Nanotechnology in Dentistry: Developing New Materials, Non-invasive Treatments and the Ethical Issues Involved in Nanotechnology.

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Abstract:

"Nanotechnology is small but its potential is vast".

I will focus on the impact of nanotechnology in medicine, specifically dentistry. After an introduction to nanotechnology and the research currently happening, I will discuss how nanotechnology could be developed into materials that mimic the natural formation of enamel and how this could result in a new way of treating diseased teeth. Furthermore, I will discuss the ethics surrounding the issue of nanotechnology and how we could use nanotechnology to develop less invasive treatment methods. I came to the conclusion that nanotechnology could be really valuable in the field of dentistry but we must remember guidelines and regulations to ensure the use is safe, controlled and ethical.

Introduction:

Nanotechnology is: "The study of manipulating matter on an atomic and molecular scale". The concept of nanotechnology first emerged in December 1959 when Professor Richard Feynman presented a lecture entitled "There's Plenty of Room at the Bottom". He described the idea of manipulating things on a very small scale by building them up one atom at a time. In September 1985 a new kind of carbon was discovered. C_{60}, made up of 60 carbons, was discovered by three chemists: Robert F. Curl Jr., Sir Harold W. Kroto and Richard E. Smalley. The spherical carbon cage was officially named 'Buckminster Fullerene' and from this, nanotechnology grew.

The advances of nanotechnology in dentistry have been relatively slow in comparison to the application of nanotechnology in areas such as medicine. Nanotechnology has proven to be incredibly useful in medicine because it allows surgery to be more precise. Nanorobots have recently been explored in medicine to undertake basic surgical procedures; they can be inserted in to the vascular system in to various vessels and may be able to perform intracellular procedures, repairing damaged cells, which would not be possible for a doctor to replicate simply because the scale is too small. Cosmetically, nanobots are favorable as they leave the patient with few or no external scars and there is no need to make an incision in to the body (an advantage as it may be prone to infection), furthermore they can be remotely controlled which means whilst in the body they can target specific cells with more ease than using surgical tools.

Nanotechnology in medicine is currently being used in areas such as drug development and imaging. Also the targeted delivery of drugs to diseased cells, such as cancer cells, this is an effective and safer way of treating a disease.

Current research in dentistry includes the use of Nano particles, which are being used in resin based composite restorations.

If nanotechnology in dentistry had advanced at the same speed as it has done in medicine we could have already been seeing changes in the treatments and procedures offered by dentists.

I intend to explore the relation of the structure to function of enamel and how nanotechnology could play an important role in dentistry by mimicking enamel and protecting it in the first place. I will also look at both long term and short term potential developments in how nanotechnology could develop to result in non invasive treatment rather than aggressive, invasive treatment in the clinic.

The application of nanotechnology is very diverse and the future implications of it are vast. Like all new technology, nanotechnology raises issues to do with its environmental, economic and social impact. In this paper I will discuss some key ethical issues of nanotechnology in dentistry in detail.

The key procedures in dentistry haven't changed in principle much since they were first around, for example Aristotle and Hippocrates were extracting teeth in 300 BC, the method of removing a

damaged tooth has, essentially, remained unchanged. This is probably due to the fact that the methods used thousands of years ago and the methods used today are perfectly practical and do the job they need to do. However is it important that we use our expanding knowledge of the world on an atomic scale to help advance and develop the procedures and methods used for so long, precision is an important part of dentistry and nanotechnology will let us achieve ultimate precision, in that every atom will be in the correct place. It is also important to remember the dentist must understand nanotechnology as well as the researchers in the lab so it can transfer to the surgery and result in better patient care and the dentist and patient are aware of the ethical issues.

Discussion:

Stem Cells:

Currently, teeth lost to trauma or disease either leaves gaps in the patient's mouth or are filled artificially by implants, dentures or bridge work. If nanotechnology could pair together with the cultivation of stem cells, there may be an opportunity to start growing real teeth, which are as sensitive and functioning as the original. They could start either in the lab to then be implanted deep in to the jawbone where they could continue to grow or they could be grown directly in to the mouth. By building the tooth up from a stem cell, we can control the build up atom by atom and make sure the material created is as similar to a real tooth as possible, resulting in a convincing, natural looking replacement that will have huge benefits for the patients who are looking for an aesthetically pleasing result.

This method may also result in better oral health for a patient as the tooth would be nearly identical to the original, rather than with fillings or an implant the artificial material may cause the surrounding tissue to react and there are more areas for food to become trapped and cause more decay.

