Increasing the Accuracy Efficiency and Affordability of Dental Implants: A Process of Invention

Senior Thesis

Submitted to my Integrated Studies Board of Utah Valley University in partial fulfillment of the requirements for a Bachelor of Science in Integrated Studies

Emphases in Biology and Business Management

By

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Thesis Approval Page

In partial fulfillment for a Bachelor of Science Degree in Integrated Studies with Business Management and Biology emphases, we hereby accept this Senior Thesis written by Michael Nuttall.

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Introduction

As an experienced carpenter I enjoy thinking of new tools and ideas to shape wood and construct things. Dentistry isn't much different. This research project will show how to improve upon an existing dental implant procedure that involves drilling a hole in the jaw bone and screwing in a post that will eventually support the new tooth.

The key to a long-lasting tooth implant is getting the metal implant screw to successfully grow to the bone. This process is known as osseointegration. For an implant to do this it is vitally important that the predrilled hole is surgically drilled in the right location at the appropriate angle. Finding the right location to drill the hole(s) for a dental implant can be time consuming, expensive and potentially an inaccurate process. A dentist will either request a costly custom guide to accurately drill the hole in a patient's jaw or simply grab the drill and free hand the hole hoping they will be successful without causing nerve damage, drilling through adjacent teeth, or even piercing through the sidewall of the jawbone. To deal with this problem, I have invented a new product called the Universal Dental Implant Drill Guide. By using this guide a dentist can increase the accuracy, efficiency and affordability of their dental implant procedures. Through creativity, gathering information from as many sources as possible, implementing engineering concepts, and re-evaluating everything, I gradually developed my drill guide.

What This Invention Will Improve

This invention will not only improve the current process for dental implants, but it will create a safer procedure that will bring a patient more emotional comfort while sitting in the dental chair. Dentists are realizing that new technology isn't necessarily what will attract patients to their office. More important is a guarantee that the dental work will be done with the highest

quality available. This type of guarantee will, attract more patients, and create a better emotional environment for the patient. This has become so important that dental professionals are calling it "The Rise of Emotional Dentistry." (Krzyzostaniak 2017) For this reason it is also vital that this invention will provide the highest quality available, and it does.

Who has the Problem?

A close examination of the dental implant process reveals that both the dental professional and the patient are affected by the current costs, accuracy and efficiency. This means that any improvements to any of these areas, will make it a win-win situation for both parties. Although, improving any single issue must not create further problems in any of the others.

Current Process

It is in the best interest for both the patient and the dentist to carefully consider every step of the dental implant process. Here is the step-by-step route of what a patient would expect if they were to begin the process.

Step 1: Consultation

In this step the patient meets with the dentist to determine the feasibility of doing the dental implants. The dentist will diagnose the condition of the patient's jaw bone, teeth and gums, through obtaining x-rays and performing other tests. Also, if no further bone grafting needs be done the dentist will make an impression of the teeth to send to a dental lab where they can build a custom drill guide to fit the patient's mouth. The patient will then reschedule with the dental office to come back for the second visit.

Step 2: Inserting Metal Implant Screw

In this step the dentist has received the custom guide from the dental lab and is ready to drill the hole. Drilling the hole is done by using a series of bits at different sizes. The dentist will then slowly drill away at the edentulous region (the drill sight on the jawbone that is missing a tooth) making sure everything is accurate and safe. Once the hole is drilled the dentist will then insert the metal implant screw. Also, depending on the density of the patient's jaw bone the dentist could place a temporary tooth on the metal implant, while the implant goes through osseointegration.

Step 3: Abutment Placement and Crown

In this visit the dentist checks the implant to see if it has grown properly to the jawbone. If all is well, an abutment will be attached to the implant. A custom crown will have been made by a dental lab, or depending on the technology the dentist has, then the crown could be carved in a CNC machine within the dental office. This crown will then be cemented to the abutment, and the patient now has a new artificial tooth.

In most cases the patient will have to visit the office three times. I don't know very many people who love going to the dentist, so I am willing to guess that a large majority of the population would choose to visit the dentist two times instead of three.

Current Cost

According to Authority Dental, a reliable source of dental health which millions subscribe to, "a single-tooth dental implant cost between $1,000 and $3,000. The abutment and crown add between $500 and $3,000. So, the total dental implant cost per tooth is between $1,500 and $6,000." (Nowak 2019) Also, most insurances will only cover a small portion of that amount. That's a pretty pricy penny. To put it in perspective. As a carpenter I only charge $3,000

to $4,500 for an entry stairway handrail and balusters. The Implant only requires one hole to drill. Whereas, the balusters for the handrail require around 400 holes.

This total price for the implant can be broken down into several visits, starting with a consultation where x-rays, and impressions are made to a few visits later when the tooth is finally placed. The only cost this invention is concerned about is the price of having a custom guide made from a dental lab. Each custom guide usually costs around $500 for the dentist, each time.

Price is not the only thing someone should consider when deciding to get dental implants. After all I would hate to bite into a big juicy steak and have a $1,500 implant break loose.

Current Accuracy

The accuracy or quality of the dental implant depends on the hole that is drilled. When a dentist orders a custom guide from a dental lab the accuracy is pretty high. This is because the lab triangulates all the angles using the patient's x-rays and advanced software to build the guide specific for each patient's mouth. The alternative to ordering this guide is to free-hand it. I consider myself a very skilled carpenter, but even I mess up sometimes when drilling holes. Likewise, in cases where a dentist chooses to free hand the hole, the accuracy and quality of the implant is hit-and-miss.

