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Dental HandPiece Scope

BME 200/300 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. Our team has designed an apparatus that can be easily attached and detached from the drill. Along with the detachability, our design integrates multiple 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 [6].

Despite the existing devices and methods, during the crown implant procedure, dentists need to have a view from the top 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 surgerical 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 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™ 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].

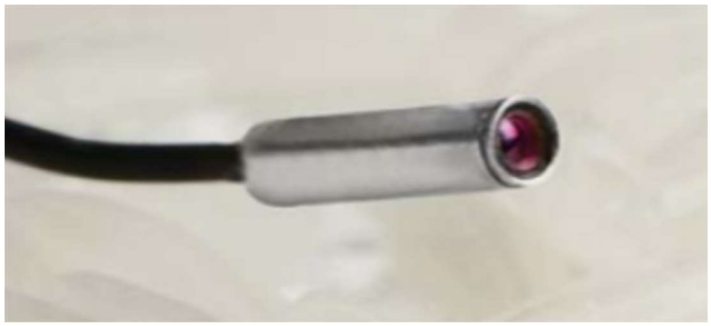

Figure 1. 1.2 mm CMOS camera offered by Medigus, LTD [9].

Shown in Fig. 1 is a camera specifically designed for endoscopy offered by Medigus, LTD [9]. Marketed as the Micro ScoutCam 1.2, it has a diameter of only 1.2 mm, well within the requirements for this project. The camera uses a low-cost, low-power draw CMOS sensor with an RGB Bayer pattern. With a resolution of 220 x 224 pixels and a framerate of 30 fps, it should be detailed enough for crown replacement viewing. The camera is also completely waterproof and has a cable length of 2 m, providing plenty of distance between the camera attached to the handpiece and the viewing monitor.

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.

Some common dental drills have cylindrical heads with dimensions of ~13 mm in diameter by ~12 mm in height [12]. Thus, the camera mount must have a cross sectional area on the order of less than ~2 mm^2 for it to be unobtrusive when mounted on the dental drill.

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 drill encapsulation shell design concept shown below in figure 2 uses a 3D printed shell that fits tightly to the dental drill. This would encase the wires and electronics to prevent water damage to the electronics, and would prevent entanglement in the wires during operation. The protrusion on the top of the drill holds the camera, which is angled towards the tip of the drill and is covered in a lens with a solution coating that prevents water build up and fog formation. The wires lead to a computer that holds a display that has settings to change the brightness of the drill along with any post processing filters.

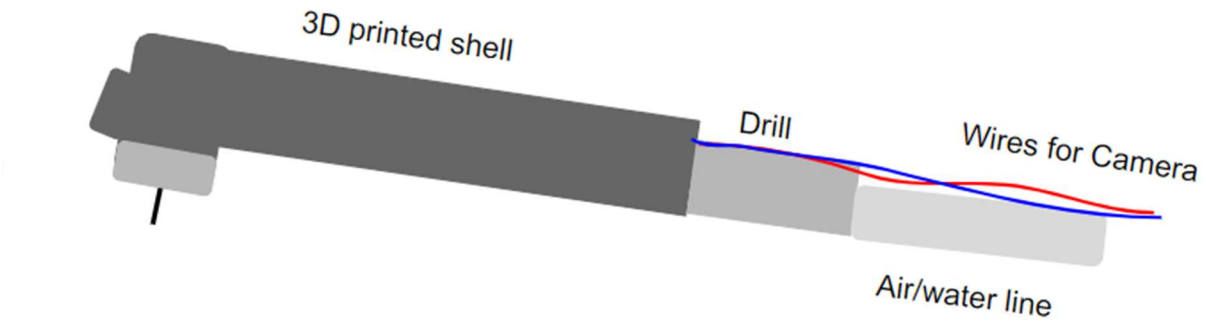

Figure 2. This design 3D printed shell (dark grey) fits over the dental drill (grey) with only room for the wiring and camera underneath. The wires would then be strapped along the hose (light grey) that holds that air and water tubes.

The Directly Mounted Plastic Housing design is displayed in figure 3. This design incorporates a small, uninvasive 3D printed housing attached directly to the downward slope on the head of the drill. Mounting the housing and camera onto the natural slope of the handpiece allows for a unique viewing angle while remaining small and unobtrusive. However, being

directly attached via only 3D-printed plastic with loose wires running down the drill-piece caused possible safety concerns. The strengths of the design are in the small profile and the cheap cost for manufacturing.

