Report

The History and Future Prospects of Dental Caries Treatment

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This report explains the evolution and future prospects of dental caries treatment. It traces the history of caries detection and removal techniques, from traditional methods to modern technologies like NIRI and laser fluorescence. The study highlights advancements in filling materials, particularly the widespread use of composite resins. Looking ahead, the note explores potential innovations such as intraoral milling machines, nanotechnology-based selective caries destruction, and 3D printing for direct resin application. The integration of AI for automated diagnosis is also discussed. While these technologies promise more precise and less invasive treatments, the paper acknowledges the challenges in their practical implementation and emphasizes the need for continued research and development in the field.

1. Introduction

Caries treatment is a crucial aspect of dental care and has been practiced since ancient times. The oldest documented account is found in Pierre Fauchard's (1678-1761) "Le Chirurgien Dentiste, ou Traité des dents". Caries treatment consists of three main components. The first step is identifying carious lesions accurately removing the carious dentin, and finally, in the case of direct treatment, filling and sealing the cavity. This report examines potential future advancements in these procedures.

2. Dental Caries

Dental caries (tooth decay) is a multifactorial disease that causes demineralization and destruction of tooth hard tissues. It is among the most prevalent chronic diseases worldwide, affecting individuals of all ages. Caries occurs when oral bacteria metabolize fermentable carbohydrates, producing acids that lower the pH in the oral environment[1,2]. This acidic environment causes the dissolution (demineralization) of tooth minerals, primarily hydroxyapatite[1].

Various factors influence the development of caries:

a. Presence of cariogenic bacteria such as Streptococcus mutans and Lactobacilli[1]
b. Frequent consumption of fermentable carbohydrates[1]
c. Inadequate oral hygiene practices[1]
d. Decreased salivary flow or changes in saliva composition leading to reduced buffering capacity[1,2]
e. Genetic factors affecting enamel formation and quality[1]

Caries can affect both the crown (coronal caries) and root (root caries) of the tooth. If left untreated, it can progress through the enamel and dentin, potentially reaching the pulp and causing severe pain and infection[1,2]. Early detection and intervention are crucial for preventing caries progression and maintaining oral health[2].

Figure1: dental caries in extracted tooth

3. History of Caries Detection

Caries detection techniques have evolved over time.

One of the oldest diagnostic methods is detection based on hardness during excavation. When a tooth is infected with caries, the dentin softens due to the destruction of the hydroxyapatite crystal structure by acids produced from sugar by bacteria such as Streptococcus mutans. Carious dentin shows a significant decrease in Vickers hardness compared to normal dentin. While the hardness of healthy dentin is about 50-60 HV, carious dentin decreases to about 20-30 HV.

This difference allows for the detection of carious areas by the sensation of cutting instruments. Current spoon excavators and contra-angle steel burs are designed based on this principle, only able to cut the low-hardness carious dentin. This allows for effective removal of carious portions while protecting healthy tooth structure[3,4].

For visual caries detection, areas stained by solutions have been diagnosed as caries. In 1972, Fusayama et al. found that 0.5% basic This staining method has been widely used as a means of accurately visualizing carious areas[5].

X-ray imaging and CT scans are widely used to accurately assess the progression of caries by providing detailed images of the internal structure of teeth. These methods enable the detection of deep caries in areas that cannot be visually confirmed[6].

In recent years, more non-invasive methods have been developed and are beginning to be used clinically, such as Diagnodent, which uses visible light laser fluorescence reflection[7], and NIRI (Near-Infrared Reflectance Imaging) technology[8]. These technologies allow for non-invasive imaging of the body and internal tooth structure, enabling early detection of caries.

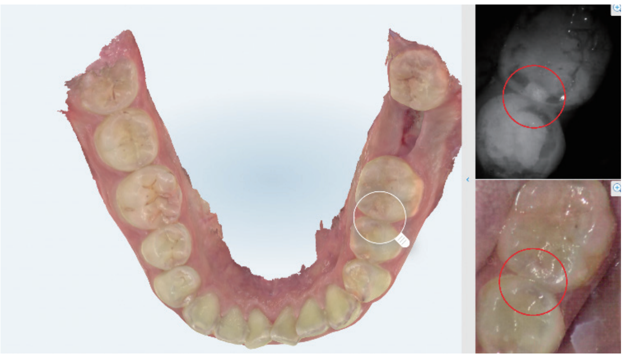

Figure2: Caries detection by NIRI

The caries area was visualized using NIRI technology. The red circle on the right side is displayed as white, and the hard tissue in that area has been destroyed. Align Technology's iTero 5D Plus was used.

4. History of Caries Removal

The development of removal techniques in caries treatment has greatly contributed to the advancement of dental care. The first major development in this field was the foot-pedal drill invented by American dentist James Beall Morrison in 1871. This drill achieved a significantly higher rotation speed (about 2000 RPM) compared to conventional hand drills, greatly improving the efficiency of cavity preparation[9].

The subsequent development was the air turbine developed by John Patrick Walsh from New Zealand in the 1950s. This technology used compressed air to rotate the drill at speeds (up to 400,000 RPM) that surpassed the electric drills of the time. This technology became indispensable in subsequent dental treatments.

Air turbines rotate diamond burs using air pressure, resulting in low torque. To improve torque, gear-driven 5x speed contra-angle handpieces were developed, achieving 40,000 RPM. Modern technology includes a cooling function that directly sprays water onto the cutting site to address the risk of pulp damage from heat generated during cutting[10].

Methods using lasers for caries removal and solvents like Carisolv to dissolve only caries also exist, but they are not widely used in clinical settings due to their lower removal efficiency compared to rotary cutting instruments.

