Review Article

University J Dent Scie 2021; Vol. 7, Issue 2

Tooth Tattoo: A New Paradigm to Detect Bacteria on Teeth Enamel.

Abstract:
Oral health is an integral part of good overall health. Dental caries and periodontitis are the most common chronic infectious oral diseases. With a greater understanding of dental caries and periodontal diseases comes an opportunity to promote 'preventive & interceptive therapy' much before the onset and progression of the disease. Central to this is early diagnosis. But many yester year diagnostic tools lack selectivity and sensitivity and others being expensive, limit the opportunity for early diagnosis. Researchers at Princeton University, New Jersey led by Micheal McAlpine and Tufts bioengineers Fiorenzo Omenetto, David Kaplan and Hu Tao have developed a tiny graphene nanosensor device for early and highly sensitive detection of bacteria on human enamel and assess patient's oral health, which they have called Tooth tattoo. The team first published their research in the journal, Nature Communications. Presently the prototype being studied, represents versatile approach just not for caries and periodontal disease detection but could provide window to patient's overall health.

Key words: Tooth Tattoo, Graphene, Nano Sensor.

Introduction:

Dental caries is a disease with both high prevalence and severity affecting over half of the population in industrialized countries[1]. Several studies show that at least 5-10 teeth in adults are affected by dental caries. Thus caries being the most significant cause of tooth loss[2]. WHO reports caries prevalence in school-age children at 60-90%[3,4]. US findings by the Centre for Disease Control & prevention (CDC) reveal prevalence of dental caries with 27% in pre-schoolers, 42% in school-goers and 91% in adults[5]. According to recent findings from the Centre for Disease Control and Prevention (CDC), one out of every two American adults aged 30 and over has periodontal disease, An estimated 47.2 percent, or 64.7 million American, have mild, moderate or severe periodontitis, or gum disease, according to an analysis of data collected as part of CDC's 2009-2010 National Health and Nutrition Survey. Prevalence rates increase to 70.1 percent for adults 65 and older [6].

With this greater understanding of dental caries comes an opportunity to promote 'preventive therapy' that encourages remineralization of non-cavitated lesions. Central to this vision is the ability to diagnose caries at an early stage. [7,8]. A range of diagnostic aids have been developed and are either currently available or will be shortly made so. But often the traditional methods of detection are too insensitive. Pitt's iceberg of caries calls the need of sensitivity of caries detection tools [9] .The primary goal of periodontal therapy is to reduce the burden of pathogenic bacteria and thereby reduce the potential for progressive inflammation and recurrence of disease. The Emerging evidence of possible periodontal-systemic co-relationship further reinforces the need for good periodontal health [10].

Access this article online

Website: www.ujds.in

Quick Response Code

DOI: https://doi.org/10.21276//ujds.2021.7.2.30

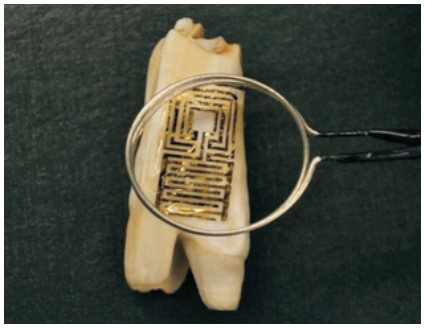
[1]POONAM SARDAR [2]BALJEET SINGH HORA
[3]KRUTIKA BORKAR [4]KOMAL SIHANI
[1,2,3]Department of Conservative Dentistry and Endodontics, Chhattisgarh Dental College and Research Institute, Ranandgaon, Chhattisgarh
[4]Intern, Chhattisgarh Dental College and Research Institute, Ranandgaon, Chhattisgarh

Address for Correspondence: Dr. Krutika Borkar
Department of Conservative Dentistry & Endodontics
Chhattisgarh Dental College and Research Institute, Sundra, Rajnandgaon, Chhattisgarh
E-mail: krutikaborkar2808@gmail.com
Email : drcsbaiju@yahoo.co.in

Received : 3 March, 2021, **Published :** 31 August, 2021

How to cite this article: Borkar, K. (2021). Tooth Tattoo: A New Paradigm to Detect Bacteria on Teeth Enamel. UNIVERSITY JOURNAL OF DENTAL SCIENCES, 7(2).: 155- 158

Researchers at Princeton University, New Jersey led by Micheal McAlpine McAlpine and Tufts bioengineers Fiorenzo Omenetto, David Kaplan and Hu Tao have developed a tiny graphene nano sensor device for early and highly sensitive detection of bacteria on human enamel which they have called Tooth tattoo which can detect bacteria on human enamel and saliva even before the process of disease process has begun.



