DEPARTMENT OF
Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Dental HandPiece Scope

BME 301 Preliminary Report

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Abstract

Crown and bridge replacements are a common procedure performed by dentists in the U.S. Currently, when working on hard to reach teeth, such as the back molars, dentists have to rely on handheld mirrors and their intuition in order to perform the procedure. There are a few designs at this point in time that seek to solve this problem. However, all of these designs focus on designing a drill handpiece that has this optical capability integrated into the handpiece itself, and these devices are quite bulky and make it difficult to maneuver within the mouth. Our team has designed an apparatus that can be easily attached and detached from the drill. Along with the detachability, our design integrates multiple digital lighting filters that can be easily added and removed in order to enhance the viewing of the tooth. The design is meant to reduce cost of the product while allowing dentists to avoid relearning the nuances of a new drill.

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Introduction

In the US alone, there are approximately 15 million people who have crown or bridge replacements for missing or damaged teeth, and this number is increasing at a rate of nearly

500,000 each year [1]. With such a large number of procedures being performed annually, it is important that dental professionals maintain the highest standard of accuracy and safety to avoid failed operations or possible injury to the patient. During crown implant procedures, dentists are often confronted with difficulties viewing the teeth of interest. They may observe the location of the operation site and the hand piece with a mirror, but depending on the size of the patient's mouth and the location of the teeth, viewing can be nearly impossible, forcing the dentist to rely on intuition to complete the procedure. A camera capable of showing a live video feed of the operation site could remove this difficulty, allowing dentists to operate without the risks associated with blind handpiece use.

Current devices designed to address this issue include US5049070A, consisting of a dental drill with a integral camera and optics [2]. US5049070A has an elongated body attached to the hand piece where the camera cable is connected to its proximal end. The cable in this design is lined externally to the handpiece and controls the operation of the video imaging units and light source for the camera [2]. EP2891467A1 is another dental drill design including a built-in camera and numbers of small LEDs around the camera [3]. This design has a similar external shape to US5049070A but different inner design. This design has a color camera module stored inside the handpiece. The color camera module consistents a camera units with a condensing lens, a color imaging sensor which can output color image signals, a set of small LEDs surrounding around the camera unit. Different from the US5049070A, the camera module in this design is attached and fixed at the internal wall of handpiece on the side where the drill locates. US5251025A is completely different dental camera design from the previous two designs. This design has the camera module designed into an individual handpiece separated from the dental drill [4]. The individual handpiece contains a camera set at an angle from the handle axis at the distal end of the handpiece, an imaging device and a color filter built inside of the body of the handpiece, and two cables with two different ways of signal outputting. US5634790A is also a design with integral camera [5]. This dental/medical instrument is structurally similar to EP2891467A1 and contains a imaging system including a CCD camera inside the handpiece body. Distinct from the previous existing devices, US20120040305A1 is a collection of methods of combining camera and dental instrument [6]. This collection includes several methods such as a detachable external camera module and built-in camera module inside body of instrument and describes the advantages and disadvantages of these methods.

Despite the existing devices and methods, during the crown implant procedure, dentists need to have a view from the top or side of the drill instead of the bottom of the drill because the vision of a camera underneath the drill can be interrupted easily by teeth, but the camera on the top of the drill can provide uninterrupted vision of the working site between the gingival and the tooth. As a result, to allow dentists to have better viewing of the working site during the crown implant surgery and prevent dentist relying on intuition to complete the surgery process, a camera system capable of showing a uninterrupted live video feed of the operation site is needed to remove the surgical difficulty, allowing dentists to operate without the risks associated with blind handpiece use.

Background

The moist environment of the mouth, and the humid air from breathing leads to challenges while trying to use a camera to gain a clearer vision of the mouth. Chemical solutions can be used to coat the lens surface, which repels the moisture and allows for clear vision of procedure site. NeverWet™ is a spray-on coating that creates a hydrophobic surface layer which repels water, causing water to bead into droplets and run off the surface of any product it coats. It has been used on electronics, clothing, and metal/wood products to prevent weathering [7]. P2i™ uses nano-technology to create a nanometer thin polymer surface that prevents water build up. The company places electronic devices into a vacuum chamber and blasts the device with a radio frequency plasma that removes contaminants and creates free radical sites on all surfaces. A monomer is introduced as a gas and a pulsed radiofrequency is used to bind the monomers together and onto the free radical sites of the device. These monomers create a tough waterproofer coating on all surfaces of the device [8].

Figure 1. 8.5 x 11.3 mm 1080p video (30fps) [9].

Shown in Fig. 1 is a small digital 5 megapixel camera [9]. This camera size is marketed as 8.5x11.3mm which suits the needs of this project well. This camera is smaller than a thumbnail but is able to capture images of an entire human body. It is attached to the Raspberry pi by a small socket on the upper surface of the board. To be specific the camera is connected to a ABCM 2835 processor on the pi by way of CSI bus. The interface the camera uses is a CSI interface which is able to handle high data rates and carry pixel data. With a resolution of 2592 x 1944 pixels and a fixed focus lens, it should be detailed enough for crown replacement viewing.

The images shown on the real-time display can be processed to allow the dentist to see a clearer picture of the drilling site than with a naked eye. While performing a crown preparation, the dentist drills through the white/grey enamel to the inner, yellow layer of dentin. The dentist would benefit from being able to see enhanced contrast between those two layers to know when the tooth has been drilled to a sufficient depth. A warming filter can be used to highlight this contrast. A warming filter emphasizes the appearance of warming colors of red, yellow, and orange, and it could allow for increased visibility of the exposed dentin [10]. OpenCV is an open source software that contains libraries for image processing and analysis [11]. This software can be applied to color detection and can detect the yellow tint of the dentin. OpenCV has libraries to detect and convert images that assign HSV values to each pixel. This value includes a hue number, saturation number, and value number to each pixel, and a threshold can be placed on the image that highlights all pixels within this range. In this application, the real time video feed could increase the brightness or supersaturated pixels in the yellow range.

