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Illuminating Dental Diagnostics: The role of fiber optic transillumination

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Abstract

Fiber optic Transillumination is a diagnostic tool in dentistry that utilizes light to illuminate tooth structures, uncovering various dental conditions. This technology utilizes high-intensity light to illuminate the internal structures of the oral cavity and has shown efficacy in identifying caries, cracks, fractures, and other anomalies that are frequently difficult to detect with traditional radiographic methods. This paper explores the principles, applications, benefits, and drawbacks of this method in dental practice, offering a comprehensive review of its contribution to improving diagnostic precision and patient care. The use of advanced technology to detect dental caries early has supported the move towards minimally invasive dentistry, highlighting a preventive approach to caries management.

Keywords: Fiber Optic Transillumination, Digital Dentistry, Dental Caries, Initial caries, Caries Diagnosis

Introduction

Diagnosis forms the basis of treatment. The horizons of diagnosis are continuously evolving. Proper use of suitable imaging technology, cost efficiency, and innovative radiographic strategies can help reduce morbidity, mortality, and improve patients' life expectancy. Digital diagnostic tools for dental caries detection have been advancing.[1] Radiation-based, light-based, ultrasound-based, and electric-based tools are now available as digital aids for detecting dental caries. These digital diagnostic tools offer advantages and certain limitations. They assist clinicians by supplementing traditional caries detection methods. However, none have demonstrated ideal performance in detecting dental caries, especially in early stages.[2] Consequently, various new digital diagnostic tools for dental caries are under development and show promise for clinical use.[3] Dental caries is an irreversible microbial condition of the tooth, marked by the demineralization and dissolution of hard tissues. Accurate diagnostics are essential for controlling and managing dental caries. Effective caries control relies on the detection of early lesions and risk assessment, which are crucial in managing the disease.[4] However, identifying visually and tactilely non-cavitated lesions, particularly on proximal surfaces, is difficult. The most common method, visual-tactile inspection, often underestimates carious lesions. Complementing this with bitewing radiography improves the detection of inter proximal caries. Additional tools include laser fluorescence, fiber-optic transillumination, and digital imaging fiber-optic transillumination. Traditional methods like visual-tactile examination, X-rays, and light-induced fluorescence help diagnose dental caries but lack sensitivity. Visual examination is subjective and technique-sensitive, and the use of ionizing radiation raises concerns, creating a high demand for advanced imaging technologies in dentistry that improve the efficiency and accuracy of caries diagnosis. Since dental caries are irreversible, early detection is crucial.

Fiber-optic transillumination represents a significant advancement in dental diagnostics, offering a non-invasive and effective method for detecting various dental issues.[5] This technology utilizes a high-intensity light source, transmitted through fiber optic cables, to illuminate tooth structures. The different light scattering and absorption properties of healthy and diseased tissues allow practitioners to identify abnormalities not visible on traditional radiographs. It operates on the principle of light transmission and scattering through dental tissues. When light is directed through a tooth, it scatters differently based on the tissue's density and composition.[6] Healthy enamel and dentin permit more light to pass through, while carious lesions, cracks, and fractures disrupt light transmission, creating shadows or dark areas. The essential components of a Fiber Optic Transillumination system include: Light Source: Typically, a high-intensity halogen or LED light is used. The fiber optic system consists of a halogen lamp and a rheostat to produce light of varying intensity. The 150-watt lamp generates a maximum light intensity of 4000 lx at the end of a 2mm diameter cable. Two attachments are utilized: a plane mouth mirror mounted on a steel cuff and a fiber optic probe of 0.5mm diameter, designed to be placed in the embrasure region. It produces a narrow beam of light for transillumination, with the rheostat set to provide light of maximum intensity.

Fiber Optic Cable: Carries light from the source to the tooth.

Hand piece: Directs light onto specific areas of the tooth.