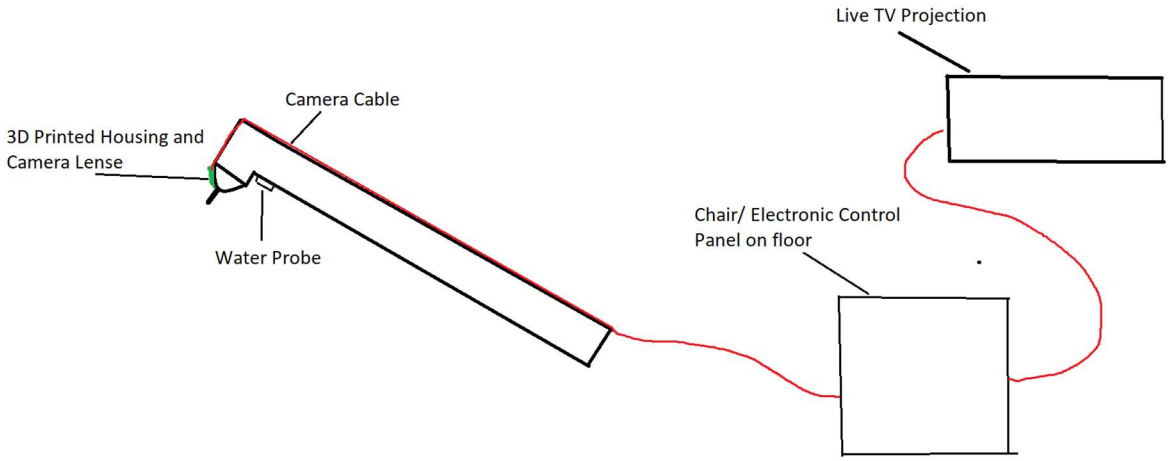

Figure 3. The Directly Mounted Plastic Housing Design (Design 2) with all components labeled.

The Angled Holder Design (aka Design 3) consists of a 3D printed plastic camera mount that is strapped onto the sides of the dental drill head and has the camera lens angle such that it is pointing directly at the tip of the drill (Fig. 4). The relative insecurity of the straps significantly damaged the safety score. The holder appears to be approximately the same size as the drill head, damaging its size score. However, its viewing angle was the best of all the designs as it deliberately extends further and more explicitly seeks the best possible viewing angle.

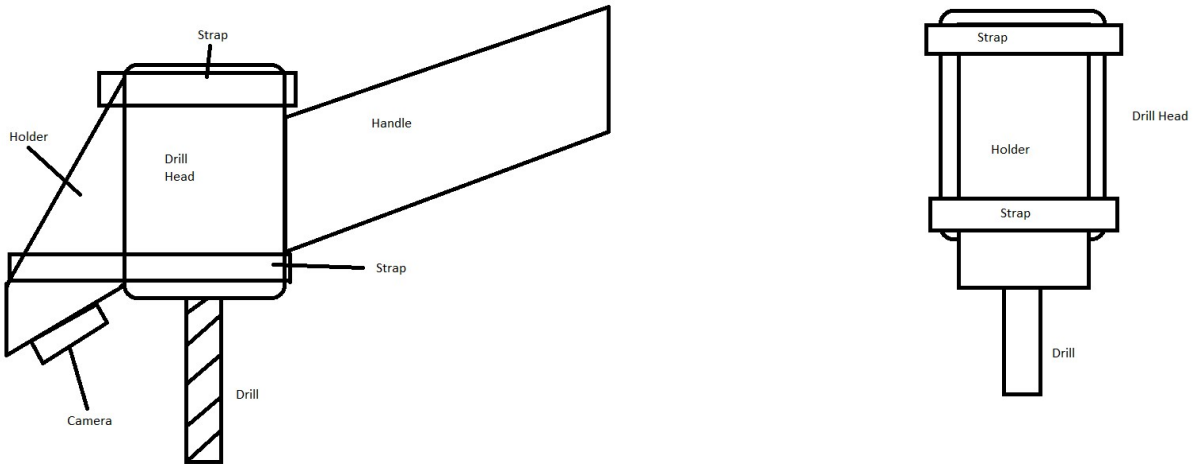

Figure 4. The Angled Holder Design (Design 3) with all components labeled.