Our client, Dr. Donald Tipple, is a practicing dentist in the southwest Madison area. Dr. Tipple told us that sometimes, after an unsuccessful attempt at using a mirror to provide a clear line of sight to the operation site in a difficult area of the patient's mouth, dentists must rely upon their intuition and a mental image of the operation site in order to perform the procedure, frequently stopping and checking their progress to ensure they do not remove too much or too little of the tooth. As this is tedious and time-consuming, he requested that we build a method of attaching or combining a camera to/with the dental drill so that the dentist can instead rely upon a live video feed of the procedure area in such situations.

Preliminary Designs

Design 1:

The Pin Holder design consists of a drill mount that wraps around the head of the drill and has 3 pairs of holes in it that allow the camera mount to lock in place. While this design all but eliminates the failure point of last semester's design as the stem is no needed to twist into place, it also has a few other drawbacks. One of these is that the pins do not have a locking mechanism to hold them in place, meaning that any jostling poses a risk of dislodging the camera mount during a procedure, a patient safety concern. Another, more minor concern is that the camera mount requires somewhat more material to be 3D printed than design 2, slightly increasing the cost of the design. Lastly, since the design uses a single material, the risk of an allergic reaction is largely dependent on the choice of material, which is equivalent between all designs and as such, does not negatively impact this design.

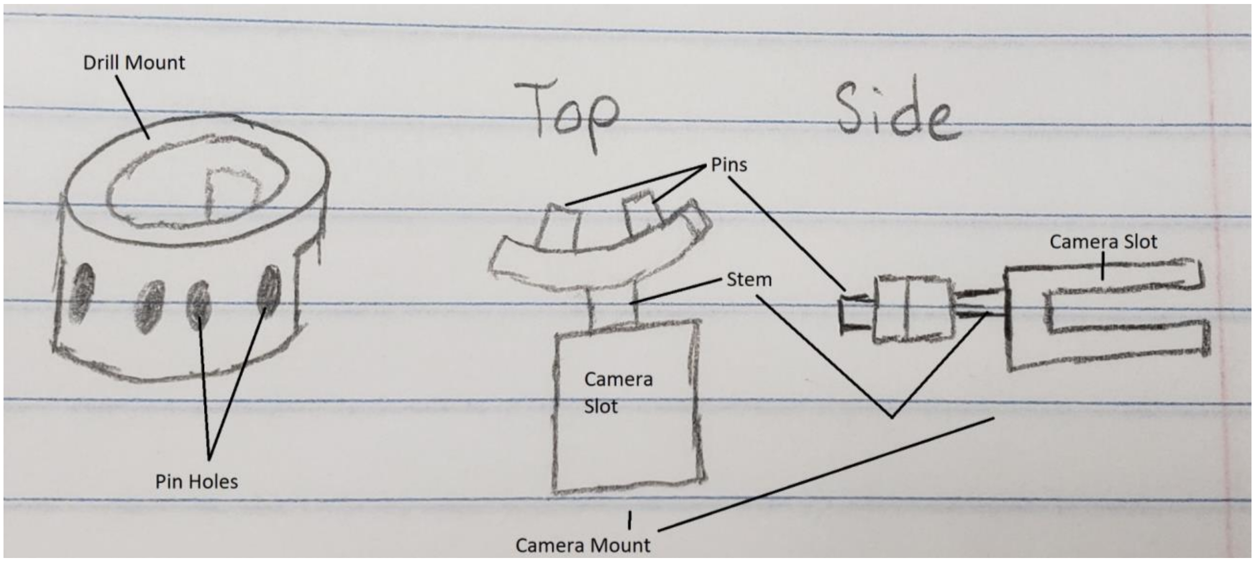

Figure 2. The Pin Holder Design with all components labeled.

Design 2:

The Modular Lock design consists of a 3D-printed attachment which snaps onto the camera and twists into ports on the sides of the drill mount (Fig. 5) to lock into place. While very similar to last semester's design, design 2 seeks to solve the issues faced previously by thickening the filament/stem shown in figure 3 and using a stronger material, such as stainless steel. Design 2 does still have the implicit weakness caused by utilizing a thin filament, and it possesses sharp edges that could cause cuts if used incorrectly. However, it is extremely low-cost, being made of very few materials, and its locking mechanism makes it one of the most stable designs considered. In part due to this degree of stability, however, design 2 is somewhat lacking in the field of maneuverability, as it must be removed and re-inserted into a different port each time the user wishes to change which side of the dental drill the camera is on.

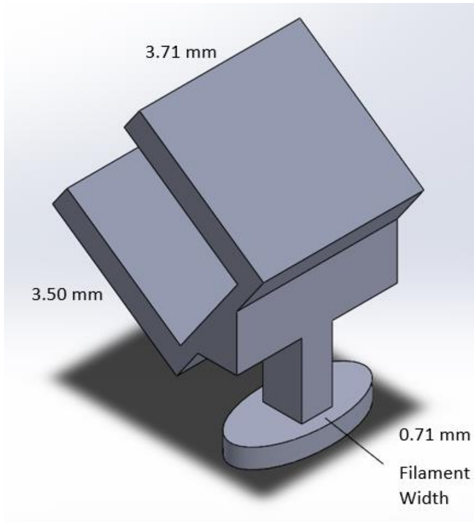

Figure 3. The Modular Lock design is similar to the previous semester's design, with improvements to the strength of the filament so as to reduce the risk of shattering.

<u>Design 3:</u>

Bearing 360, design 3, was designed in part because of the desire to have a camera that was able to go all around the patient's mouth. Design 3 has 2 distinguishing features. One being the slots for each camera. Every 2mm, there is a divot on the camera attachment allowing the doctor to be able to move the camera either towards the tongue or towards the cheeks. The second interesting aspect of this device is that it is stable because of the large surface area attaching the camera holder to the device. Its strength is average in comparison to other designs. It's made out of hard plastic so the strength is not one of its fortes. The device has divots which makes room for cuts to the occur inside the mouth. This device will be pricey because we need to find a sliding-lock device that allows for the camera to rotate 360. It ranks highly in the maneuverability because of its ability to move all over the device holder.