Detection System: In advanced configurations, this may include cameras or sensors to capture and analyze the illuminated images.[7]

Discussion

Fiber optic transillumination is highly effective in detecting early enamel and dentin caries, revealing de mineralized areas as dark spots against the translucent healthy enamel. Diagnosing cracks and fractures in endodontics can be challenging with traditional methods, but Fiber optic Transillumination enhances visualization by highlighting disruptions in the tooth structure.[8] It operates on the principle that a carious lesion has a reduced light transmission index, causing the area to appear darkened. For examination, the probe tip is placed in the embrasure beneath the contact point of the proximal surface to be inspected, either on the buccal or lingual side, depending on the tooth. The basis of fiber optic trans illumination is that decayed tooth material scatters light more intensely, resulting in a lower light transmission index compared to healthy tooth structure. This reduced transmission is interpreted by the observer, typically using a standard rating scale.[9] Accurate identification of the pulp chamber and canal morphology is crucial in endodontic therapy, and it aids in visualizing internal structures, locating canals & facilitating more precise treatments. It also helps to locate calcified canals. Additionally, during restorative procedures, ensuring the complete removal of carious tissue is essential, and it helps identify any residual caries, ensuring thorough debridement. It is particularly useful for detecting inter proximal caries in anterior and posterior teeth, where traditional radiographs might be less effective.[10] Kühnisch et al. in 2016 assessed the validity of transillumination for detecting inter proximal caries but did not examine the examiner's role or the effect of the images' technical quality.[11]Dentists can use this diagnostic aid to monitor the progression of caries over time, aiding in the decision-making process for restorative treatments. It assists in identifying secondary caries around restorations, which can be difficult to detect with conventional methods. It aids in evaluating the integrity of existing restorations, detecting fractures or gaps that could lead to future issues. [12]

Diagnosing a broken tooth is one of the most challenging tasks for dentists, as symptoms vary among patients. External inspections can be difficult, with some teeth showing no visible cracks despite symptoms, while others display noticeable lines without causing patient discomfort. Transillumination is a technique dentists use to detect cracks or fractures. They interpret the light transmission pattern to make a diagnosis. [13] Fiber optic transillumination in orthodontics serves as valuable diagnostic tools for improving the detection of dental anomalies and conditions that may affect orthodontic treatment planning.[14] Its applications include identifying inter proximal caries, essential for planning braces or other orthodontic appliances to ensure teeth are healthy before treatment starts. By illuminating teeth, it helps identify cracks, fractures, and other structural issues that might impact tooth movement during orthodontic procedures. During treatment, fiber optic transillumination can monitor enamel health, detecting early signs of demineralization or white spot lesions common around brackets or bands. It assists in ensuring clean and intact enamel surfaces before bracket bonding, enhancing the success and longevity of the bonding process. Overall, integrating fiber optic transillumination into orthodontic practice improves diagnostic precision, facilitates early issue detection, and contributes to more effective and tailored treatment plans, ultimately leading to improved patient outcomes.[15] Advantages of fiber optic transillumination include its non-invasive nature, reducing patient discomfort and eliminating the need for radiation exposure. It is a low-cost, simple-to-use, and effective diagnostic method. It offers an alternative to radiographic methods, avoiding radiation and associated risks. It enhances diagnostic accuracy by providing clear visual cues of dental pathologies and internal structures, thereby improving diagnosis and surgical planning.[16]

Practitioners benefit from real-time visualization, enabling immediate clinical decisions and assessments during procedures.