The Process of Inventing

At the outset of this project I didn't have a clue about what to invent, but I knew what I needed to do. I picked up the phone and called my brother, Matt Nuttall a dentist in Tacoma, Washington. I explained my ambition to invent a tool to be used by dentists and that I needed his help. I asked him if there were any issues or inefficiencies that he notice with any procedure he performs throughout a normal day? He began to spout off a few things, but they weren't very

interesting. After a minute he said, “Oh wait, actually there is something.” He then proceeded to describe the process he uses when doing dental implants. He either has to order a custom guide for drilling the hole in the edentulous region or try to free-hand super carefully. This was it; this was an issue that seemed like it could be feasible to improve. I asked him what he would prefer instead. He then described a tool that is used for root canals, where an electric current is sent through the root of the tooth to find the apex of the root to give a measurement. I knew what he was talking about, because I had a root canal done a few months prior and the dentist I visited knew my interest in dentistry, so he let me hold the gauge and observe what it was doing. My brother thought it would be nice to have something similar to put on the edentulous region so he could drill more accurately by quickly free-handing it. (Nuttall 2018)

The device my brother was talking about is called an Apex Locator. Turns out this device uses pretty simple physics. There is a pointy tip that is narrow enough to slide into the exposed root of a tooth. An electric current streams out of the tip, through the narrow root of the tooth, and back to a diode usually attached to patient’s mouth, making a full circuit. While the current is flowing the dentist will either hear a beeping noise or a continuous flatline. The beeping noise indicates the resistance is really high. The flatline noise indicates the dentist has gone past the apex of the root. The device has a series of lights that light up to show the depth of the tip once the dentist feels he/she has reached the apex, then the dentist will proceed with the rest of the root canal process. (Gordon 2004)

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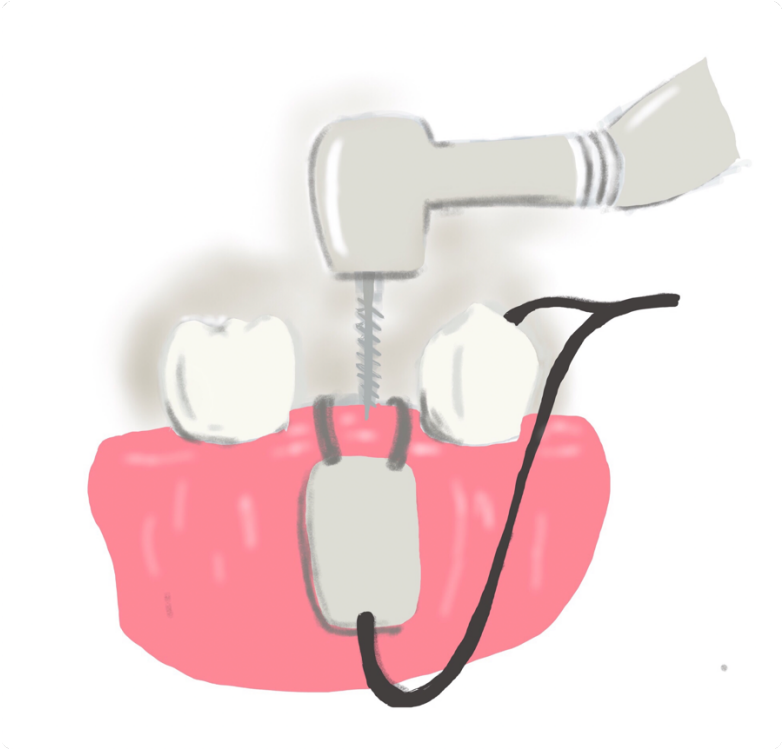
1st Concept

How would I apply this to drilling implant holes though? After several sketches I came up with a concept that reflected what my brother was aiming for.



The grey pad has a diode inside it. An electric current is sent from the visible pad through the jaw bone and into another pad on the opposite side which also has a diode to complete the full circuit. That was easy to think of. The tricky part was how to get the device to beep as the drill penetrates down into the jaw bone. If the device could measure the resistance of the jaw bone and do some calculations to find the center of the bone, then the dentist could lock that value into the device. Next the drill bit would have to attract the current to it, then calculate that it is in the center of the jaw bone as it sinks. This is how it would work in theory.

Not quite though. I needed some expert opinion, so I sought help from a physics professor. I showed him this design and he immediately said. “No that won’t work.” Ouch! He then explained why. Essentially, bones are not uniform in density. For instance, the middle of the

