The Potential Use of Lasers within Dentistry to Improve and Enhance Current Techniques

By

Courtney Moffitt

Grade awarded: Fail

RESEARCH PAPER
BASED ON
PATHOLOGY LECTURES
AT MEDLINK and VET-MEDLINK 2014
Abstract

In this paper I have discussed how the use of lasers can enhance and improve many common dentistry techniques, the main two being fillings and tooth extraction. I have explained how this could be achieved, as lasers may be able to change an ameloblast life-cycle to form enamel that has the potential to repair and restore itself. I have looked at the benefits of this futuristic technique including how it is less invasive and the recovery time is shorter, but I shall also highlight the potential pitfalls that may occur, including ethical and consensual implications.

Introduction

The term stem cell was first proposed over a century ago by Histologist Alexander Maksimov in 1909. Since this time there have been many radical developments within stem cell research, thus giving us a greater and a more in-depth knowledge about post-natal stem cells. The main difference between embryonic and post-natal stem cells is the fact embryonic stem cells are pluripotent, so have the ability to differentiate into any type of cells, whereas post-natal stem cells are multi-potent, so only has the ability to differentiate into cells that derive from the harvested stem cells original tissue of origin.

This knowledge has given us the potential to change, improve and enhance many common dentistry techniques. A subsequent research project into post-natal stem cells, which are the stem cells present after development, has meant that Dr Sangtao Shi made, arguably, the most notable breakthrough discovery of the 21st century within stem cell research, which was the detection of postnatal multi-potent stem cells within the dental pulp in 2003, demonstrated by the work of Sangtao Shi (2003). He discovered that adult multi-potent mesenchymal stem cells can be located within the dental pulp of both permanent and non-permanent teeth. Mesenchymal stem cells are stem cells that have the potential to differentiate into osteoblasts, chondrocytes and adipocytes, discovered through the work of Anna et al. (2008). This means that adult stem cells can now be easily harvested from children’s ‘baby’ teeth when they naturally fall out and can be frozen for future use. This discovery also means that the harvesting process for mesenchymal cells can now be faster, cheaper and painless for the patient, compared to the more conventional technique of having to have them harvested from the patient’s bone marrow. As this means there is no after care required for the patient as they will not have to have a surgical procedure to harvest the post-natal stem cells so therefore there will be little need for any anaesthetic.
One of the radical developments that has been able to take place due to the detection of the postnatal stem cells, has been conducted by Dr Pavreem Arany of NIH’s National Institute of Dental and Craniofacial Research (NIDCR) and Dr. David Mooney, a bioengineer at Harvard University. Arany and his team conducted their experiment on rats; they drilled one hole in two molars of each rat, imitating the cavities in human teeth that may be formed from decay. They aimed the low-powered lasers for five minutes, into one of the cavities and left the other one untreated, they then capped both of the cavities so that no moisture could enter them. They found that in twelve weeks there was approximately 20% more knobs of dentin formed in the base of the cavity of the molar which had the laser therapy, compared to the cavity which did not. Figure 1 shows the result that proves that it is possible to trigger the stem cells to differentiate at a faster into dentin using a laser, as more dentin was formed in the cavity which had the light therapy compared to the cavity which did not, in rats.

Figure 1

![Figure 1](image)

Figure 1 shows the positive results (the yellow hashtags on the red photo shows the original place where the dentin stopped, the blue photo shows the place where the newly formed dentin finishes, once again highlighted by the yellow hashtags). This is due to the fact they realized that if they aimed the laser in a dose dependent manner, at the reactive oxygen species (ROS). ROS is a chemically active molecule that contains oxygen which plays an important role in cellular function. By triggering the reactive oxygen species then this would initiate the start of a chain of chemical and biological events within the tooth, as this would cause the activation of the latent protein molecule TGF-β1. It was this protein molecule that stimulated the stem cells within the dental pulp to differentiate into dentin, as demonstrated by the work of Arany (2014). Therefore causing the regeneration of the bulk of the tooth.

This major discovery of stem cells within the dental pulp and their ability to differentiate and regenerate into dentin, with the help of a low powered laser, has the potential to lead to a vast array of enhancements within the dentistry profession. That would mean that dentists would not only be able to treat their patients to a higher and more accurate procedure, but they would also save themselves time in the long run, as they would no longer be using inert materials for a vast
number of the common practices, for example fillings, that would deteriorate over time. This means that the detection of these stem cells has been able to pave the way to make a more efficient dentist. I will now discuss what I believe could happen in the future with the help of lasers in dentistry, building upon the knowledge I gained from Arany's research. I shall highlight how you could potentially grow the enamel, allowing dentists to regenerate a whole tooth.

