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Review Article

Application of atomic force microscopy in conservative dentistry and endodontics - A short review

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ABSTRACT

AFM has evolved into one of the most used imaging tool in the fields of physics, biology and material science. AFM is based on mapping of an atomic-force field on a surface of materials with nondestructive probes. It provides a detailed topographical investigations and three-dimensional image of an object surface. One of the main advantages of the AFM method is the flexibility of the conditions in which it is used. AFM imaging can be conducted in an ambient or liquid environment with minimal compromise to its resolution.

1. Introduction

Atomic Force Microscopy (AFM) is a multifunctional imaging technology that helps in visualization of biological samples from single molecules to living cells. AFM is a very high resolution type of scanning probe microscopy. AFM can be used to study, investigate and analyze any type of surface including polymers, ceramics, composites, glass and biological samples. It was developed as a three dimensional topographic non optical imaging method, first demonstrated by Binning and Quate in 1986.[1] In the past decades AFM has come forth as a tool to get nano-structural details and biomechanical properties of various biological samples. AFM can be used to investigate and measure mechanical property of cell membranes, cell stiffness, adhesion and viscoelasticity (i.e.) rheological properties of cell. AFM has been widely used for investigating DNA condensation mechanism and for gene analysis. Recent data shows use of AFM in cancer research and diagnosis and to investigate the ultrastructure of cancer cell.[2]

AFM has a wide array application in the discipline of dentistry. AFM can be used to analyse the surface topography of tooth i.e to investigate the chemistry of enamel, dentin and various dental materials used. Topographic investigation of non-carious lesion by AFM would help us to understand the mechanical and visco-elastic properties of various non carious lesions. It can also be used to analyze the surface topography of various dental materials. AFM can also be used to investigate dental biofilm samples, thereby helps in evaluating the morphology of bacterial cells, their interactions and their dynamics as biofilm.[2]

2. Principle of Atomic Force Microscopy

Atomic Force Microscopy is one of the best methods for detecting material properties. The main objective of AFM is to measure the intermolecular forces in nanoscale. It therefore utilizes three major working principles like Surface sensing, Detection and Imaging.

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2.1. Surface sensing

AFM accomplishes the principle of surface sensing by using the sharp tip of the cantilever on a micro- machined silicon probe to scan over the surface of the sample. An attractive force will be created as the distance between the sample surface and cantilever tip is reduced. Nano-scale tip is attached to a small cantilever thereby forming a spring. The cantilever bends when the tip contacts the surface and a repulsive force will be created which obviates the cantilever tip from the surface. Their bending is indicated by a laser diode and a split photo detector which represents tip-sample interaction.[3]

2.2. Detection

In the course of cantilever's tip deflection away from the sample surface, a change in the beam's reflective direction is observed, during which the laser beam reflects off a beam from the flat surface of the cantilever. These deflection changes and change in the reflected beam's direction are being tracked and recorded by Positive- Sensitive Photo-Diode.[3]

2.3. Imaging

An image of the sample's surface topography is obtained by scanning the cantilever over a section of interest. The feedback loop present in the AFM, maintains the cantilever's tip above the sample surface and the position of the laser on the photo detector is utilized by feedback loop to track the surface for imaging and measuring thereby to produce a precise image of the sample's surface.[3]

3. Uses of AFM in Dentistry

AFM is used as a nano-characterization tool to analyze the topographic, mechanical and biomechanical properties of tooth structure. It is also a distinctive tool for the evaluation of biological samples (living and dead cell surface) in nanometric form. It has extended a new pathway for the study of different fields such as cell biology (analysis of bacterial cell), dental material quality analysis, molecular interaction, preventive dental therapies (remineralisation).[4]

3.1. Uses of AFM in the field of conservative dentistry

1. Recent investigations utilize the AFM as a research tool to study the enamel erosion and dentin demineralization process.[5]
2. AFM can be used to analyze the topographical changes and the protective effect caused by newly developed remineralising agents.[6]
3. Atomic force microscopy enables to observe micro-morphology of non-carious cervical lesions as well as functional width of the dentino-enamel junction. Inspecting the dentin surface, dentinal tubules and collagen network at the nano-scale can trigger the improvements in the field of restorative dentistry providing a path to Dentin biomodification.[5,6]
4. AFM enables the understanding of the interaction between dentin adhesives with tooth hard tissues i.e integrity of hybrid layer characterization.[6]
5. AFM can be used for the nano-characterization and topographic analysis of newly developed dental materials i.e like viscoelastic properties and surface characteristics.[6,7]
6. AFM is a vital tool to investigate the ultrastructure of Biofilms and biophysical properties of surface of bacterial cell or the entire microbial cell. It can be used to analyse the adhesion of bacteria to other microbes, particularly investigating the dynamics of interactions between surface receptors and its ligands.[8]

3.2. Uses of AFM in the field of endodontics

1. AFM in endodontics can be used to analyse the surface characteristics of Gutta Percha by providing a three dimensional structure of the sample.[9]
2. AFM is used to measure the surface roughness and wettability of root canal dentin subjected to irrigation with common endodontic irrigating solutions such as sodium hypochlorite. Viscoelastic properties of dentin following treatment with various endodontic irrigants can be assessed via AFM technology.[10,11]
3. AFM widely used to evaluate the surface topography both qualitatively and quantatively of Nickel titanium rotary instruments. Surface characteristics changes on nickel titanium instrument upon exposure to various irrigants can be investigated using Atomic force microscopy. Atomic force microscopy provides detailed information with measurable parameters of possible alterations and irregularities present on the surface of the instrument. Surface analysis of NiTi instruments subjected to various surface treatments like cryotherapy, oxide coating, thermal treatments to enhance the functional properties of NiTi instruments in endodontics.[12]
4. Amplitude-modulation atomic force microscopy (AM-AFM), also known as tapping mode AFM, is a variant of scanning probe microscopy. AM-AFM has the ability to measure simultaneously the surface morphology and the compositional variations of the mapped surface. This variant form of AFM can be used to analyse the adhesion strength of the materials and can also be utilized for characterization of nanoparticles. Nanopaticles has gained much popularity in the field of endodontics for disinfection of root canals.

4. Conclusion

Atomic force microscopy considered to be an effective and versatile tool for the surface topographical analysis of tooth and various dental materials. Research through AFM can help towards selection of suitable materials for clinical use and the refinement of existing clinical practices. The growing number of researches on AFM in the field of dentistry proves its usefulness and effectiveness.

5. Conflict of Interest

None.

6. Source of Funding

None.

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