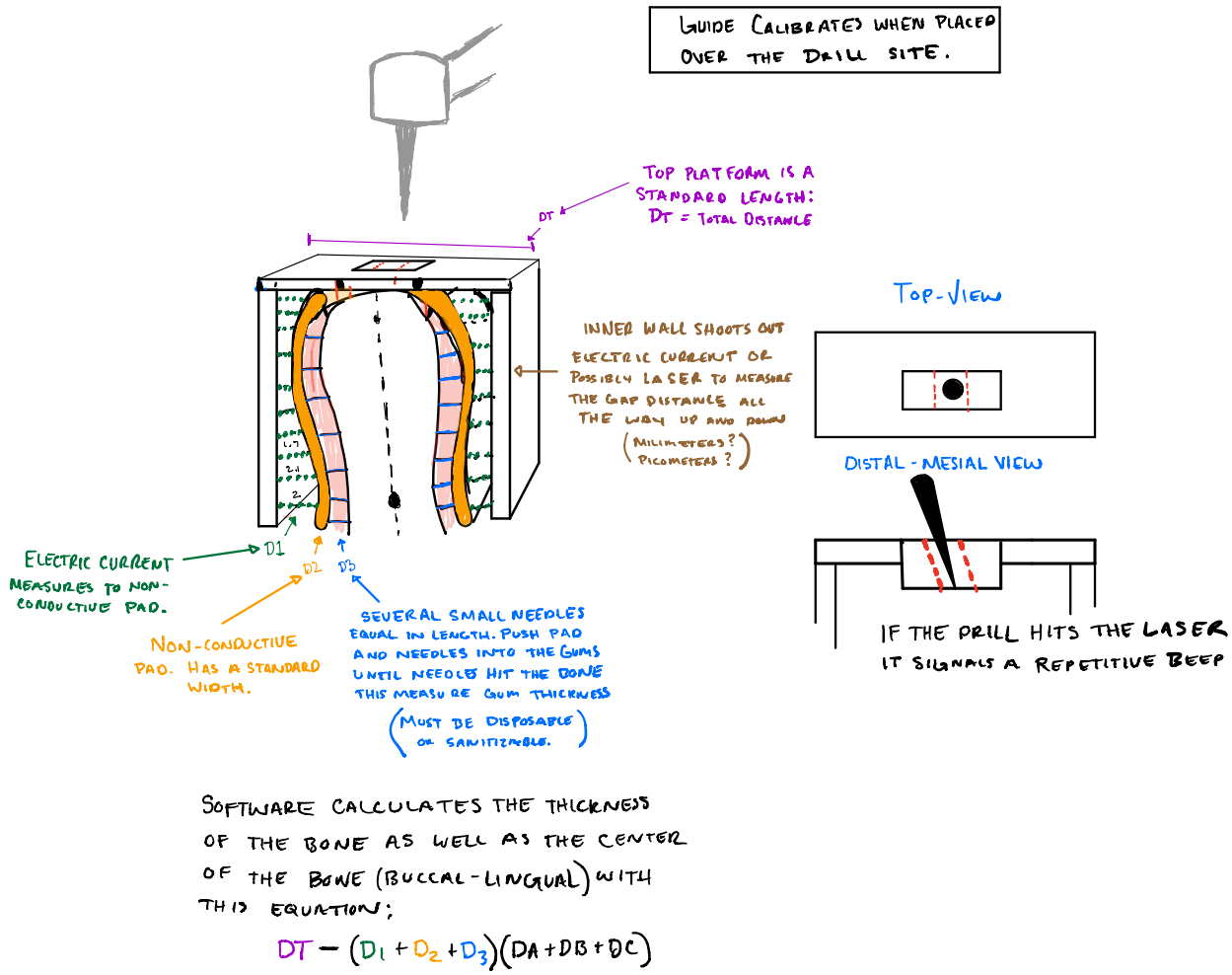
jaw bone could be really dense for one person and less dense for another. The denser areas of the bone give a certain value of resistance and the less dense areas of the bone give another value of resistance. This means that the device would only beep in the center of the jaw bone in rare instances. Most of the time the hole would be drilled closer to one of the sidewalls of the jawbone.

After just five minutes of conversation with this professor, I realized this was going to be harder than I thought. The impracticality of this idea was solidified as I learned from other sources that "the structure of the bone is quite complicated and can be seen as a network of different parts all intertwined in a specific manner. …The bone can be simplified as a sum of three different parts: Haversian canals, Volkmann canals, and the rest of the bone which [is]… referred to as the bone matrix." (Newton 2013) This put me at a dead end. I didn't want to invest more time into defying the laws of physics, so I decided to attack from a different angle.

2nd Concept

If a current couldn't be uniform through the jawbone, then I thought I could use the current to measure to the jawbone and calculate the correct angle through simple trigonometry. With this idea I designed a new concept. How would the device sense that the bit was penetrating at the correct angle without the current traveling through the jaw bone? This was where I had to think outside the box or in other words outside the jaw bone. I came up with an idea to use laser sensors. Depending on the triangulation calculated inside the box, the lasers would turn on with a relative angle at the point where the drill bit is inserted and as the drill bit is penetrating it will sound a rapid beep if it hits

any of the lasers. Sort of like that childhood game where you pull out the heart and other organs from the patient.



I could finally see this working, but there were still a few problems. I couldn't think of a way for this contraption to be used efficiently in the dental office. It was just too complicated and a pain for the dentist to set up. Also, in order to get an extremely accurate angle, I need a bunch of needles to penetrate into the gum to measure the gums thickness. When I showed my brother this concept he said, "I don't think anyone would want a bunch of needles stabbed into their gums." I hit my forehead. What was I thinking? I considered this design failure number two. Nevertheless, I remember a history class over a decade ago when we were learning about