The integrated lighting design in (Design in Figure 5) requires a 3D printed metal drill head with an extra housing for the camera and cable, which is used to replace the old drill head. The housing of the camera needs to have an angle from the axis of the body of the dental drill to ensure that the lens of the camera can focus on the working place of the drill. Also, this design requires the rearrangement of the components in the inner structure, which is difficult in terms of technique. In this design, there are four small LEDs around the camera, which is redundant because there is already a light source on the original dental drill handpiece. Also, there is a small cavity in the design to protect the lens, which makes the head of the dental drill hard to clean, leading to low score in sterilizability of this design. Due to the fabrication and erection difficulty and the low score in sterilizability, this design was not selected. However, the idea of 3D printing of metal could bring professional effectiveness if there was no production difficulty because the printed part is rigid and durable.

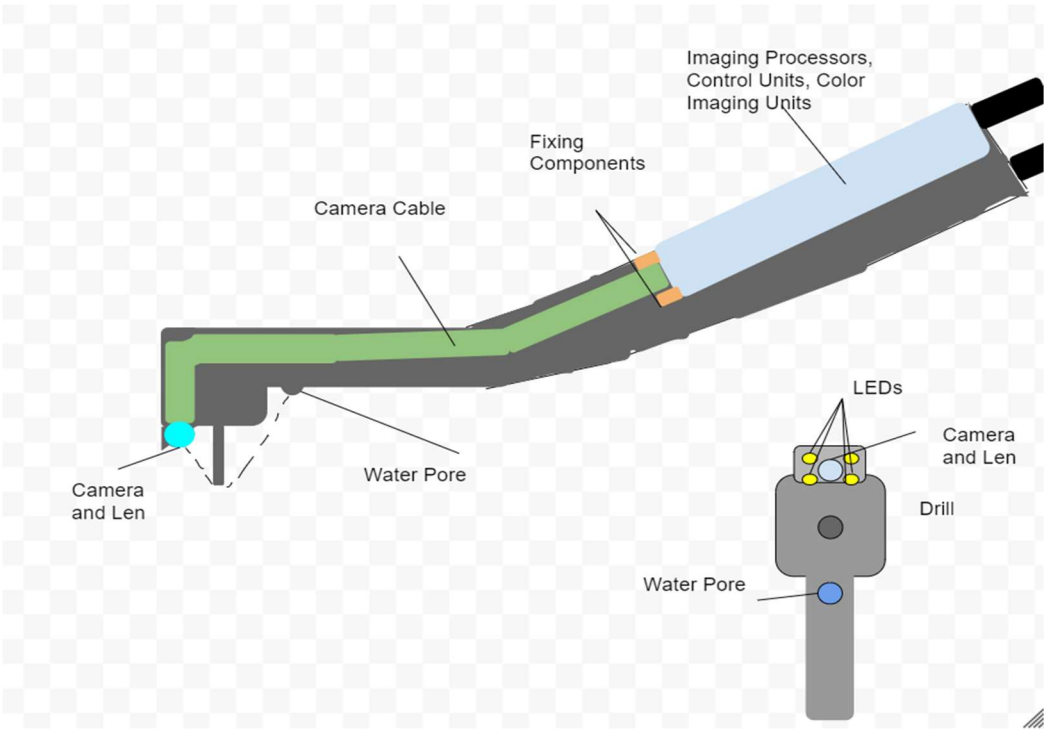

Figure 5. This concept includes LEDs to provide additional visibility around the operation area. The video processors, color filters, etc. are integrated into the handle of the dental handpiece.

The modular design (Fig. 6) utilizes a 3D-printed camera mount designed to snap on to the head of the dental handpiece. This makes it very easy to implement in dental offices, as the installment would consist merely of attaching the camera to the drill and aligning it. This design also makes use of visual post-processing through an Arduino (or similar device) to apply a color filter to heighten the enamel-dentin contrast during the operation. This image would then be projected to a screen for the dental professional to look off of over the course of the procedure. The lens of the camera would also be coated to prevent loss of vision from water and debris. The overall cost of this design would be financially very feasible, due to the cheap cost of 3D-printing and consumer electronics. There is a small safety consideration surrounding the possibility of the camera mount slipping, as it is snapped on. However, this could be remedied

using another 3D-printed piece to stabilize it from the opposite side of the drill. The field of view from the camera granted by this design is also more than adequate for the operation, and the line of sight directly to the drill tip allows for excellent viewing of the operation site. Where size is concerned, this design also performs very well, as the camera plus its housing should not extend more than a few millimeters from the drill head itself, minimizing the chances of contact with the patient's mouth. The detachable nature of the camera mount also lends itself towards easy sterilization, since both components, the camera/mount and the handpiece, can be cleaned separately.