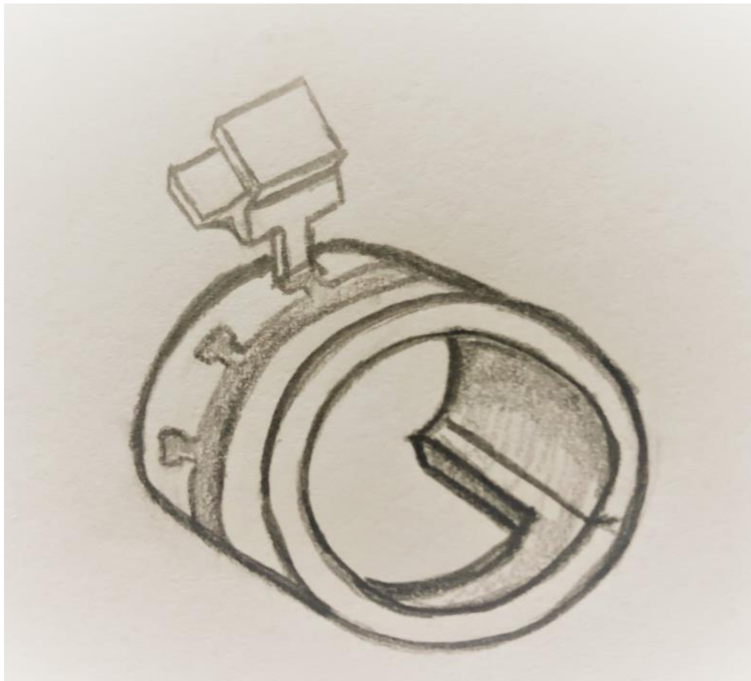

Figure 4. The Bearing 360 design with handpiece mount.

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Preliminary Design Evaluation

Criteria (weight)	Design 1 Lucas	Design 2 Jonah	Design 3 Tirhas
Strength (25)	5/5 (25)	3/5 (15)	3/5 (15)
Hypoallergenic (20)	3/5 (12)	3/5 (12)	1/5 (4)
Cost (10)	3/5 (6)	5/5 (10)	1/5 (2)
Stability (25)	1/5 (5)	5/5 (25)	5/5 (25)
Maneuverability (20)	1/5 (4)	3/5 (12)	5/5 (20)
Total (100)	54	74	66

Table 1. Design matrix including scores for each of the design concepts above.

Design 1 or the Pin Holder Design was the strongest design, but not really stable, less maneuverable, and fairly cost more than design 3. Design 2 or the Modular Lock design has the highest score compared to design 1 and 3 as it was the most stable and the cost effective. However, this design was not easily manipulated because the camera attachment need to be readjusted every time the user want to change the side of the camera. Design 1 and design 2 have the same score for hypoallergenic as both will depend on the choice of material that we will be using for the camera attachment. Design 3 or Bearing 360 is a relatively stable, maneuverable, and fairly strong design. However, it has a lower safety factor and is more expensive than other design, because this design required more materials than such as bearings, that could possibly cause an allergy reaction in the patient.

Proposed Final Design

The Modular Lock design (design 2) was chosen as the proposed final design due to its low cost, relative sturdiness and excellent stability. Through the flexibility of 3D-printing, it will be possible to rapidly iterate through prototypes as we refine the design. A major focus of this semester's work will be on strengthening the connection between the camera attachment and the drill mount, thus an eventual design step will be to fabricate this connection from metal. For reference, a sketch of the final design configuration is shown in figure 6.

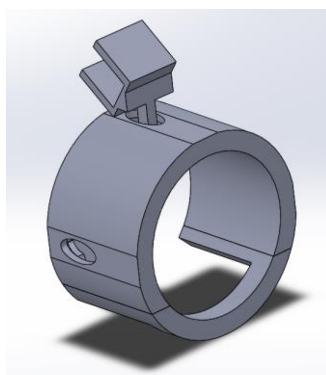


Figure 5. The drill mount and camera mount (design 2) lock to form a cohesive part able to sturdily hold the camera during the course of dental restoration.

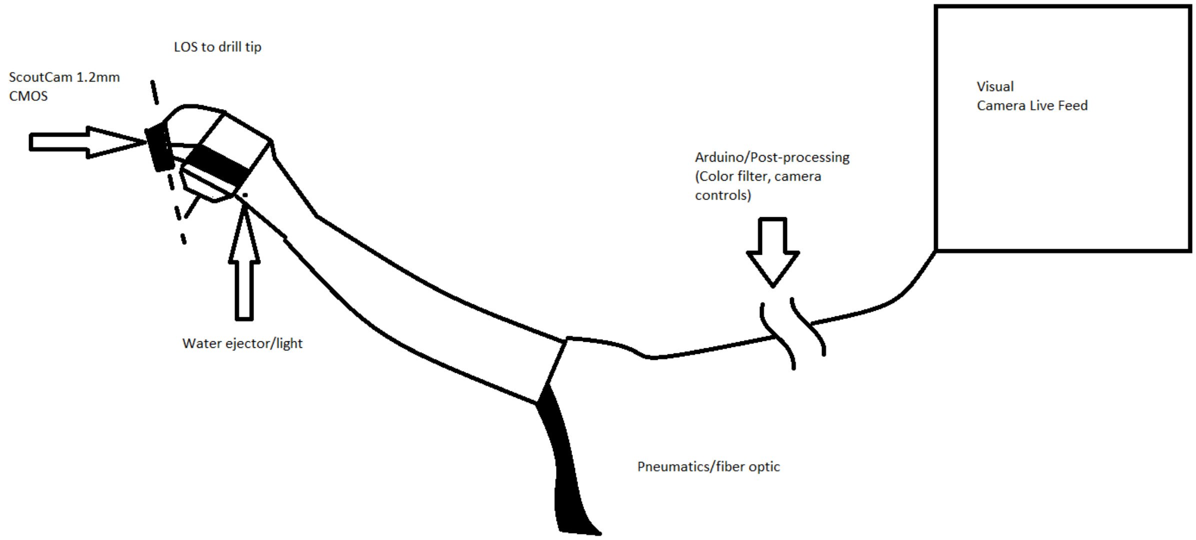


Figure 6. The modular design concept consists of a plastic, 3D-printed camera mount which is snapped on to the handpiece. The data from the camera is then filtered for color contrast and sent to the video screen in real time