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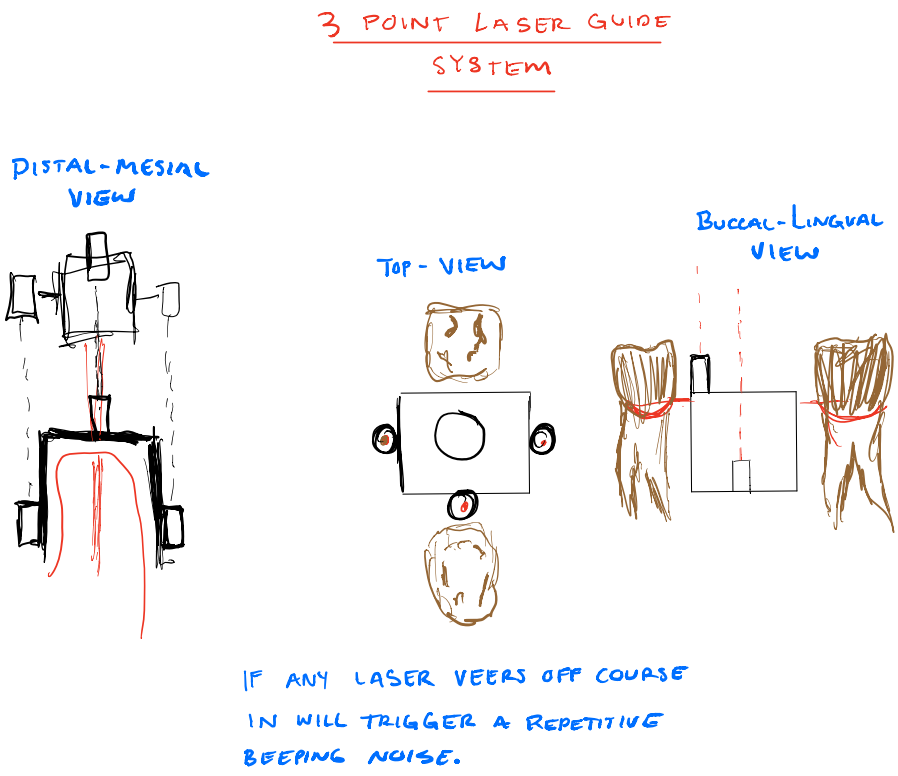
Thomas Edison and his light bulb invention and how he failed few more times than twice. This kept me going.

3rd Concept

This led me to designing a completely new concept. In this design I placed three laser sensors on the outside of the contraption. The drill bit also had three corresponding laser projectors on it. The dentist lines up the lasers to hit the sensors and if the lasers veer off course as the drill penetrates into the jaw bone then the device will sound a beeping signal. From the picture you can see that I didn't spend much time on the sketch. This is because I quickly discovered that I still had this problem of trying to triangulate the contraption to get the correct angle, both mesial-distal and buccal-lingual.

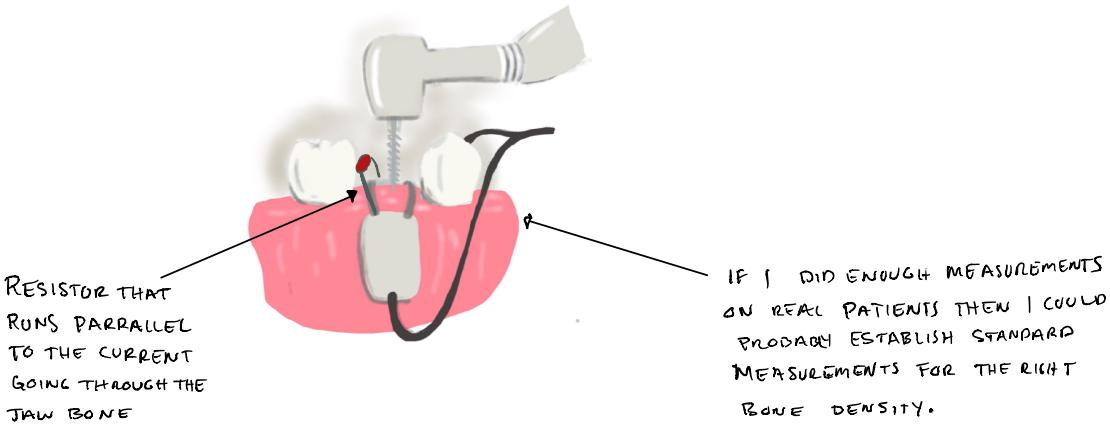


I needed to make this device attractive to dentists and I kept thinking they were just going to discard this idea due to the complexity of setting it up even if I built it in a

way that would get the correct angle. I decided to just move on and start concept number four.

4th Concept

Much like the lasers veering off course, I decided I was veering off course from what I originally set out to do. So, I took another look at the first concept to see if I could think of anything different. By this time, I had taken a physics course and knew quite a bit more about electrical resistance. I ended up designing a completely different tool that would be useful for many different things. Not limited to dentistry. I call it the Bone Density Indicator. Using the same design of the first concept and adding a resistor that runs in parallel with the electric current flowing through the jawbone and given the specific value of the resistor we can determine what the resistance of the jaw bone is with very little error. I still couldn't think of a way to find the center of the jaw bone due to the different parts of bone tissue that is completely random in each patient.



Despite this inability to make this concept work for improving the drilling of implant holes, it actually has potential to turn into another noteworthy invention that measures the density of a person's bone. Which would be good for determining whether or not the patient needs bone grafting done before implant surgery. As far as I can tell it wouldn't be a very big