The tooth tattoo is made of graphene, silk, gold and Anti Microbial Peptides.

1. Graphene - is one atom thick planar sheet of SP2 bonded carbon atoms packed in honeycomb lattice. It was isolated in 2004 by Andre Geim, Manchester University, UK. In recent years, it has created lot of interest in material science and medicine for being the thinnest and strongest ever supermaterial. In addition, graphene is known for its excellent electrical properties, mechanical properties, biocompatibility, low cost and for being environment friendly [11,12].

Scope for use of graphene in Tooth Tattoo:

Graphene as a new nano material has found various bio medical applications. To name a few, in drug delivery [13] and gene delivery [14], cancer therapy [15], bio-sensing [16] and bio-imaging [17], graphene based antibacterial materials [18] and graphene based scaffold for cell culture [19].

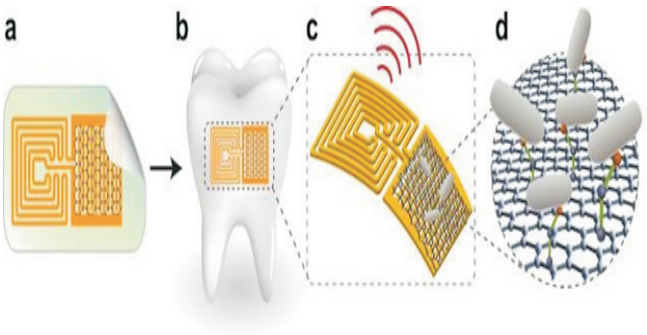
2. Silk - Natural fibrous proteins produced by Bombax mori silkworm are increasingly finding its application in biomedical field because of its biological and chemical properties. In addition, silk also exhibits unique properties including non toxicity, biocompatibility and biodegradability [20]. Silk is strong enough to hold the sensor components in place, but soft and pliable enough to wrap easily around the irregular contours of a tooth.

3. Gold - is a noble yellow metal. It is good conductor of electricity, tarnish and corrosion resistant, malleable and ductile. It is soluble in most of the acids [21].

4. Anti Microbial Peptides (AMP) - These are naturally occurring and serve as robust bio recognition molecules with broad spectrum activity towards various pathogenic bacteria. Unlike antibodies, AMPs are more stable and exhibit broadband detection of bacteria [22].

Large area graphene (c) monolayers are integrated with water-soluble silk fibroin films using simple transfer printing process. Electrodes of gold (L) are then incorporated onto silk-graphene hybrid using electron beam evaporation. Thus now the circuit has a parallel inductance-capacitance (L-C). The resulting device is wireless and battery free remote sensing device. Now anti Microbial Peptides (AMP) are attached onto this assembly. Electrical conductivity of this parallel circuit is monitored using Radio Frequency (RF) reader device [22].

The Tooth tattoo is bio transferred onto tooth surface, keeping the tooth surface wet. Complete dissolution of silk matrix in water leads to a strong attachment of graphene- gold electrode structure within a time period of 15-20 minutes. Upon recognition and binding of specific bacterial targets by the AMPs, there is electrical conductivity in the parallel circuit of graphene-gold (inductance-capacitance). This is wirelessly monitored using Radio Frequency reader [22,23].



Biotransferrable graphene wireless nanosensor. (a) Graphene is printed onto bioresorbable silk and contacts are formed containing a wireless coil. (b) Biotransfer of the nanosensing architecture onto the surface of a tooth. (c) Magnified schematic of the sensing element, illustrating wireless readout. (d) Binding of pathogenic bacteria by peptides self-assembled on the graphene nanotransducer.

Discussion:

The direct integration of highly sensitive nano sensors with biomaterials such as tooth enamel has enabled monitoring of pathogenic bacteria. As a sensing system, the resulting device has several key meritorious properties, including extremely high sensitivity owing to the graphene network, biotransferability offered by the water-soluble silk fibroin platform, broadly selective biorecogniton enabled by the AMPs and the ability to achieve battery-free, wireless remote sensing device. So, appropriate preventive measures can be shaped accordingly. There is accuracy and bio selectivity to even single cell level. In addition to detecting caries and periodontitis, patient's overall health can be assessed as biological markers for many systemic diseases appear in human saliva. Yet, these results are only a prototype 'first generation' platform for interfaced graphene nanosensors. Future work by Michael McAlpine's team and Tufts bioengineers' team of researchers will involve strategies to improve selectivity into multi-ligand and antibody based biorecognition with improved stability to provide stringent discrimination between species of pathogenic bacteria.

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