It facilitates early detection of dental issues, allowing for timely and less invasive interventions. It is particularly effective in identifying early-stage caries and cracks, supporting preventative measures and early treatment. It also aids in visualizing the extent of soft tissue lesions, facilitating precise surgical excision and enhancing patient outcomes.[17] Limitations of fiber optic transillumination include limited depth penetration, making it more effective for surface and near-surface anomalies, while deeper lesions may not be detectable. Its effectiveness relies on the operator's skill and experience in interpreting visual data. The high initial investment in equipment can be a barrier for some practices. Technological limitations also exist, as current technology may not always clearly differentiate between healthy and diseased tissues.[18] Improper transillumination is most commonly found in the 1st premolars and 2nd molars, with underexposure more frequent in molars, particularly the 2nd molars. Conversely, overexposure is most common in premolars, especially mandibular 1st premolars (34% of all overexposed teeth). Projection failures are predominantly in premolar areas, accounting for majority of all poor projections. Saliva bubbles appeared equally across all locations. The fewest missing surfaces are in the 2nd premolars and 1st molars, but 39% of all missing surfaces are in 2nd molars, followed by 1st premolars. The distal surfaces of the 2nd molars have the highest proportion of failed images, with 86.5% in mandibular and 81.7% in maxillary 2nd molars. A study showed failed mesial surfaces was 51.0% in mandibular and 64.4% in maxillary 2nd molars, showing the greatest difference between mesial and distal surfaces for missing surfaces.[19] Cone beam computed tomography offers three-dimensional imaging for comprehensive diagnostic information but involves higher radiation doses. Fiber Optic Transillumination complements Cone Beam Computed Tomography by providing real-time, radiation-free diagnostics for surface anomalies and specific diagnostic needs. [20]

The prevailing treatment concept in restorative dentistry primarily focuses on early detection and diagnosis of dental caries to prevent and avoid extensive intervention. Intraoral camera transillumination enhances clarity with each patient.[21]The LUM sub-enamel illumination, the latest advancement in dental imaging technology, is an add-on attachment to an intraoral camera that enables dentists to instantly document all findings, including cavities, stains, and caries. Additionally, activating the camera's blue filter and fluorescing with UV light allows dentists to reveal surface lesions not visible to the naked eye. If transillumination reveals a crack, dentists aim to capture it with a digital intraoral camera to include it in the patient's permanent record. Intraoral transillumination technology can significantly enhance diagnostic capabilities. For example, identifying cracks in teeth and cavities becomes manageable using the dental camera's features.[22] The transillumination technology enables dentists to uncover issues that digital X-rays don’t reveal. For instance, the technique helps dentists to identify caries that dental X-rays may not have detected. Best of all, the technology enables the dentist to diagnose and recommend early treatment to prevent the progression of tooth decay. The state-of-the-art technology adopted by dentists has left many patients amazed, as they prefer modern dental offices over traditional practices that still rely on outdated dental technology. Furthermore, dentists don’t need to use multiple devices to obtain patient diagnostic images.

Instead, the transillumination attachment easily clicks onto the intraoral camera, capturing sharp and clear images, allowing dentists to diagnose conditions early and propose appropriate treatments. Recently intraoral cameras have also made their mark in detecting and diagnosing dental caries, especially at the earliest ages.[23]

Fiber optics have been used in dentistry for adjunctive illumination of other devices such as hand pieces and ultrasonic scalers, as well as attached to magnifying loupes.

A fiber optic wand can be positioned at the cervical area to direct light perpendicular to a tooth's long axis. Turning off any overhead light source during transillumination can sometimes aid in identifying an orifice. Digital imaging fiber-optic transillumination, developed by Schneidermann et al., is the digitized version of Fiber Optic Transillumination. Images of teeth are captured using visible light through fiber optic transillumination.[24] Light travels from the optic fiber through the tooth to a non-illuminated surface, typically the opposite side. The images are captured by a digital Charged Couple Device camera, with the data sent to a computer for analysis and stored in a database for comparative review over time. It uses an intense band of white light that spans the entire visible spectrum, shining through the tooth from any angle above the marginal gingiva.[25] Benefits include enabling dentists to detect demineralization on all tooth surfaces and inspect the tooth's integrity for fractures, decalcification, wear, and the condition of amalgam, composites, sealants, and orthodontic bands. It reduces the variability of visual detection using fiber optic trans illumination between different examiners.[26] Since digital images can be viewed instantly, Digital Imaging Fiber Optic Transillumination allows dentists to educate patients during examinations and discuss treatment options. It serves as a tool to monitor the efficacy of caries control measures. The captured images can be conveniently stored in a Personal Computer database, printed, or transmitted over the internet. However, it's important to note some drawbacks. Firstly, detecting proximal lesions using Digital Imaging Fiber Optic Trans illumination requires precise angulations, which can be challenging. Additionally, it cannot measure lesion depth accurately since it only provides surface or near-surface images. Furthermore, despite the ability to compare images over time, it lacks the capability to quantify lesion progression. Its heightened sensitivity, coupled with somewhat lower specificity, increases the risk of over diagnosis.[27]