Fabrication/Development Process

Materials

- Form II Dental SG Plastic
    - A certified biocompatible photopolymer resin that is specifically designed for Form 2 3D printer. This material can be sterilized by autoclave, or by gamma-ray sterilization, and in compliance with ISO standards. [12]

Methods

- Each prototype iteration of the camera mount was 3D printed using the MakerSpace Form II 3D printers

- The 3D printing process starts with taking a Solidworks file and then exporting it to the .STL file type which is compatible with the Preform software that the Form 2 3D printers use. Then, the prototype is created in the software and the supports necessary for printing are generated. The supports that were auto-generated by the software always clogged up key points on the prototype, so they would have to be moved to areas on the device where they could be removed without compromising the structure of the prototype itself.

  Once the design was prepped for printing on the Preform software it had to be converted to the preform file type in order to give the printer the command to print. Once the file was converted, a simple informational file was filled out that detailed the type and amount of material that was to be used so the worker's in Makerspace knew and could keep track. Then, the 3D printer was linked to the computer system and the print started. Post print procedures included wetting down, and then heating the newly printed plastic piece.
- After the final prototype was completed, heat shrink was used to waterproof any exposed electronic parts.
- Waterproof electrical tape was then used to secure the camera cable to the handpiece body (see Final Prototype).

<u>Final Prototype</u>

- While the majority of fabrication occurred based off of the design shown in Figure 5, our team came up with a new and better concept (Figure 7) within the last month of the semester. This new design is far stronger than previous iterations, solving the recurring issue of physical prototype failure that we had been dealing with. It is also able to hold the camera in a relatively stable fashion, preventing it from shifting while still being able to withstand larger forces against it. Its operation relies on the innate elasticity of the material it is 3D printed from. Each clip holds the camera cord against the rest of the camera mount, while friction prevents the camera cord from slipping.

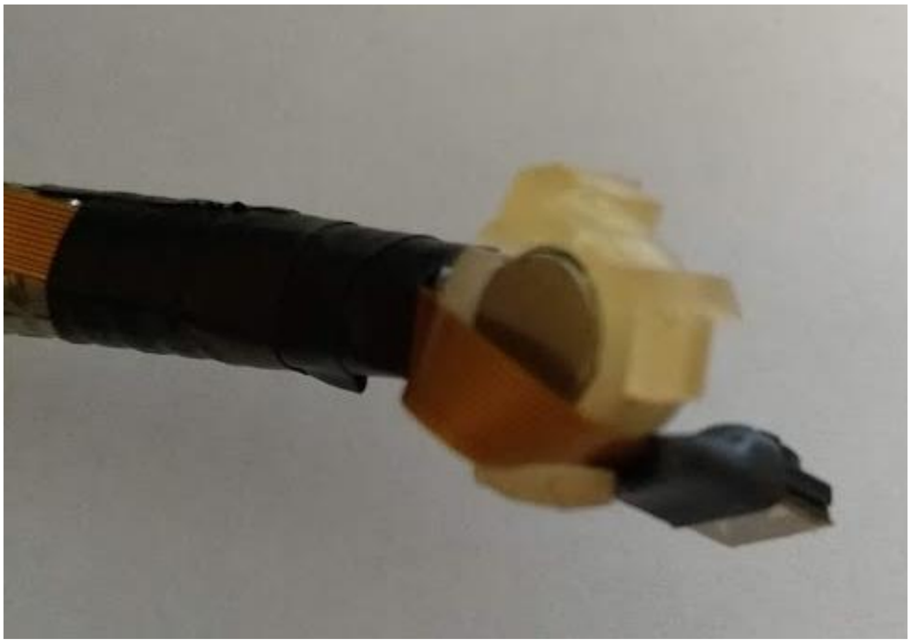


Figure 7: The final clip prototype attached to the dental drill, holding the camera in place for operation.

Testing

Electronic Waterproofing

To ensure that the water present in a patient's mouth during dental procedures, both from saliva and rinsing water, do not damage the camera's electronic components, the exposed components of the camera that conduct electricity were covered with heat shrink to prevent their exposure to water. Testing of the electrical conductivity of the components was conducted prior to application of the heat shrink so that a minimal amount of heat shrink material would be used. This testing was achieved through the use of a digital multimeter in the connection detection setting where each component was separately touched to a probe to verify whether these exposed components were electrically connected to the camera circuitry. The only exposed electrical components were near the camera itself and near the point of attachment to the extension cable and thus, these are the only two areas that were coated in heat shrink.

SolidWorks Stress Testing

The purpose of the SolidWorks testing was to see how much force the camera had to have before the camera holder broke. The material one uses is important in determining how much load can be applied to the camera holder. In our case, we used dental SG. This material is very similar to high density polyethylene. In accordance with that, the average ultimate strength of the material is 20.3MPa(site). In addition the average strain is 0.1. As one increases the percent of high density polyethylene, the higher the strain level. With this in mind, we conducted a simulation using Solidworks.