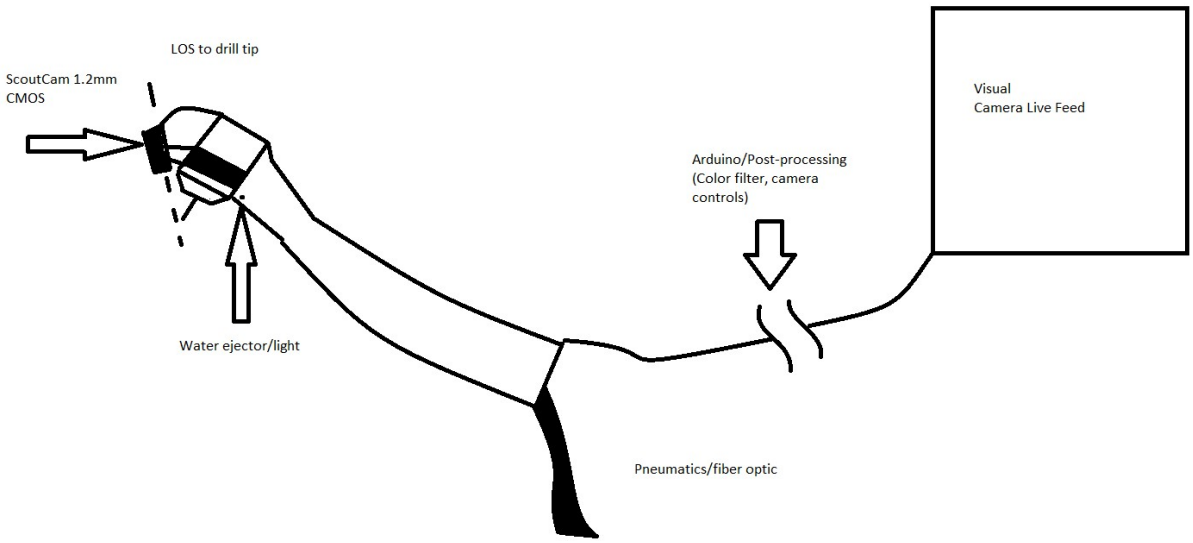

Figure 6. The modular design concept consists of a plastic, 3D-printed camera mount which is snapped on to the handpiece. The data from the camera is then filtered for color contrast and sent to the video screen in real time.

Preliminary Design Evaluation

Criteria (weight)	Design 1 Hunter	Design 2 Joe	Design 3 Lucas	Design 4 Yanbo	Design 5 Jonah
Ease of Use (25)	5/5 (25)	5/5 (25)	5/5 (25)	5/5 (25)	5/5 (25)
Safety (25)	5/5 (25)	3/5 (15)	3/5 (15)	5/5 (25)	4/5 (20)
Viewing Angle (15)	4/5 (12)	4/5 (12)	5/5 (15)	4/5 (12)	4/5 (12)
Size (15)	3/5 (9)	4/5 (12)	3/5 (9)	4/5 (12)	5/5 (15)
Cost (10)	2/5 (4)	5/5 (10)	4/5 (8)	4/5 (8)	5/5 (10)
Sterilizability (10)	5/5 (10)	3/5 (6)	3/5 (6)	3/5 (6)	4/5 (8)
Total (100)	85	80	78	88	90

Figure 7. Design matrix including scores for each of the design concepts above.

Design 1 was one of the safest designs and was easily sterilizable but was also bulkier and more costly, reducing this design's overall score. Design 2 was one of our most cost effective designs and had fairly good viewing angle setup and unobtrusive size. However, it was not as safe or sterilizable as most other designs. Design 3 had the best viewing angle of all designs but was lacking in nearly every other category. Design 4 was a very good design all around but it was slightly bulkier and more expensive than Design 5 and was not so easily sterilized. Design 5 was the highest scoring design in our design matrix so we are using it as our proposed final design. However, we will likely work on improving Design 5's safety rating by incorporating some aspects of Design 4.

Proposed Final Design

Design 5 consists of a small clip-on camera mount that is both easy to fabricate, easy to install, and effective. One added benefit of this easy fabrication is that it will allow us to iterate through the design process (something we rarely get to do in one semester) because we should be able to have a viable prototype much sooner than if we had decided to pursue another design.

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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 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.

Client requirements:

- Create a small uninvasive camera to mount on top of a dental, drilling handpiece in order to make hard-to-see 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 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 patients tooth.
- 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 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 and water jet during drilling.
- All components must withstand the vibrations from the drill.

f. Ergonomics:

- The camera must not add too much weight to the dental drill handle, 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 and 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 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 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 (along with the dental drill) and must be stored in the standard dental drill holder connected to the dentist's chair.

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).