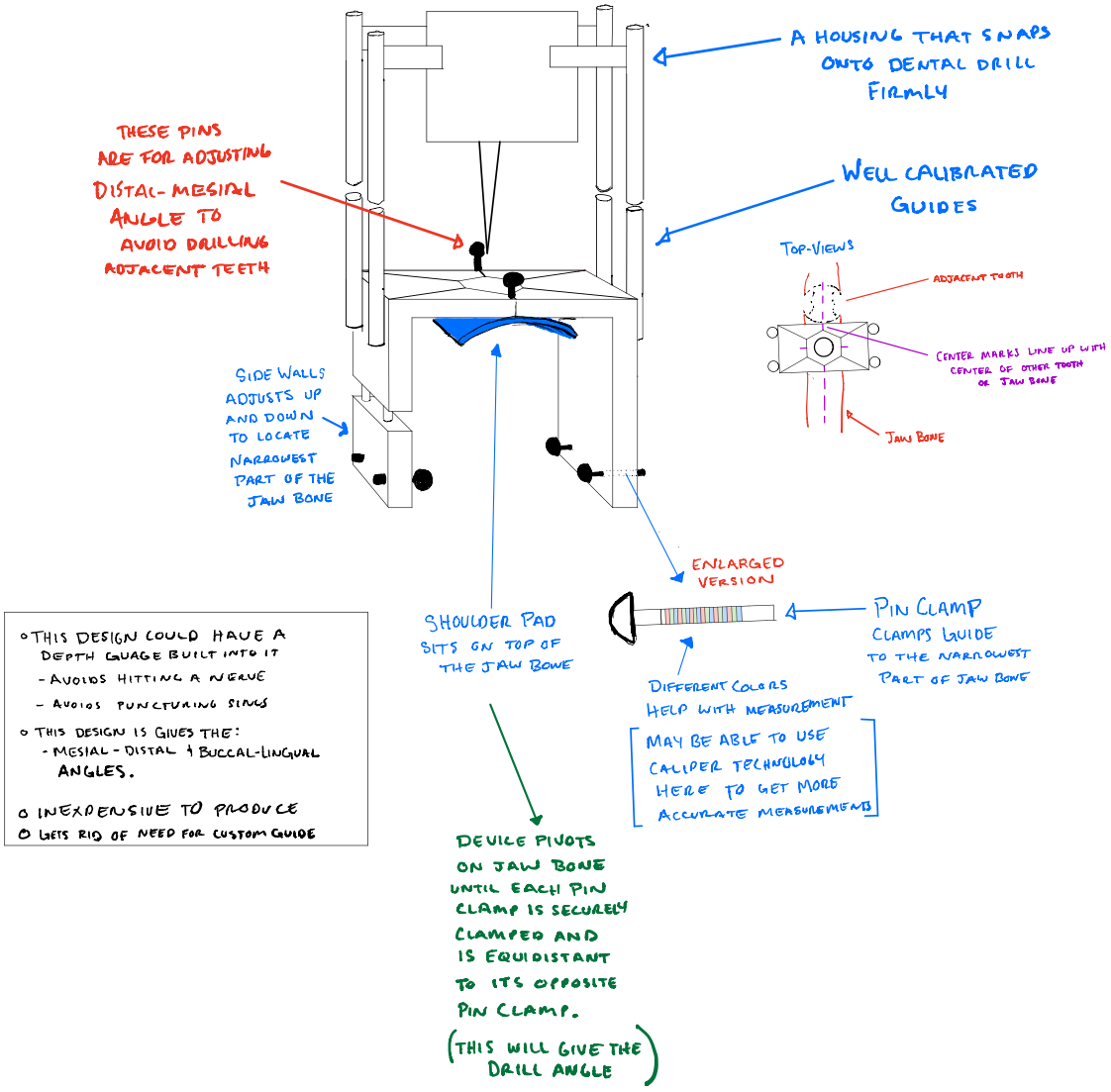
improvement from determining the bone density from a patient's x-ray. Nonetheless, there are many other applications within the medical and dental fields that could potentially use this technology. I plan to pursue a patent on this idea later, but because of my stubbornness, I am not giving up on designing a tool for improving the dental implant procedure.

5th Concept

Through re-evaluating what I had come up with so far and consulting with dental professionals, physics professors, biology professors, and as many articles I could find relating to this invention, I realized every concept was only addressing the issue of accuracy and affordability, but I had strayed away from trying to make this more efficient. This is what led me to the next concept.

This concept gets rid of all electronics. It simply slides onto the patient's jaw. The dentist adjusts the mesial-distal angle by a simple tweak and then the buccal-lingual angel by a simple tweak. The contraption then locks into place. This design comes with a drill attachment that snaps onto the drill. Four posts on the drill contraption then line up with the slots on the jaw clamp. From there the dentist doesn't have to worry about the bit veering off course or slipping--it simply slides down at the correct angle as the drill penetrates the edentulous region. The slots are also adjustable to set a depth beyond which the drill bit must not pass. This ensure that any nerve will be avoided. Likewise, this will avoid any chance of the drill bit protruding out the side of the jawbone or into adjacent teeth. I ran this idea by my brother and other dentist I knew, and they were impressed. This was it. I finally created an idea that would work. Not only was this idea

extremely accurate, and a cheaper alternative to custom made guides, but it is also efficient. I decided to call this The Universal Dental Implant Drill Guide.



The Universal Dental Implant Drill Guide in Detail (Concept #5)