Because the camera holder has 3 similar places the camera can be placed in, we only conducted the Solidwork simulation on one on the holders. Similarly, for the mesh option, we set it to the least amount. This was due to the fact, it wouldn't run without doing so. Consequently, the standard of error is greater. With these criterias in mind, We collected the stress and strain of the camera holder.

Ethanol Resilience

Ethanol is a common sanitizing agent that is very effective at killing bacteria and viruses. However, due to its inability to destroy fungal spores, it is not often recommended as a sanitizing agent in medical applications [13]. A more commonly used medical sanitizing agent is the gaseous ethylene oxide. Testing was conducted with ethanol due to the unavailability of ethylene oxide and the difficulties associated with proper handling of the gaseous sanitizing agent. The testing consisted of prolonged exposure (30 minutes) of excess pieces of Dental SG plastic to a 70% ethanol solution with masses measured before and after the 30 minute period of submergence. As detailed in Table 2, the two pieces underwent exactly opposing changes in mass equal to the uncertainty of the scale with the average net change in mass being 0.00 g, indicating perfect ethanol resilience.

	Piece 1	Piece 2	Average
Initial Mass (g)	0.57	0.66	0.615
Final Mass (g)	0.56	0.67	0.615
Net Δ Mass (g)	-0.01	+0.01	0.00

Table 2: Mass measurements and calculations for the measurement of degradation due to prolonged ethanol exposure.

Survey

After completing the final prototype, we met with our client, Dr. Tipple, so he could test out the design in a human mouth. One of our team members volunteered, and Dr. Tipple performed a brief examination using the camera to view the subject's teeth. He was careful not to actually touch the subject's mouth with the device. While he continued the examination, we asked him questions based on how useable he felt the drill was with the prototype attached. These questions and answers can be found the survey in Appendix D.

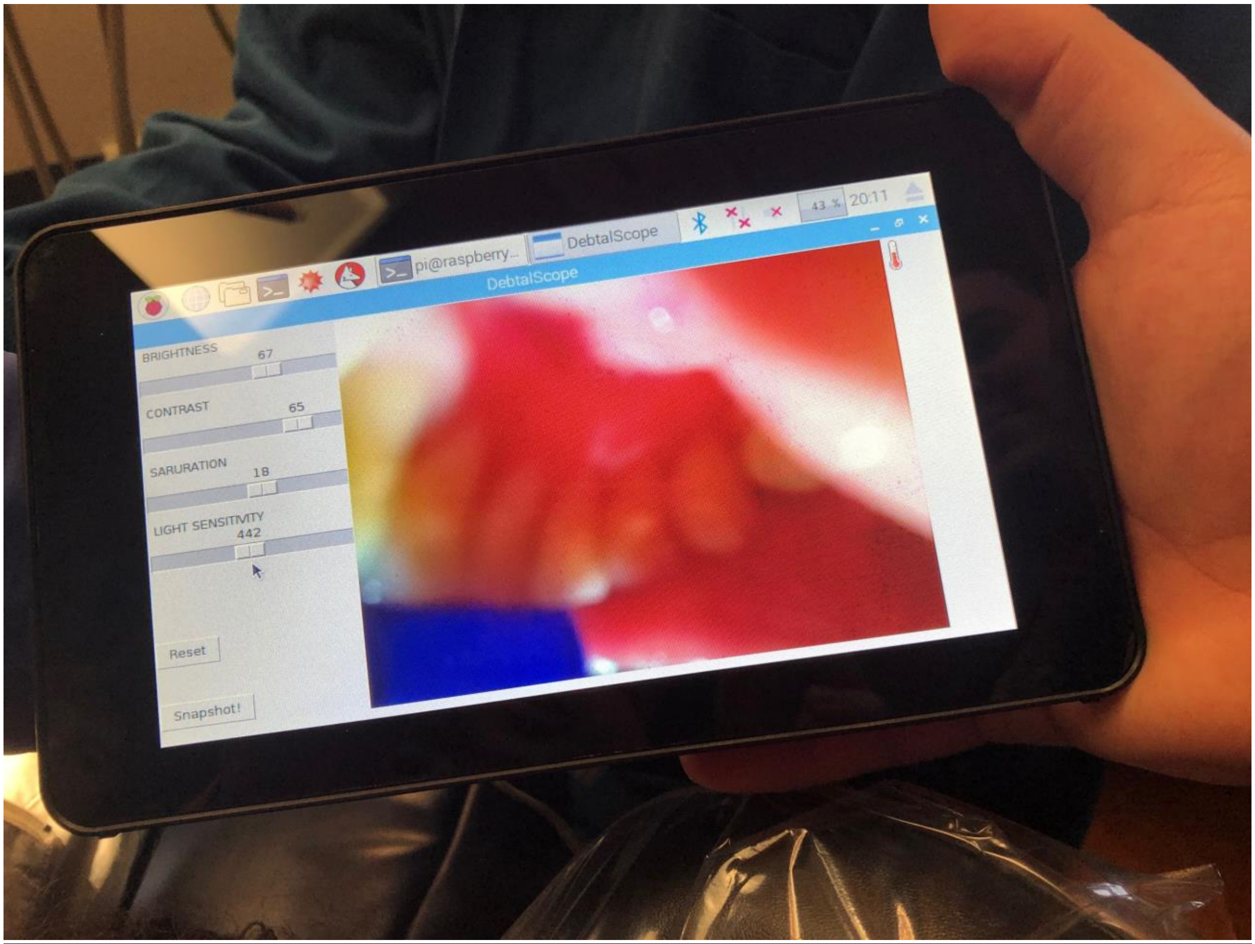


Figure 8: Image of practical application of the prototype

Results

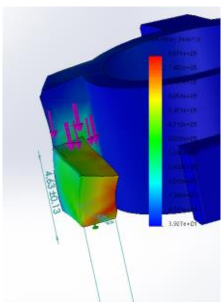
Electronic Waterproofing

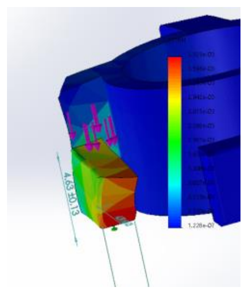
The waterproof testing after the application of heat shrink showed that the areas of the camera cord which had previously demonstrated connectivity with internal components were no longer exposed electrically to a surface which may be contacted by water.