Figure3:High speed dental handpiece

The turbine head can be fitted with any cutting burr, has lights and can spray water and wind while cutting.
https://www.japan.nsk-dental.com/products/contra-angles/contra-ti-max_x/ (accessed2024-08-31)

5. History of Cavity Filling

After removing caries, materials are inserted to fill the excavated area. Fauchard's book described the use of gold foil or mercury for filling, but currently, composite resins are widely used. Composite resins improve wear resistance by incorporating ceramic fillers into the resin[10]. Furthermore, light-curing technology allows for rapid hardening in the oral cavity[11].

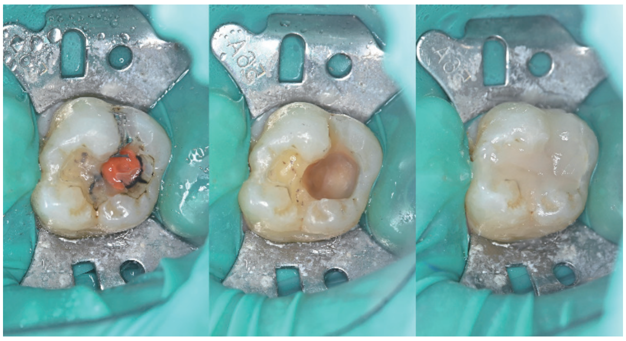

Figure4: caries treatment procedure

Cavity and old fillings are removed to expose a fresh surface which is then filled with composite resin.

6. Future Caries Removal Technology

The need to cut hard tissues is likely to continue in the future. Current cutting technologies face several challenges. In particular, the impact of heat and vibration generated during cutting on the dental pulp and surrounding tissues is a significant issue that cannot be ignored[4]. Moreover, enamel is extremely hard, with a Vickers hardness of about 343-430 HV[1]. Cutting tools with high torque and rotation speed are required to deal with this hardness[4].

In the future, it is possible that systems will be introduced where small milling machines are inserted into the oral cavity, with drills moving freely like CAM systems, controlled by cameras. These systems are expected to have functions for power supply, water injection, and drainage via cords, greatly improving treatment efficiency.

With the advancement of nanotechnology, it may be possible in the future to realize systems that selectively destroy carious sites at the molecular level[12]. For example, mechanisms where specific nanoparticles bind only to carious portions and those portions are selectively destroyed using lasers or ultrasound are being considered. This technology is expected to enable more accurate and effective treatment while protecting the surrounding healthy tooth structure.

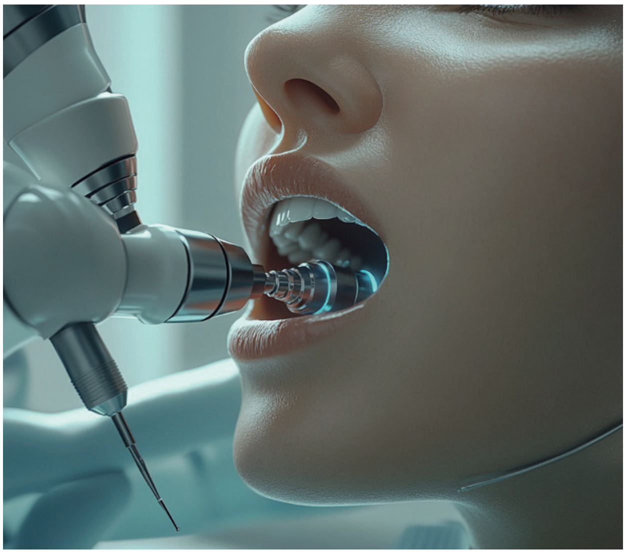

Figure5 Future intraoral milling machine

7. Future of Filling

In the future, methods using small 3D printers inserted into the oral cavity to directly 3D print resin onto teeth are expected to become mainstream. This technology is anticipated to shorten treatment time and improve accuracy. Additionally, AI-based automatic diagnosis will be used to determine the areas for excavation[13].

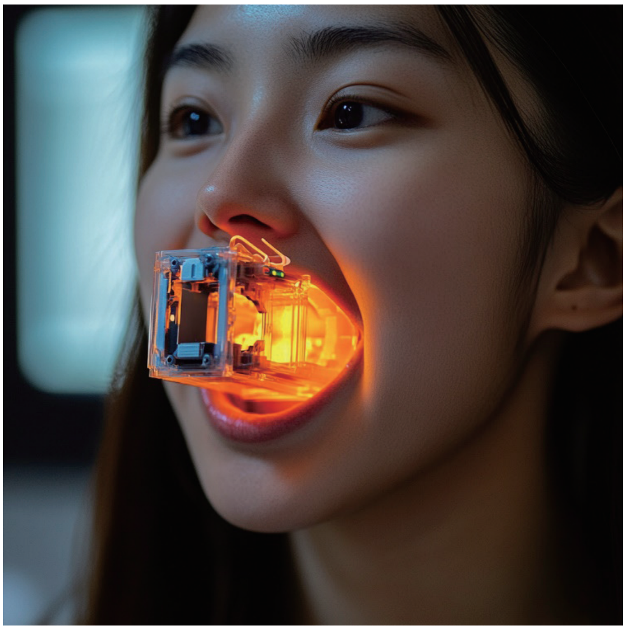

Figure6 Intraoral 3D printer

Conclusion

Future caries treatment has the potential to evolve significantly with the development of nanotechnology, AI, and 3D printing technologies. These technologies are expected to enable more precise and less invasive treatments, greatly reducing the burden on patients. However, many challenges remain for the practical application of these technologies, and it is anticipated that it will take time to resolve them. It is hoped that with the progress of future research and development, even more effective and patient-friendly caries treatment methods will be established.

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