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Dental HandPiece Scope

BME 301 Preliminary Report

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Client:

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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. 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 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^{TM} is a spray on coating that creates a hydrophobic surface layer that repels water, and this surface causes 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^{TM} 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 is marketed as a a 8.5x11.3mm which is a requirement for this project. This camera is smaller than a thumbnail but is able to see people. 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 a procedure area in a difficult area in the patient's mouth, dentists must rely upon their intuition and a mental image of the procedure area 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

The Pin Holder design (aka Design 1) 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.

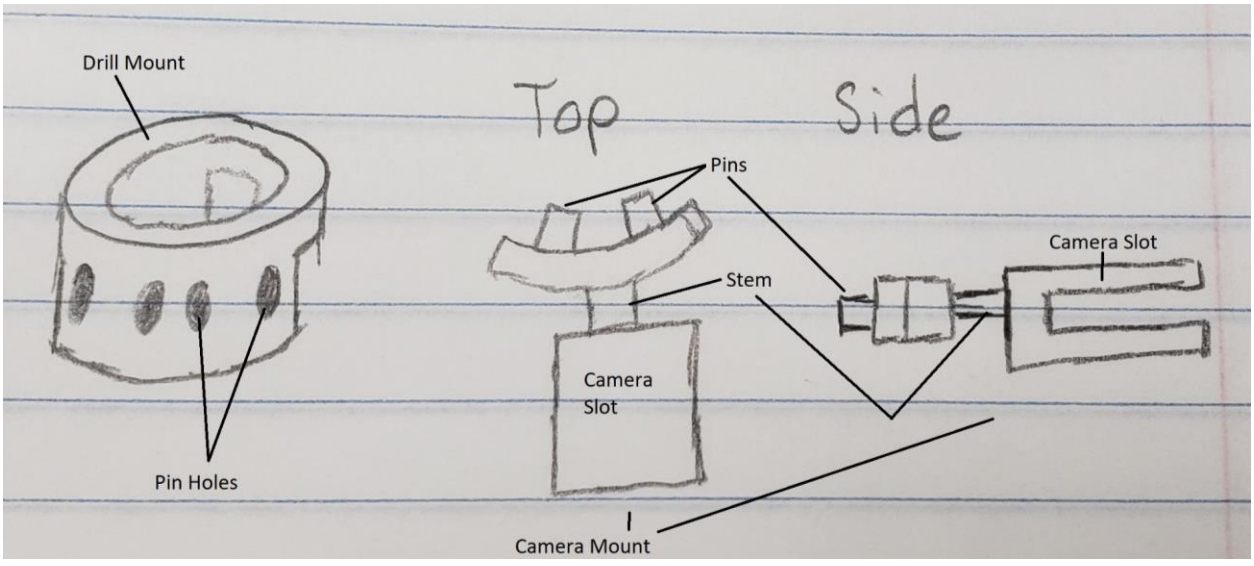

Figure 2. The Pin Holder Design with all components labeled.

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.

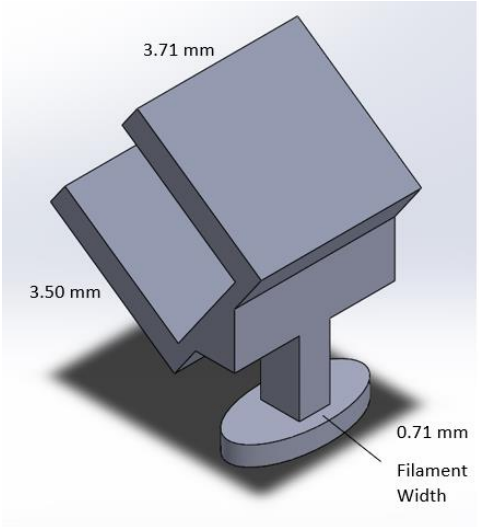

Figure 3. The Modular Lock design is similar to the previous semester's design, with improvements to the strength of the filament so as to reduce the risk of shattering.

Design 3:

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.