SolidWorks Testing

As one can observe from figure (1), the stress level is greater at the edge of the camera holder compared to the the rest of the device. This same token applies to the strain diagram (figure 2). When looking at the displacement simulation, it was a bit different. The greatest displacement would occur at the edge-inner part of the camera holder (figure 3).

The camera that was used was Spy camera Raspberry Pi with a mass of 1.9g. Because the mass is so small, it is negligible. Even though a lower percent of high density polyethylene is better for the strength of the camera holder, in this case, it wouldn't matter.





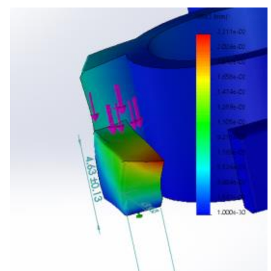


Figure 9: Stress simulation **Figure 10:** Strain simulation **Figure 11:** Displacement simulation

Ethanol Resilience

As stated previously, the ethanol testing showed near-perfect resistance of Dental SG to 70% ethanol solutions, meaning it is suitable for use in this application.

Survey

After Dr. Tipple completed the survey, it was clear that our design still has a lot of improvement to undergo. Out of 5 possible ratings (with 5 the highest and 1 the lowest), our design averaged a rating of about 3. Dr. Tipple commented that the camera is large enough that it throws off the balance of the drill during operation, and the camera's focus is less than ideal at close ranges. The camera mount itself also increases the size of the drill head in a way that makes it difficult to maneuver, which could render any procedures undertaken using the prototype unsafe.

Discussion

With regards to the ethical implications of the completed product, it seems to be negligibly different from devices commonly used in the dental industry and thus, likely as ethically acceptable. There is an issue of privacy in that we do not specify the conditions under which the images and video feed obtained by the camera must be used but this should fall under the same privacy protections as other images obtained for dental procedures, making this consideration significantly less imperative.

One possible source of error during the testing process is that, while conducting the ethanol resilience testing, one piece's mass decreased by 0.01 g and the other's increased by the same amount. While this may seem to indicate degradation by or absorption of ethanol solution, this value is also the uncertainty of the electronic scale used to measure the masses of the pieces, meaning this too is likely insignificant. A method of verifying the insignificance of this abnormal change in mass is to repeat the testing with an electronic scale that has a smaller uncertainty.

Another source of error during the testing phase is the fact that it was assumed that the electrical connectivity of the exposed camera components as measured by a digital multimeter is an accurate measure of a component's ability to be short-circuited by water. If this is not the case, then the waterproofing testing was essentially pointless and testing with actual water exposure must be conducted.

Testing for the SolidWorks was not exactly accurate because of the big file we had. In addition, we used the SolidWork form online; this meant that it was easier to fail. However because the meshing wasn't as precise, we were able to get an estimate of the stress and strain of the camera holder. For next time, we would run the SolidWork simulation under rigorize conditions to increase the accuracy and to decrease the error.

Conclusions

During crown replacement surgery, dentists often need to rely on their intuition whenever working with desired teeth, especially at the back of the mouth. Our team sought to solve this problem by incorporating an optical capability by placing a small camera with a holder at the head of the dental drill, to allow dentists to have better viewing of the operation site. Based on all the testing conducted, the material that we used, Dental SG resin, is suitable for the application as a dental tool due to its resistance to sterilization using 70% ethanol solutions and the design is strong enough to withstand the weight of the camera that is fairly negligible. The clip final design is much stronger than the previous prototypes, but the possibility of the camera slipping out of a clip during an operation still exists. Where water resilience is concerned, the waterproofing testing showed that the design is capable of operating in a patient's mouth while the drill is running and debris is splashing up, and covering the exposed electrical components of the camera and extension cord with heat shrink seems to have solved any problems of shorting or corrosion that might occur. When our client tested the design in one of of our team member's mouth with the drill attached to the handpiece, we can see the teeth clearly from the tab's screen, but the image of the image of the drill was out of focus due to its close proximity with the camera. Later on, we can either change the camera that has proper focal point, or incorporated a lens to have a sharper image. Our client also mentioned about the bulkiness of the camera holder, as it might hinder the use of the handpiece with patient that has smaller mouth, and the sharp edges that possibly cause an injury. In the future, if possible, we can obtain a smaller camera or integrate the entire camera device into the handpiece itself to have a more compact design. During fabrication process, we encountered with problem of removing the supports of our 3D-printed prototype, where we accidentally broke the prototype itself. We did look into metal 3D printing, but due to high cost and time constraints, we continued with plastic 3D printing from Makerspace. Another major goal would be implementing arm-like mechanism to attach the touch-screen interface that has six degrees of freedom for increased use of access to the dentists. We also would like to explore the possibility of implementing the camera on the handheld mirror, instead of the drill, and observe which application would be more convenient for the dentists to use.

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Appendix

Appendix A: Product Design Specifications

Function:

The dental handpiece scope should consist of some optical device with the ability to take visual information from the operation site in a dental crown replacement, and project it onto a screen for the dentist to view, while being attached to the dental handpiece. This visual aide should be detailed enough to assist the dentist in completing the procedure with full view of the operation site, increasing the overall safety and efficiency of the technique.

Problem Statement:

During crown implant procedures, dentists are often confronted with difficulties directly viewing the teeth of interest. They may observe the location of the operation site and the hand piece with a mirror, but depending on the size of the patient's mouth and the location of the teeth, direct viewing can be nearly impossible, forcing the dentist to rely on intuition to complete the procedure. A camera capable of showing a live video feed of the operation site could remove this difficulty, allowing dentists to operate without the risks associated with blind handpiece use.