Enamel and Nanotechnology:

The high mineral content of enamel makes the tissue the hardest substance in the human body; it also makes it very susceptible to a demineralization process which leads to cavities which need to be treated. Demineralization can occur because of many factors however the most common cause of tooth decay is having too much sugar in the diet. Tooth cavities are caused when acids dissolve tooth enamel:

$Ca_{10}(PO_4)_6(OH)_2(s) + 8H^+(aq) \rightarrow 10Ca^{2+}(aq) + 6HPO_4^{2-}(aq) + 2H_2O(l)$

Enamel has a non-reparative character; it has a dynamic structure with a partially permeable membrane. Once it has been broken down on the teeth it cannot be remade.

One aim of nanotechnology could be able to treat cavities at an early stage so its not aggressive and non invasive and the patient doesn't need to keep coming back for treatment. Nanotechnology and modern dentistry concentrates on preventative techniques rather than restorative techniques as there may be less complications and it is usually cheaper and easier for the patient.

When we look at enamel under electron microscopes we could see in detail its form, we could use what we see to recreate enamel, copying its nanotechnological mechanism and its interaction with the material around it, building it up atom by atom to make a new innovative material and in turn have clinical procedures with finer restorative techniques. Nanotechnology may allow us to engineer and create enamel for use in repair, this ties in with the modern "preventive not restorative" ideas of dentistry, when a small cavity appears they could be tackled in non aggressive ways that may be more successful as the tooth could be restored to its natural form rather than using amalgam or an unnatural resin to fill the cavity.

Nano rods may also be used in restorative dentistry. They have a structure similar to enamel, specifically similar to the enamel rods (Measuring 4–8 μm in diameter, enamel rods are tightly packed masses of hydroxyapatite crystals in an organized yet very complex pattern that make up the fundamental crystalline structure of enamel.) Nano rods may enable us to artificially create this

naturally occurring compound which would mean cavities and decaying teeth could be restored to their natural state without having to have amalgam or composite fillings or having to extract the tooth. Current dental restorative processes (crowns and veneers) involve removing the enamel of the tooth, if nanotechnology advances it will save the enamel as cavities will be spotted long before a crown or veneer is needed so the enamel will be safe. Enamel prism-like hydroxyapatite (HA) nano rods have already been created that show self-assembly properties. Since they are similar to the enamel rods that make up the basic crystalline structure of dental enamel, nano rods could contribute to a practical artificial creation of the naturally occurring structure.

Non Invasive Methods:

After a treatment, one cause of concern for dentists is infection, especially after a treatment such as an extraction. Nanotechnology could aid in reducing the chances of infection after treatment. Nanobots could contain antibiotics or disinfecting fluids within carriers such as buckyballs which can help to combat infection. They could be situated in the vulnerable site and this would mean patients wouldn't have to put up with the pain of infection or the cost and time of another appointment to sort it out.

Before a filling, root canal treatment, crown or bridge prep, extraction and many other dental procedures, an injection of anesthetic is needed in the gum or palate to numb the area ready for treatment. After observing in many practices, I have come to the conclusion that the injection is the part of their visit that patients are the most nervous about. The needle and syringe together look rather daunting, especially for young children who need teeth removed before orthodontic work, this can be a really scary time. I believe the use of nanotechnology can come in to play here to make patients feel more relaxed and at ease, this would, obviously, make less people afraid of the dentists chair and make the whole procedure easier for the dentist! We can apply the idea of the 'dual sorption' model to transport drugs through the skin. A panel exists which sends drugs through the cells of your skin when you just place it on the surface, this invention stemmed from the idea of delivering insulin to diabetics but this could also be a way to deliver local anesthetics for those patients who don't feel comfortable with injections. Again, carbon carriers such as buckyballs could carry anesthetic to the localized place that needs to be numb.

Nanobots could be used extensively in dentistry for procedures such as root canal fillings. Currently the process requires the patient to sit for a long time in the chair, it is a very intense treatment and has a lot of scope to go wrong (there is currently a 70% success rate in NHS root canal treatments) as the dentist has to use a degree of guess work as he or she cannot see in to the root so it is difficult to tell where abouts in the root their tools are, meaning if they leave a gap at the end the root is susceptible to infection, this causes unnecessary pain for the patient. Nanorobots mean endless possibilities for this sort of treatment: They could be equipped with a miniature camera so the dentist can see for themselves the way the root bends and where it finishes. They could also be used to clear out infection quickly and effectively, as mentioned previously, carriers such as buckyballs could contain antibiotics or other drugs to combat infection in a targeted area. Finally, the carriers could also carry stem cells in to the empty root canal space to encourage the growth of new dental pulp and nerve cells, this would recreate the tooth to its most natural form, it would be unlikely that the body would reject the new stem cells and this treatment means the patient would not have to have the dentist invading their root canals with sharp rotary tools. Yet another advantage for the patient is that the tooth would be as sensitive and fully functioning as before.

Ethics of Nanotechnology:

There are many ethical issues surrounding nanotechnology, some are not specific to medicine whereas others are.