**Discussion**

Enamel is the visible, semi-translucent outer most layer present on every tooth. It is the hardest, most mineralised substance within the body, it is also composed of four different components which are: outer enamel epithelium, inner enamel epithelium, stellate reticulum and stratum intermedium. The enamel is made up of approximately 95-98% of calcium and phosphate ions that make up the strong hydroxyapatite crystalline structure, it is this crystalline structure which gives the enamel its strength. To work out how you could potentially regenerate the enamel, I believe you must first look at the cells that caused the formation of the enamel in the first place.

Enamel is formed by the interaction between two main components, the first is called the squamous dental epithelium cells, which derive from oral ectoderm, which will differentiate in the enamel secreting ameloblasts and mesenchyme stem cells which will differentiate into dentin secreting odontoblasts, shown through the work by Thesleff (2005). Both cells are equally as important as you require a tissue capable of producing the primary stimulus, and another tissue having the correct receptors so it is therefore capable of receiving and responding to the stimuli. The interactions between the tissues involve signalling networks and receptors, the receptors are complementary and specific to the particular signalling molecules being sent.

It is these signals from the dental epithelium cell that causes the first cell differentiation of the mesenchymal cells into odontoblasts. The odontoblasts deposit the dentin matrix and will send the signal to the inner enamel epithelial, which will cause the subsequent differentiation of the epithelial cells into becoming ameloblast, shown through the work of Karcher-Djuruci (1985). It is then the ameloblast's job to secrete the enamel protein called enamelin and amelogenin, which with later mineralise into the enamel, shown through the work of Gallon V (2013). However just before the tooth erupts through the gums the ameloblasts breakdown, this is the reason why enamel doesn't contain any living cells. It is for this primary reason that the enamel cannot regenerate and repair itself when damage has been done to it, for example through decay.

After reading the above I believe you can cause enamel regeneration by altering one of the six stages that makes up the life-cycle of an ameloblast. The stage that I believe humans have the potential to change is stage 3, which is called the transitional stage.

Figure 2 shows how each stage contributes to the formation of the enamel. It is during the transitional stage that the enamel reaches its full thickness. Once this happens the ameloblasts begin to change, they firstly decrease in height and the number of protein synthesising organelles dramatically reduces (the three major protein synthesising organelles are ribosomes, the rough
endoplasmic reticulum and the golgi apparatus) These changes mean that the number of ameloblasts is estimated to decrease by approximately 50% of their original number.

Figure 2

I hypothesise that if you prevent the protein synthesising organelles reducing then there would be subsequently more ameloblasts going into the fourth and fifth stage, which have the potential to survive when the tooth erupts from the gums. The increased number of protein synthesising organelles means there will be more proteins produced within the ameloblast, this means there will be more proteins to provide structural support within the fluid mosaic of the cell membrane. I propose that you could disrupt the transitional stage by focusing a low powered laser on to the ameloblast as this would then disrupt and alter the deoxyribonucleic acid, or as it's more commonly known as DNA. This disruption would mean that the ameloblast would no longer be in 'self-destruct mode' when the enamel is at its full thickness and kill itself. Therefore the number of ameloblasts would remain high going into the fourth and fifth stage.

If my hypothesis is correct then there would be an increased chance that some of the ameloblasts would not mineralise but would in fact stay 'alive'. Therefore making the enamel like other tissues within the body, as it would contain living cells, which could reproduce by mitosis to create genetically identical daughter cells, to regenerate and repair the enamel, like other tissues found within the body, if it became damaged. This would mean that you could regenerate a complete tooth, without having to remove the tooth from the gums. The consequences of the enamel being able to regenerate itself could lead to an array of improvements to current dental techniques. As dentists would no longer have to using amalgam as the material to fill cavities, like they have for the past 150 years, according to the British Dental Foundation, but will instead be using the patient’s own stem cells. It also means that the need for the extraction of teeth will become a less common practise, as the dentist will be able to stimulate the regeneration of the tooth. This means that the patient will not only be able to maintain the function of the tooth, but it will also mean that they will be less like to have a dentures in the future as they are maintaining the function of their teeth for longer. This is another positive point to using stem cells to regenerate a
tooth as dentures can be very painful for the patient if they do not sit properly. It also means that many common procedures will become less invasive as there will be not be as greater need to remove the tooth, so there will be a smaller need for anesthetics.

However there are many ethical concerns about the research into the manipulation of stem cells, in particular embryonic stem cell research. This is due to the fact embryonic stem cells research requires the scientist to 'kill' the embryo, when the embryo is between three to five days old, as this is when the embryo is in its blastocyst stage of development. The scientist does this by removing the inner cell mass called the embryoblast from the outer cell mass called the trophoblast. The outer cell mass would eventually form part of the placenta, whilst the inner cell mass is made up of the group of cells that would have differentiated to become all the structures of an adult organism. It is the embryoblast that is the source of totipotent embryonic stem cells. Many people from differing religions are against this research as it requires the destruction of a potential human being in particular the Roman Catholics, as embryonic stem cells research goes directly against one of the ten commandments 'thou shalt not murder'. However as my research proposes the manipulation of adult stem cells, there is not as much as an ethical problem as the manipulation of the ameloblasts, which are formed through the coordination of the dental epithelium cells and mesenchyme stem cells, would not cause death to the patient.