Client requirements:

- Create a small uninvasive camera to mount on top of a dental, drilling handpiece in order to make obscured teeth visible.
- The main focus of the project is to create a functioning camera mounted on the dental drill.

- The device can be made of hard plastic, or stainless steel.
- The camera needs to be able to project a live video feed onto a TV screen.
- The camera and surrounding equipment needs to be able to be put into a human mouth without causing harm to the patient or the camera.
- The camera needs to be able to see through water mists and splashes coming off the teeth.
- The camera will need to be waterproof.
- If initial design prototypes prove to be successful, the client would like us to integrate wiring directly into the dental handpiece rather than down the side.

Design requirements:

1. Physical and Operational Characteristics

a. Performance requirements:

- The dental scope must be able have adequate spatial resolution to capture details of the tooth.
- Must be able to differentiate between the white/grey enamel and yellow dentin of the tooth.
- The chassis must be able to fit on the drill with a minimal size profile.

b. Safety:

- The electronics should not cause electrical shock to the user or patient.
- The device should not have sharp/rough edges that cause unnecessary damage to surrounding gums or soft tissue.
- The device should not dissociate inside the patient’s mouth

- The dental scope must be sanitizable to prevent bacterial growth.

c. Accuracy and Reliability:

- The dental scope must be able to accurately provide a view of the desired location on the patient's tooth.
- There should be no or minimal latency of the device.
- The camera must be able to have an accurate autofocus to maintain a clear image of the tooth.

d. Life in Service:

- The device must maintain its structure and function over many daily uses.
- The device must last at least 10 years (average is 15 years).
- The electronic systems must be resilient for repeated use without breakdown.
- The device should work reliably during normal use for the same period of time as the drill it is attached to.

e. Operating Environment:

- The camera and electronics must be waterproof to withstand the saliva, pieces of food and water jet during drilling.
- All components must withstand the vibrations from the drill.
- The camera attachment mechanism must be sturdy enough to survive bumps and jolts without shattering.

f. Ergonomics:

- The camera must not add too much weight to the dental drill handle to avoid reducing the drill's ease of use.
- The camera must interface securely and minimally with the dental drill to ensure waterproof characteristic and reduce the external profile of the camera apparatus.
- The housing of the camera must not cause discomfort or injury to the patients.
- The camera must be fixed rigidly with the drill to prevent disassembling of the camera.
- The shell for the wire that powers the camera must not make the drill hard to handle.

g. Size:

- The camera needs to be able to fit on top of the drilling handpiece without being too bulky as to interfere with the dentists' ability to drill the tooth. 5x5 mm.

h. Weight:

- The camera apparatus needs to be light enough so as to not offset the weight and balance of the drill a considerable amount. 2-3 ounces.

i. Materials:

- Glass and stainless steel/plastic for the camera apparatus.
- Hard plastic for the housing of the camera.

j. Aesthetics, Appearance, and Finish:

- Skin safe coating and material for use inside the mouth.
- The apparatus should not visually present itself in a way that could cause discomfort to patients. It should integrate nicely with the design of the dental handpiece and not stand out.

2. Production Characteristics

a. Quantity: 1 (prototype).

b. The total cost of the device should be less than $250.

3. Miscellaneous

a. Standards and Specifications:

- No international or national standards need to be met while the device is in the prototype phase of the design process.

b. Customer:

- Customers (practicing dentists) would desire a camera with a minimal external profile to reduce the amount of additional space required to use the drill in a patient's mouth. They would also want the camera to be waterproof and water-repellant to ensure circuitry security and unimpeded view.

c. Patient-related concerns:

- The device must be sterilized between uses (separately from the dental drill) and must be stored in the standard dental drill holder connected to the dentist's chair.

- Material of the device doesn't cause an allergic reaction in the mouth.

d. Competition:

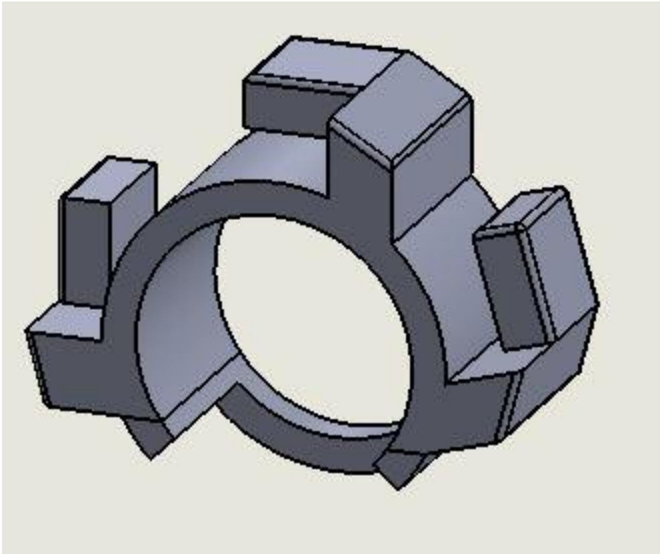
- Dental drill integral camera and optics (US5049070A).
- Handpiece with built-in camera and dental treatment method using said handpiece (EP2891467A1).
- Electronic video dental camera (US5251025A).
- Imaging device for dental instruments and methods for intra-oral viewing (US20120040305A1).
- Video dental medical instrument (US5634790A).
- Dental handpiece with observational function (JPH0956730A).