One common worry, not specific to medicine but based on nanotechnology as a whole is the question of responsibility of humankind on a global level. Nanotechnology allows us to manufacture miniature weapons and explosives as well as surveillance equipment; this could render privacy a thing of the past and cause more wars and unrest between countries.

An ethical issue linked more directly to its application in areas such as medicine and dentistry is that nano gives us more "God like" powers which many people believe is wrong as we are not his equal. It is un-natural for us to recreate molecules from such fundamental principles and some people may argue we are playing God and we have no right to change and mimic the basic structure of natural compounds, because nanotechnology is, essentially, attempting to copy nature. For example, Christians may believe "The body is a temple of the holy spirit" and by altering it at such an in depth level we are going against "Gods plan" which they believe to be morally wrong. Moreover, many believe that the use of nanotechnology would reduce their "sanctity of life", their holy relationship with God. Also, nano medicine may stray from healing and curing and have other aims such as enhancement of individuals; this may also be deemed by some people as wrong.

Another ethical issue which should be considered is the fact that some people may be unhappy to think that man made devices such as nanorobots may remain in the body after treatment. This may make them feel un-natural and not close to God.

Finally, we must consider the changes nanotechnology may have on the health of a person. Nano particles have a large surface area:volume ratio. The greater the specific surface area, the more chance it could lead to increased rates of absorption through the skin, lungs, or digestive tract, this could cause unwanted effects on the lungs and other organs in the body, as non-degradable nano particles could accumulate. Another concern is the potential interaction with natural biological processes in the body. This is primarily down to their large surface area, nano particles, upon exposure to tissue and fluids will straight away absorb onto their surface some of the macromolecules they encounter. This could cause problems as substances may not be where they need to be in the body. However, the particles must be absorbed in sufficient quantities in order to pose a health risk and so in most treatment in dentistry, this should not be an issue.

Conclusion:

It would be difficult to reject the idea of nanotechnology as it has already infiltrated so many areas of society. However I believe it is a good idea to have regulations and guidelines on the development of nanotechnology so it does not become out of control. It is important to remember as well as huge benefits there are also potential dangers so we must develop it safely and ensure that organizations do not start using it for harmful activities, for example, explosive devices. We must also take in to account different religions and their medical ethics and make sure there are still treatment options for everyone, as some people may object to the use of nanotechnology.

I believe that the use of nanotechnology could be very valuable in the field of dentistry and result in a number of new minimally invasive procedures, which are beneficial because the recovery time for the patient will be shorter, as will the time taken for the treatment to take place, there will be fewer external scars and the procedure may even be less painful.

However, there are some problems with the ideas stated above. Since nanotechnology is a very recent discovery and is only just being put in to use, there are issues that need to be addressed. Firstly, the long term effects of nanotechnology are unknown, therefore problems caused by nanotechnology might not show for many years. For example, because the technology is on an atomic scale, it could have unwanted effects on the DNA of cells, which could potentially cause

genetic defects, if this were to happen it would take a lot of time and research to put right. In humans, these side effects wouldn't show for some time, it may even take generations for any side effects to show, to overcome this problem we could run clinical tests on bacteria or animals that breed and grow fast, any effects of nanotechnology will show as each generation has treatment. This means that nanotechnology may be developed to avoid any negative genetic influence. Since this is a problem due to the invasion of cells, a solution could be to create particles that cannot pass through cell membranes, and reach the genetic information.

We must always remember to enforce regulations and guidelines when it comes to the use of nanotechnology. We don't want to have to totally rely on nanotechnology as it could become out of hand but merely use it along side our current treatment methods, to improve and enhance the dental experience.

Nanotechnology is such a new and exciting area of science so there are many ways in which it can progress: It would be beneficial if treatment involving nanotechnology could be done for free so it encourages the idea of preventative dentistry because more people would be able to have the treatments offered, it would be fair then, as everyone would have the option of better dental care.
However this raises economical issues as nanotechnology is so intricate, difficult and time consuming to develop and then put in place in the wider community. Some people who do not agree with the idea of nanotechnology may be unhappy that tax is going towards this area of research.

Despite a number of problems with nanotechnology, the new era of nanotechnology in dentistry could change many people's views of the dentists. It may have the power to put the fear of the dentists at bay as large drills won't be as commonly seen, the public should be educated in the area of nanotechnology so they understand the developments in the treatment they are receiving.

I acknowledge that many of the ideas put forward in this paper may not be entering dental practices in the near future or coming in to the public eye for a good few years as they would require extensive research, time and money, for example using stem cells and nanotechnology to grow teeth. (After being finalized in the lab, new procedures would first be seen in hospitals and dental clinics before becoming readily available to private practices on the high-street.) On the other hand, some ideas may be close to being used on a day to day basis in the dentists and we could, in our lifetime, see a real impact and change in the way dental practices are run. Nanotechnology is new and exciting and I am certain that we will be seeing more of it in the years to come.

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