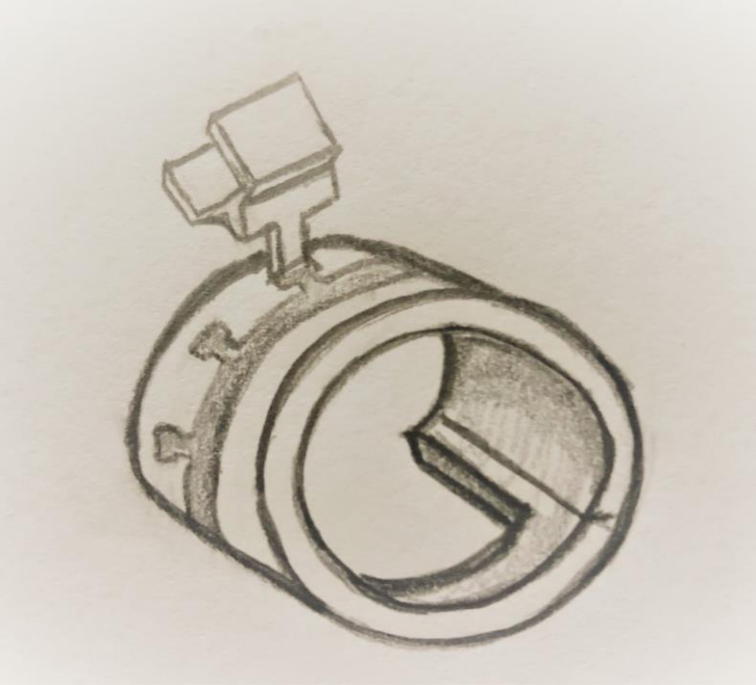

Figure 4. The Bearing 360 design with handpiece mount.

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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.

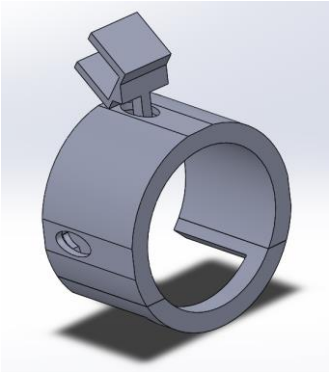

Figure 5. The drill mount and camera mount (design 2) lock to form a cohesive part able to sturdily hold the camera during the course of dental restoration.

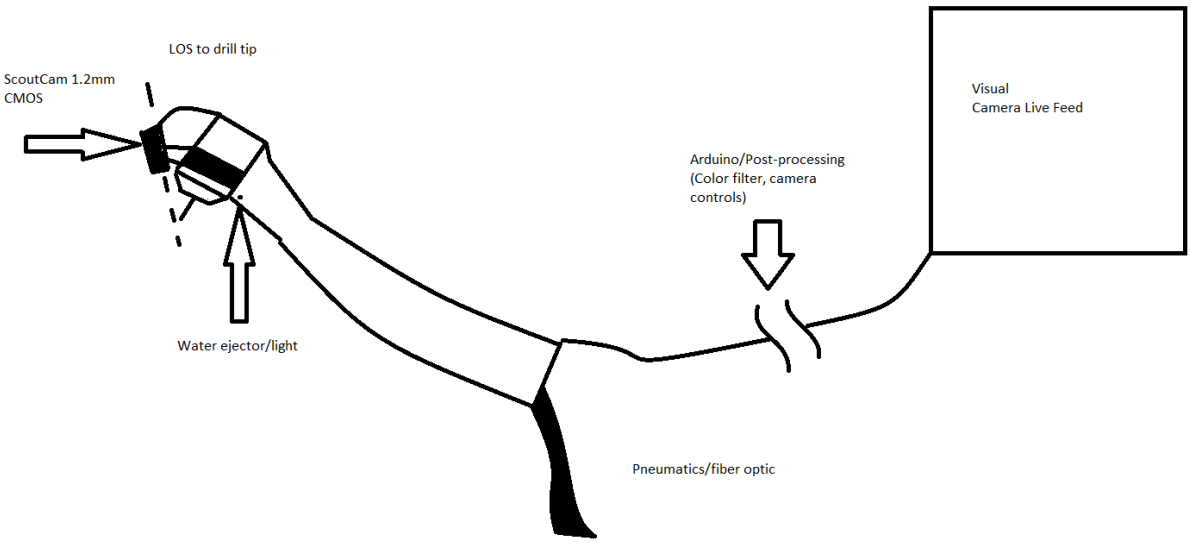

Figure 6. The modular design concept consists of a plastic, 3D-printed camera mount which is snapped on to the handpiece. The data from the camera is then filtered for color contrast and sent to the video screen in real time

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Appendix

Product Design Specification

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).