Appendix B: Material Expenses

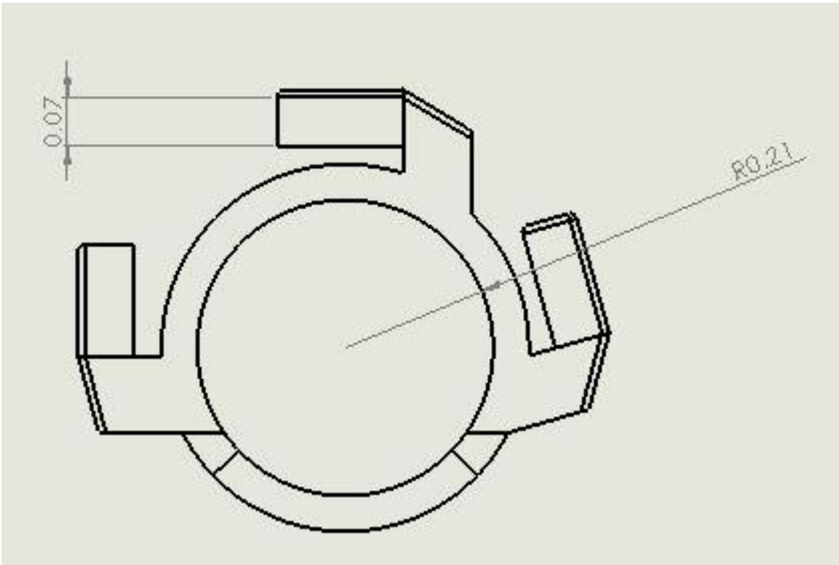
Date	Item	Description	Manufacturer	Part Number	QTY	Cost Each	Total
2/27/2019	Camera Attachment III	3D printed using PLA material	Makerspace	-	1	$0.07	$0.07
2/27/2019	Camera Attachment III	3D printed using Form 2 plastic (Tough)	Makerspace	-	1	$0.34	$0.34
3/7/2019	Camera	3D printed using Form	Makerspac	-	1	$0.73	$0.73

	Attachment IV	2 plastic (Dental SG)	e				
3/27/2019	Camera Attachment V	3D printed using Form 2 plastic (Dental SG)	Makerspace	-	1	$0.70	$0.70
4/3/2019	Camera Attachment V	3D printed using Elastic Resin	Makerspace	-	1	$0.39	$0.39
4/3/2019	Camera Attachment V	Selective Laser Sintering using Polyamide	Midwest Prototyping	-	1	$53.00	$53.00
4/17/2019	Clip handpiece attachment	3D printed using Form 2 plastic (Dental SG)	Makerspace	-	1	$0.63	$0.63
4/22/2019	Clip handpiece attachment	3D printed using Form 2 plastic (Dental SG)	Makerspace	-	1	$0.69	$0.69
						TOTAL:	**$56.55**

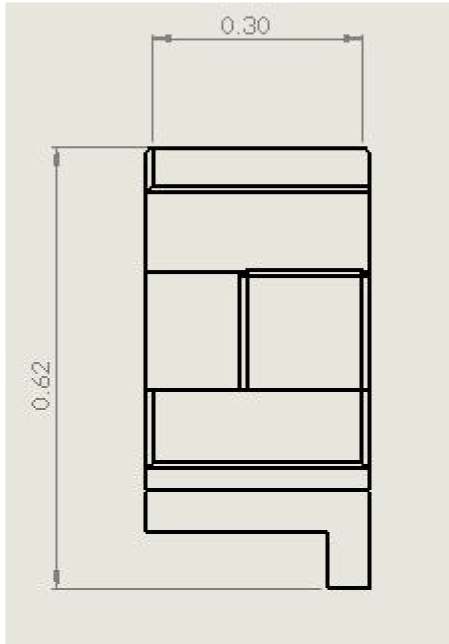
Appendix C: Final Prototype CAD



Appendix C Figure 1: The clip prototype SolidWorks image. Each of the three clips can hold the camera independently, allowing the dentist to move the camera to the correct side of the mouth for whatever operation he or she is trying to perform.



Appendix C Figure 2: The clip prototype front view. Dimensions are in mm.



Appendix C Figure 3: The clip prototype side view. Dimensions are in mm.

Appendix D: Survey

/

4/23/19

Dental Scope Survey

QUESTIONS: Rank the statement from 1-5 . 1= not very 5= very

PERFORMANCE

A. How in control do you feel of the device? out of balance

1 (2) 3 4 5

B. How easy it is to observe hard-to-see teeth? (accessibility) out of focus, screen should flip

1 2 (3) 4 5

C. How safe does it seem? round edges

1 2 (3) 4 5

D. The cost($80) matches the outcome/performance

1 2 3 4 5

E. The resolution of the camera is adequate

(1) 2 3 4 5

F. Other dentists would be interested in this device not yet - too big

1 (2) 3 4 5

fit camera into handpiece

MECHANISM

G. How easy is it to navigate the operation site with the camera?

1 (2) 3 4 5

H. It's easy to transition to using the device learn a certain way in school - 2U hrs Use

1 (2) 3 4 5

I. How easy is it to move the camera from slot to slot? loose

1 2 3 (4) 5

J. Would it be simple/effective to sterilize the instrument? ethylene oxide

1 2 3 4 (5)

K. Would it be simple/effective to instead utilize disposable parts on the instrument?

1 2 3 (4) 5

"always more convenient"

STRUCTURE

L. Is it easy to maneuver the instrument?

1 | (2) | 3 | 4 | 5

M. Would changing the positions of some parts of the device facilitate easier maneuverability? slits in cartridge

1 | 2 | 3 | 4 | (5)

N. Would it be more convenient to have the camera where it is now, or on a separate device (like a mirror/tongue depressor)? "worth a try, could interfere w/ indirect"

1 | 2 | 3 | (4) | 5

O. Is the device too fragile? forgive it camera wire could break

1 | 2 | 3 | (4) | 5

P. Does the device impede the usual handling of the dental drill during a dental procedure? large size

1 | 2 | 3 | (4) | 5

Q. Would this be safe for an actual patient?

1 | 2 | (3) | 4 | 5

Other comments/suggestions/feedback:

"chip air" all-in-one concept

Faster, easier, higher quality ≠ bigger

simpler = better

try camera on mirror perhaps

- have interchangeable parts instead of all-in-one