Moreover, it accentuates the surface disparities between less dense mineral and normal tooth mineral even more than radiography due to its heightened sensitivity. It predominantly detects surface alterations visible to light rather than discerning the subsurface caries phenomenon in its early stages. Clinicians must interpret these images for diagnosis. While it can identify advanced and incipient lesions, fractures, cracks, and secondary caries, it lacks depth insight into caries penetration.[28] For instance, the new DIAGNOcam from KaVo, Biberah, Germany, employs near-infrared light (at 780 nm), invisible for transillumination. Near-infrared imaging emerges as a crucial tool for early caries detection, utilizing light at 850 nm for heightened sensitivity. Upon interaction with the tooth, near-infrared radiation forms images based on dental tissue's optical properties. Operating on the confocal laser principle, scanners focus on detecting caries by preserving and collecting in-focus light while discarding off-focus signals.[29] Furthermore, diverse imaging technologies utilizing this principle deploy varied light sources, with light transmission through the alveolar process enhancing diagnostic image quality. The main criticisms of the Fiber Optic Trans illumination system revolve around unit noise and its cumbersome design. Many users prefer a light source integrated into the dental unit, possibly within a hand piece. The tips guiding the light into a narrow beam and directing it between teeth were considered overly long. Additionally, this technique proved ineffective when large proximal restorations blocked the light beam's path. High-quality Digital Imaging Fiber Optic Transillumination images clearly depict the depth of caries lesions in the tissue, aiding clinicians in deciding between noninvasive or invasive treatment options. This could potentially reduce unnecessary restorations and facilitate successful preventive measures. [30]

Digital Imaging Fiber Optic Transillumination images offer detailed information, albeit focusing on one tooth at a time, surpassing Bite Wing radiography when high-quality images are obtained. Acknowledging the quality and challenges of Digital Imaging Fiber Optic Trans illumination images is crucial, warranting further research. In comparison to Fiber Optic Transillumination, Digital Imaging Fiber Optic Transillumination's advantage lies in image storage and ease of use for monitoring lesion progression and preventive measure effectiveness. The real-time view not only aids dentists but also educates patients about their dental condition, potentially motivating improved home care practices. Fiber optic transillumination has also emerged as a vital diagnostic tool in oral surgery, enhancing the ability to detect and evaluate various oral pathologies with precision. [31]

Future Directions and Technological Advancements Integration with Digital Workflows: The future of Fiber Optic Transillumination includes integration with digital dental records and imaging systems, streamlining diagnostic and treatment workflows. Advances in fiber optic technology and improved Fiber Optic materials may enhance resolution and depth penetration, broadening diagnostic capabilities of this technology. Artificial Intelligence could analyze Fiber Optical Transillumination images, offering automated diagnostic support and minimizing operator dependency.[32]

Conclusion

Fiber optic transillumination is a valuable diagnostic tool in dentistry, offering a non-invasive, radiation-free method for detecting various dental pathologies. Its ability to provide real-time visualization enhances diagnostic accuracy and supports better surgical planning and patient outcomes. Despite some limitations, ongoing technological advancements and integration with digital platforms hold promise for expanding the clinical applications of Fiber optic transillumination in dentistry.

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