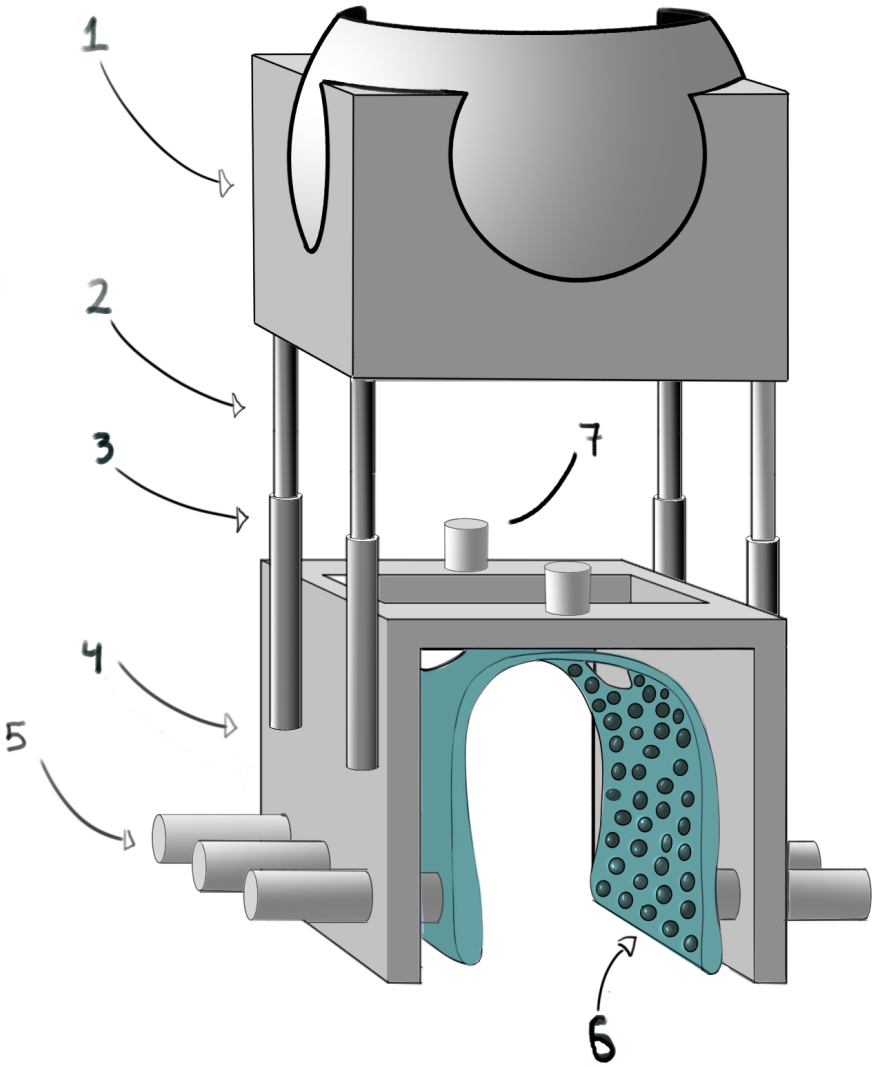
The Universal Dental Implant Drill Guide is designed to accurately guide a dental drill at a precise angle both mesio-distal (MD) and buccal-lingual (DL). Its purpose is to increase the accuracy, affordability and efficiency in drilling a hole for dental implants. This guide can be

configured to mount anywhere on the upper and lower jaw bone. No need for adjacent teeth. This guide also allows the dentist to have complete view of the osteotomy to monitor for anything out of the ordinary. It is designed to simply slide over any jaw bone. Once positioned over the edentulous region, the dentist uses a disclosed method (included with the purchased product) to adjust the MD angle as well as the BL angle. The contraption is designed to easily find the narrowest part of the lower and upper jaws and adjust equally BL by using the locking push pins with set measurements inscribed on them. The dental professional locks the push pins at equal measurements on both sides. This is to give the most accurate angle. The Dentist uses another disclosed method (included with the purchased product) to adjust the MD angle in relation to what X-rays show. The top part of the guide is designed to allow the dental drill to attach. The entire contraption has four posts that run parallel with the dental drill bit. These posts are designed to slide up and down inside well calibrated slots and will do so at the precise angle. The dentist can then use his/her own method from that point to drill the hole but be at peace knowing human error won't cause the drill to veer of a straight and narrow course.

In this final more detailed concept drawing, there are numbers indicating different parts I will describe them as follows:

1. This is the housing that the dental drill attaches to in a fashion that places the drill bit parallel with the four posts.
2. These are the four posts that slide up and down into slightly larger hollow posts
3. These are the slightly larger hollow posts that allow (2) to slide up and down freely. These posts are also calibrated to the correct drilling angle to allow the drill bit to penetrate at the same precise angle, both MD and BL.
4. This is the box. A solid structure built at exact 90-degree angles. Made of metal.

5. These are the locking push pins located on both sides of the box. The dentist can adjust both sides to be exactly the same length protruding outside the box. By doing so this will give the precise angle in BL direction. They also have the ability to lock and push the grip material against the patients gums to clamp the contraption securely.
6. This is the grip material that is pressed against the gums. Made out of a silicone rubber composite.
7. These are the upper push pins and must be adjusted prior to the lower push pins. This allows the dentist to place the guide at the precise MD angle.



Conclusion

Dentistry is moving to an era that is more concentrated on bringing emotional peace to the patient as they are sitting in the dental chair. This invention should be one arrow in a dentist's quiver that serves that purpose. A dentist can promote this tool as a means to drill very accurate holes in a patient's edentulous region that will allow for the utmost ability for the osseointegration of metal implant screw. This is product promotes high quality.

No longer do dentist have to refer patients to another dental professional for implants because of the cost and hassle of ordering a custom dental implant guide. With the universal implant guide the dentist can be confident in their ability to drill the hole accurately and with little cost.

Furthermore, with this tool both the dentist and patient can finish the dental implant process a whole month earlier. This is because there is no longer the need to order a custom guide that will take a month to be built and shipped to the office. Also, instead of using the time to order custom guides, or using the money to pay an employee to do it, the dentist can use that time to perform other dental procedures and the money whichever way he/she chooses.

Through a process of creativity, gathering an ample amount of information, drawing concepts, failing, and re-evaluating, I have successfully shown a way to increase the accuracy, affordability, and efficiency of a current method used in dental implant surgery. It will work, but the next step is to determine if this product is attractive enough for dentists to purchase. The best way to go about this is to obtain a larger sample from dental professionals for any critiques of this product. This will show whether or not this tool solves a large enough problem in the dental industry to attract buyers. If it does, then there is no reason not to perform a thorough patent search, fine-tune the device and apply for a patent.

