization enhances diagnostic accuracy as well as the quality of treatment, particularly in the difficult field of endodontics.

- First Use of Operating Microscope: Its employment starts in 1907 when Bowles was the first to experiment clinician using this instrument. However, its widespread use only took place in the late 20th century.
- Widespread Adoption: With technological breakthroughs through the 1990s and the early decades of the 2000s, the DOM became affordable and readily available, which explains the reason for its wide use in dental practice today worldwide.

Applications of Dental Operating Microscopes in Endodontics

The DOM has become indispensable in the endodontic practices where such precision is discerningly demonstrated. Visualization of such small details within the teeth structures has improved almost all aspects of endodontic care-ranging from diagnosis to treatment.

- **Detection of Caries and Cracks:** Rashed et al. (2019) has shown that a DOM with methylene blue dye was more effective in detecting dentin microcracks than with other conventional methods like CT or optical coherence tomography.
- **Conservative Access Opening:** According to Mamoun (2016), under microscopic magnification through coaxial illumination, there is a greater conservative access opening that also safeguards the delicate anatomical structures of the pulp chamber.
- **Identifying obscure anatomy:** According to Yoshioka et al. (2005), DOM provides higher visibility of anatomy that is hidden or additional root canals missed without magnification.
- **Calcified Canals Management:** Iandolo et al. (2023) have proved in numerous studies that most of the times DOMs provide better diagnosis and treatment of calcified canals thereby significantly reducing the risk of iatrogenic errors by a huge margin.
- **Systematic Pre-obturation Canal Cleanliness:** DOM facilitates to check for the presence of residual debris intra-canal so that the canal is actually clean before obturation leading to better treatment outcomes.
- **Retrieving silver point, separated instrument, and fractured post:** Kaul et al. (2022) shows a high success rate in removing broken instrumentation by the DOM with minimal damage to the root canal. Gencoglu and Helvacioglu (2009) demonstrates that through the use of a microscope's magnification

and illumination, endodontists can examine the most coronal aspects of fractured posts enabling the removal of these objects with minimal loss of tooth structure and perforations.

- **Endodontic microsurgery:** Floratos et al. (2023) showed that DOMs make periradicular surgery, such as osteotomy, root-end resections, and retrofilling, more precise, resulting in a better success rate in complex cases.
- **Improves Negotiation of Second Mesiobuccal Canals in Maxillary Molar:** M O mer Go illustrates the use of operating microscope efficiency for pursuing difficult MB-2 canals with greater precision and minimizes the amount of peripheral dentin removal thereby reducing clinical time (Görduysus et al., 2001).
- **Cleaning and Shaping Procedures:** The DOM enhances the diagnostic capability and smoothes out the cleaning and shaping procedures in the therapy of root canals. Researchers have demonstrated that such improved visualization offered by the DOM allows clinicians to reach all the canals with utmost efficiency while sacrificing the least possible amount of healthy tooth structure.
- **Addressing Endodontic Complications:** DOM aids in the retrieval of separated instruments, fractured posts, and other complications within the root canal system (Yoshioka et al., 2005).
- **Management of Root Resorption:** Wang et al. (2022) Investigate DOM's role in diagnosing and managing root resorption, including both internal and external types.
- **Postoperative Evaluation and Follow-Up - Assessment of Healing:** Review the use of DOM in evaluating the healing process post-treatment, including checking for signs of complications or treatment failure. Long-Term Monitoring: Explore how DOM facilitates long-term monitoring of treated teeth, aiding in the early detection of potential issues.
- **Management of Perforations:** Biswas et al. (2011) demonstrates the use of operating microscope to visualise and treating accessible perforations nonsurgically.

Application of Digital Technologies in Conservative Dentistry

DOMs with digital technologies have several benefits for conservative dentistry both for the clinician and the patient:

- Improved Visualization: DOMs help to spot minute defects in enamel and caries thereby giving more accurate diagnoses and more relevant treatment plans.
- Minimally Invasive Treatments: Higher magnifications allow for the removal of less dental tissue and potentially lesser discomfort for the patient, thus improving the results of healing.

Improvements in Restorative Procedures

- Inlays and Onlays Placement: Review the use of DOM in ensuring accurate placement and fit of inlays and onlays, enhancing overall restoration quality.
- Composite Resin Application: Explore how DOM improves the application and finishing of composite restorations, focusing on achieving better aesthetics and functional outcomes.
- Margin Detection and Adjustment: Investigate the role of DOM in evaluating and adjusting restoration margins to ensure optimal sealing and longevity

Advantages of Using Microscope in Dentistry

The advantages of using DOMs in clinical practice are multi-fold, merging the ergonomic benefits with clinical advantages:

- Better Visualization: Higher magnification is useful for identification of microcracks, initial caries, and microleakage. Dentists can also assess better the resected ends of roots for fractures and extra canals (Low et al., 2018).

- Improved Ergonomic Conditions: DOMs will reduce muscle fatigue and stress as the operative posture might be more ergonomic, hence extending the hours clinicians may work and thus reducing long-term musculoskeletal morbidity (Low et al., 2018).
- More Referrals: Advanced equipment in the form of a DOM typically makes a patient feel more confident, and hence will also refer others more freely, as well as enhance professional reputation (Low et al., 2018).
- Better Quality of Treatment: The magnification associated with the DOM enables the clinician to see cavity preparations, matrix fittings, and applications of restorative materials in finer detail which promotes better results (Bud et al., 2021).
- Avoiding Iatrogenic Error: With a potential reduction of excess tissue removal and damage to adjacent structures, DOMs prevent iatrogenic injuries (Bud et al., 2021).

Limitations and Challenges of Dental Operating Microscopes

There are quite a number of limitations despite the strengths of DOMs:

- Diminished Field of View: The field of view tapers with greater magnification, and depth of field is shallower.
- Illumination Problems: The greater the magnification, the less the effective aperture, and hence less illumination of the surgical site.
- Cost: DOMs are too expensive for most practitioners, especially for many developing countries (Low et al., 2018).
- Cross-contamination and sharp injuries: reckless practices in handling instruments and bad habits of sterilization often seem to lead to a high risk of cross-contamination and sharp injuries in the dental field (Low et al., 2018).

Future Trends in Dental Operating Microscopes

With the promising future of DOMs in dentistry, much advancement is now targeted at better light management, robotic positioning, and integration of other technologies like CAD/CAM systems, CBCT, and intraoral scanners. For instance, Labomed Dental Microscopes set forth models like the Labomed Magna, Prima DNT, and Prima Mu, offering better optical quality with anti-reflective and anti-scratch properties.

Conclusion

The DOM has undoubtedly revolutionized the field of dentistry, enhancing treatment accuracy, allowing better visualization of intricate structures, and facilitating the execution of complex procedures. It has significantly contributed to improved patient outcomes, greater procedural efficiency, and advancement in dental research. However, high costs associated with acquisition and maintenance, steep learning curves for clinicians, and the potential for ergonomic challenges during prolonged use can hinder widespread adoption.

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