However, one issue with my hypothesis that could cause a lot of backlash is the fact that you would have to experiment my theory on a child. As the enamel makes up the crown of a tooth, the crown is the visible aspect of the tooth. Demonstrated by the work of Ash (2003) Figure 3 highlights how young the patient would have to be, as the crown and the mandible of a permanent tooth is approximately completed within the first three years of development. This means to find out if my hypothesis is correct you would have to test my theory out on a child who is approximately just two years old, as you want the enamel to be partially complete, so that way the ameloblasts would be in their third stage of their life cycle.

**Figure 3**

<table>
<thead>
<tr>
<th>Permanent teeth</th>
<th>Maxillary (upper) teeth</th>
<th>Mandibular (lower teeth)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Central</strong></td>
<td><strong>Molar</strong></td>
<td><strong>Molar</strong></td>
</tr>
<tr>
<td>Initial calcification</td>
<td>3–4 mo</td>
<td>10–12 mo</td>
</tr>
<tr>
<td>Crown completed</td>
<td>4–5 yr</td>
<td>4–5 yr</td>
</tr>
<tr>
<td>Root completed</td>
<td>9 yr</td>
<td>10 yr</td>
</tr>
</tbody>
</table>

As the patient would be so young consensual implications would become prevalent, as the child would not understand what is happening to them or what they will encounter within the experiment, so the guardian would have to make consent on the child's behalf. Therefore some
may argue that the guardian should not be able to make this decision as the guardian may not understand what some of the possible consequences of the experiment may be, as the scientists themselves cannot be 100% sure of the outcome of the experiment, as it has never been performed before. One possible side effect could be the psychological issues that the child may get from the experiment, if the child finds the experiment unpleasant. These psychological issues may become apparent later on in the child's life, as they may take the form of dentophobia. Dentophobia is the irrational fear of the dentist, recent figure released by the British Dental Association, on BBC news health, show that 25% of all British citizens suffer from some level of anxiety when going to the dentists, but around 12% of the population suffer an extreme level of anxiety classing it as a phobia.

This could be a potential side effect, as according to the behaviourists approach in psychology phobias can be conditioned through classical conditioning. So in the future the patient may now only associate pain with the dentists, giving them the negative feeling of fear towards giving to the dentist. This would mean the scientists who do the experiment would have to provide an aftercare system that not only checks the patient's teeth, to make sure the experiment has worked. But they may have to provide an aftercare service to check the child's mental health, this may have to span out years, so that way they would be completely sure that the child has not left with any psychological issues. This service may have to come in the form of a counsellor, to decondition the phobia out of the child; this may mean the counsellor would have to perform systematic desensitisation therapy, as this therapy tries the make the patient less sensitive to their phobic situation. However this aftercare service may become very expensive, if the child does in fact incur psychological problems, as the therapy may take many years to complete. This would be a major financial problem if the experiment in fact does not work.

However there are many positive reasons for using lasers within dentistry. This is shown through the 325 different studies using lasers that have taken place in 82 different institutions from 37 different countries, demonstrated by the work of Tunér (1998). Of these studies a staggering 90% of them have shown positive effects to using laser therapy. One reason for these positive effects is due to the fact laser therapy is minimally invasive, this means it may reduce the anxiety levels of some patients as there is less pain, therefore reducing the amount of anesthetic needed. This adds another positive point on to my hypothesis as this means the patient would be in very little physical pain. This point is also backed up by two different studies one is demonstrated by Parker (2000) and Bouneko (2000) both of these studies highlight that there was an overall significant improvement in wound healing and tissue regeneration. This shows that my procedure has the potential to be painless; not only during the procedure but the recovery period will be painless.

**Conclusion**

The research into stem cells has led to a vast array of different potential uses within the dentistry field that has the power to transform and improve common current techniques and procedures. These enhancements will not only benefit the patient, as the uses of lasers will mean the procedure will become less invasive compared to the more conventional techniques, this
therefore means that the patient’s recovery period will be shortened, as there will be less trauma caused to the gums surrounding the tooth that has been treated. These enhancements will also benefit the dentist, as this means he will be saving time in the long run as they will no longer be using materials that will eventually need replacing. However the potential consensual issues of my idea as the procedure may have to be undertaken on a young child, may cause a great problem and has the potential to hinder the research into the future potential uses of stem cells to regenerate the enamel. I predict that in the future it may become possible that future generations will never have to go through tooth extractions as the regeneration of a complete tooth will be possible and accessible to all.

References

- dentophobic figures - ‘Fear of dentists and needles needs sympathetic ear’ www.bbc.co.uk/news/health-12182855
- Figure 1- Harvard Wyys Institute and SEAS
- Figure 2- http://course.jnu.edu.cn/xxy/eruption/news/system/knowledge/oral%20histology/Oral%20Histology7.htm