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Annotated Bibliography

Patents

(Google 2019). Retrieved April 27, 2019, from https://www.google.com/?tbm=pts

List of Patents Reviewed from www.patents.goole.com

US20120251978A1- Very expensive & Expired

EP1364625A1 - Very different, Expires 2032

US8333587B2 - Very different, Expires 2030

1. Cements the contraption to adjacent teeth.
2. Only usable when adjacent teeth are there.

CN103142320B- ??? China, Expired

US7905726B2 – Most Similar, Expires 2027

US5833693A - Expired

US6913463B2- Expires 2022 attaches to adjacent teeth

WO2015029023A1- Expired different

Bird, B. (2017, November 21). What Happens to a Patent When it Expires?

Retrieved from https://info.legalzoom.com/happens-patent-expires

20317.html

"A patent allows you, and only you, to profit from your genius when you invent something new. No one else can manufacture or sell your invention unless you give permission. However, this protection does not last forever. Depending on what you've invented, your patent will expire in either 14 or 20 years. When this occurs, anyone can copy your idea and market it. When a patent expires, the protection it offers ceases to exist."

Steinberger, J. (2008, September 11). How to Search for Existing Patents. Retrieved From https://www.entrepreneur.com/article/196928

"*A patentability search is conducted by examining published patents that relate to your own invention to figure out whether your idea has already been patented. You can also see similar inventions, allowing you to improve and refine your own invention without infringing on someone else's patent. And you can do all this before you have spent many hours and thousands of dollars on an idea that you can't patent."*

Inventions in Dentistry

Gordon, M. P., & Chandler, N. P. (2004, June 08). Electronic apex locators. Retrieved August 27, 2018, from https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2591.2004.00835.x?sid=nlm:pubmed

The 1st concept was based on the technology of this device. Specifically, how the current travels through the root of a tooth and the resistivity value given determines the apex of the root. I thought we could do something similar with drilling implant holes.

Krzyzostaniak, L. (2017, December). The top 10 developments in dental technology in 2017 ... Retrieved September 24, 2018, from http://www.dentalproductsreport.com/lab/article/top-10-developments-dental-technology-2017?page=0,1

The most important thing I gathered from this article is this new focus dental professionals are putting on what people are calling *"the rise of emotional dentistry."*

Cost of Dental Implants

Alderman, Lesley. "For Most, Implants Beat Dentures, but at a Price." ***The New York Times*****, The New York Times, 30 July 2010, www.nytimes.com/2010/07/31/health/31patient.html.**

"An implant to replace a single tooth can cost $3,000 to $4,500, depending on where you live. Implants to replace a full or partial set of teeth can run from $20,000 to as much as $45,000.

This average cost was from research done in 2010 the cost may have changed since.

Nowak, S. (2019, April 08). Dental implants cost from $2,000 up to $34,000. Retrieved May 1, 2019, from https://www.authoritydental.org/implants-cost

"A single-tooth dental implant cost between $1,000 and $3,000. The abutment and crown add between $500 and $3,000. So, the total dental implant cost per tooth is between $1,500 and $6,000."

This is a more recent article. This just shows that some dentist have found a way to bring costs down. But on the other hand some have found a way to raise the costs.

Also, we know quite a bit more about the process and something might play a factor such as: The density of the patients jaw bone is insufficient for

osseointegration to occur. Therefore, bone grafting must take place prior to drilling the implant hole.

"Patient FAQ for Dental Implants." ***American Academy of Implant Dentistry*****, www.aaid-implant.org/faq/.**

"The cost for a dental implant to replace a single tooth is estimated to be in the range of $3,000 to $4,500, according to The New York Times. ***However, the key for you to get the lowest possible cost*** *is to check with a credentialed dental implant expert."It is essential to choose a dental implant expert with the training, skills and experience to assess your situation and custom design a personalized treatment plan just for you. We have assembled a searchable directory of implant dentists who meet those criteria."*

By inventing this tool we can broaden the selection of which dentist to see because it will create a more accurate hole at a cheaper price

"The Cost of Dental Implants Broken Down." ***The Cost of Dental Implants Broken Down - Dental Articles for Individuals | Spirit DentalBlog*****,www.spiritdental.com/blog/individuals/the-cost-of-dental-implantsbroken-down&highlight=WyJicmlkZ2UiXQ==.**

"Consultation: This is the appointment during which your dentist will check your mouth, get some x-rays, and diagnose the condition of your teeth, gums, and jawbone to determine if you're a good candidate for an implant. If you wish to proceed with an implant, your dentist will then take an impression of your mouth to get you started on the road towards getting your smile back. Insertion of Implant: During this appointment, your dentist will drill a hole into your jawbone

and insert the implant. If necessary, you will also get a temporary tooth at the end of this procedure. Placement of the Abutment: After your gum has healed from the implant insertion, it is time for your dentist to screw an abutment into your implant. This is basically the piece that will connect your existing implant with your future permanent crown. At the end of this procedure, you might get a temporary crown as well. Placement of the Crown: Finally, your dentist will be able to remove the temporary crown and replace itwith the permanent crown that will look like a real tooth. Your dental implant is complete!"

Before going further into the invention, I need to really search any related patent Thoroughly.

"Under the heading Related USPTO Services, click on Tools to Help Searching by Patent Classification. You can now start searching. Patent searches may also be done at google.com/patents and at a number of other free sites."

Dental Implant Processes and Procedures

Dental implant surgery. (2019, January 29). Retrieved from https://www.mayoclinic.org/tests-procedures/dental-implant-surgery/about/pac-20384622

"Dental implant surgery is a procedure that replaces tooth roots with metal, screwlike posts and replaces damaged or missing teeth with artificial teeth that look and function much like real ones."

This is a great definition of what a dental implant surgery actually does.

"The major benefit of implants is solid support for your new teeth — a process that requires the bone to heal tightly around the implant. Because this bone

healing requires time, the process can take many months."

I keep finding ads online that say a dental implant can be done in one day. I find it hard to believe that the metal screw can go through osseointegration with the jaw bone that quickly. This statement from the Mayo Clinic is claiming that the process for the bone to heal tightly around the dental implant takes a lot more time than just one Day. If a dentist is promoting a one-day procedure then I would be wary of all the other work he is doing. I am a carpenter by trade, and I have had to fix many things done by other carpenters who tried to do things even 5 min too fast. The goal of this thesis isn't to compromise quality to increase efficiency. Rather it is to increase efficiency while maintaining quality or improving it as well.

"Like any surgery, dental implant surgery poses some health risks. Problems are rare, though, and when they do occur they're usually minor and easily treated. Risks Include:"

- **a.** Infection
- **b.** Injury to adjacent teeth
- **c.** Nerve Damage, which can cause pain, numbness
- **d.** If implant is in upperjaw the drill bit can pierce the sinus

"Because dental implants require one or more surgical procedures, you must have a thorough evaluation to prepare for the process... Dental implant surgery is usually an outpatient surgery performed in stages, with healing time between procedures. The process of placing a dental implant involves multiple steps"

- **a.** X-rays and or 3D imaging

b. Review of Medical history

c. A proposed treatment plan

d. Damaged tooth removal (maybe)

e. Bone graft to strengthen jaw (maybe)

f. Drilling the hole (with a guide or without a guide)

g. Inserting metal screw

h. Allowing bone to heal around screw

i. Place abutment

j. Place artificial tooth on abutment

"Most dental implants are successful. Sometimes, however, the bone fails to fuse sufficiently to the metal implant"

To make sure the bone heals properly, and the artificial tooth is long lasting the patient has to do their part by good oral hygiene, avoiding habits like grinding teeth, and seeing the dentist regularly.

Rosenberg, E. S., BDS, H. DIP. DENT, DMD. (2008, February 1). Dental Implants. Retrieved October 10, 2018, from https://www.deardoctor.com/articles/dental-implants/

This article outlined the process for dental implant procedures. That is in line with other sources.

Types of implants and techniques. (n.d.). Retrieved from https://www.aaidimplant.org/dental-implants/types-of-implants-and-techniques/

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Dental professionals use mainly 2 types of implants. The first drills into the bone and the second the implant lays on top of the bone. The latter is only used when the bone isn't dense enough.

"State-of-the-art, highly precise 3D digital imaging and implant surgical planning software have made implant procedures faster and highly predictable. Your dentist can use these tools to analyze the anatomy of your jaw and determine the best sites for implant placement before surgery. This saves time and money and shortens recovery time."

At first after reading this paragraph about 3D imaging it appears that they have already answered my thesis. But the cost to have one of these machines is over $150,000.00. If I can create a product for $500 dollars that will still provide an accurate way of implanting, then it will still improve the process and prove this thesis.

Zentist.io. (2017, May 19). The Different Types of Dental Implants Procedures. Retrieved from<u>https://blog.zentist.io/the-different-types-of-dental-implant-procedures-55eD8851c070</u>

"no one mouth is the same; and what will work for one person may not work for another. Based on each situation, a dentist may have to tweak up the procedure to fit your needs and have a successful surgery."

Basically, it might be hard to create a new dental tool that can be used by every type of patient in every situation. There are single tooth implants**,** temporary bridgework Implants**,** multiple tooth implants and even a temporary anchor implant for Orthodontics

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Important Biological Research

Bell, T. (2017, October 8). What Makes Metals Conductive? Retrieved September 2, 2018, from https://www.thebalance.com/electrical-conductivity-in-metals-2340117

This article helped me understand a little more about electrical resistance through materials.

Newton, M., Peng, K., & Sonera, E. (2013, April 5). Electromechanical Properties of Bones - University of Arizona. Retrieved September 8, 2018, from http://math.arizona.edu/~gabitov/teaching/131/math_485_585/Midterm_Reports/Bones.pdf

This article addresses the problem I was having with getting the current to flow at an equal rate through the jaw bone.

"*The structure of bone is quite complicated and can be seen as a network of different parts all intertwined in a specific manner. Since the goal is to model the total conductivity of a bone, the structure of the bone can be simplified as a sum of three different parts: Haversian canals, Volkmann canals, and the rest of the bone which will be referred to as the bone matrix."*

The different densities of the bone is evident in the different parts of the bone. To get a current to flow through the jaw each of these canals would have to be a standard size and in a standard location. But everyone has a unique jaw that would be impossible to get a standard measurement from sampling. Essentially the standard deviation would be too high for the desired ideal of this product.

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Interviews

Nuttall, M., DMD. (2018, April 8). Phone Interview with Matt Nuttall [Personal interview].

The initial phone interview was where we were able to establish the main problem with dental implants that set the direction this research would go. Many subsequent phone calls were made to run ideas by him and address the accuracy, affordability and efficiency of each design I came up with.

Rogers, B., DDS. (2018, October 1). Face to Face Interview with Brad Rogers [Personal interview].

The initial interview was face to face. Where I presented my first idea. He gave me some corrections. Several subsequent face to face interviews as well as phone call interviews followed as the research developed.

Seastrand, M. (2018, September 17). Meeting with Mark Seastrand the Director of Entrepreneurship at Utah Valley University [Personal interview].

Mark is a process mentor. It this meeting with him he told me the basic steps to take when considering a new invention. He listed the steps as follows:

1. What is the problem?
2. Who has the problem?
3. What is the solution to the problem? (invention)
4. Can it make money?

This was very helpful in guiding this entire research.

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