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Article

Patient Room Controlled By Sensors in he Home

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Abstract: The aim of this study is to design and implement a wireless intraoral dental camera that could help the dentist to get a clear view for the oral cavity and aid in the diagnosis of the cases and treatment plans. Tremendous advancement in information technology has completely changed the portals of communication between health care personnel and patients. Newer techniques and advancements used to diagnose diseases remotely in real-time and simultaneously seek expert consultations and advice regarding the treatment protocols for various conditions using established telemedicine platforms are now available. In this review, we aim to discuss the various clinical applications of IOC and its possible impact on patient compliance for dental care. It can be concluded that IOC has diverse applications in oral health care and can effectively assist dentist, dental hygienists, and oral health care providers. Also, the compliance of the patient can be increased by the use of IOCs in diagnosis, treatment planning, goal setting, oral hygiene instructions, and maintenance. However, studies are scant in this area, and a precise understanding of the mechanisms of IOC by which patient compliance can be increased is not very clear for many other potential applications.

Keywords: Wireless intraoral camera, dental diagnostics, digital dentistry, telemedicine, 3D printing, real-time imaging, patient compliance, remote consultation

Introduction

Many innovative technologies are being developed that can aid oral health care providers and clinicians to render care effectively. Such novel techniques are generally non-invasive and easy to use with many other benefits for patients and clinicians. One such device that has become an indispensable tool in the provision of oral health care is an intra-oral camera (IOC), which gained its inception in 1987 when the first handpiece was fabricated from the. [1] These first dental IOCs were cumbersome and required too much space and at a high cost of about 40,000 per unit. Today, IOC systems are about the size of the previous handpiece and cost less than 5,000. The cumbersome docking station has been replaced with a USB connectivity and is lightweight and much more comfortable to operate as well as

more powerful in taking higher quality images. These major technological upgrades have made the system easy to use, requiring very little training and a standard part of every IOC systems consist of video display, processing unit, and intra-oral camera with a light source. Widely ranged features for intra-oral cameras including Macro mode (magnification), curing light for composite, LED lights, picture or video record, fluorescence for detecting various stages of caries, plaque and gingival inflammation are now available. These features in the intra-oral camera can have numerous applications in providing treatment and to communicate with experts regarding diagnosis, treatment decisions, and protocols. Moreover, increasing patient compliance and motivation before, during and after the course of dental treatment, patient knowledge and awareness of the various common oral conditions, as well as allowing effective communication between the patient and dentist, remotely of different oral health conditions. Tremendous advancement in information technology has completely changed the portals of communication between health care personnel and patients. Newer techniques and advancements used to diagnose diseases remotely in real-time and simultaneously seek expert consultations and advice regarding the treatment protocols for various conditions using established telemedicine platforms are now available. In this review, we aim to discuss the various clinical applications of IOC and its possible impact on patient compliance for dental care. The aim of this study is to design and implement a wireless intraoral dental camera that could help the dentist to get a clear view for the oral cavity and aid in the diagnosis of the cases and treatment plans. Tremendous advancement in information technology has completely changed the portals of communication between health care personnel and patients. Newer techniques and advancements used to diagnose diseases remotely in real-time and simultaneously seek expert consultations and advice regarding the treatment protocols for various conditions using established telemedicine platforms are now available. In this review, we aim to discuss the various clinical applications of IOC and its possible impact on patient compliance for dental care.

2.1 Intraoral Dental Camera

The first real IOC was introduced in the late 80 s. Fuji Optical Systems (Los Gatos, California) received the registered trademark of dental IOC on 7th July 1987 and released DentaCam. Later in 1989, Video Dental Concepts launched a novel IOC device that uses dental endoscopic handpiece. It had dental endoscope, a light source, and a remote head micro camera. Subsequently, many manufacturers modified and enhanced the features that resulted in sophisticated high-end IOC. [1,3]

Initial IOC devices were cumbersome, bulky, expensive, and occupied substantial space in the dental office. These had handpiece, video processor, dedicated computer to process the images and videos that were captured through the devices. Currently, IOC is a small handheld device which is ergonomic, lightweight, comfortable to use, relatively inexpensive and can capture highquality images and videos that are readily available for the patient and the clinician which can be magnified and viewed. [4]

IOC has a sensor located in the handpiece, which can be a charge-coupled device or a complementary metal-oxide-semiconductor sensor. [5] These sensors receive light which is converted to an electronic signal that is processed by IOC imaging software to produce an image on the computer monitor. Better quality images are obtained when the sensor is placed closer to the lens. The LED lighting provides a continuous source of light to eliminate the need for a flash. [6] Images captured by most of the IOC are stored in the in-built memory or can be stored in the computer. In-built proprietary software's help in archiving patient photographs and videos. Alternatively, one can use cloud-based storage systems to overcome the limitation of storage space. Development of cordless IOC, which can transmit videos and images in real-time and display in the monitor along with in-built functions like Bluetooth and Wi-Fi connectivity, can increase the portability and

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2.2 Applications of Intraoral Camera

Applications of IOC can be classified into direct (clinical) and indirect (remote) oral care applications. Clinical or direct applications can be before, during, and after the treatment. Remote applications can be broadly classified into diagnosing, monitoring, and preventive maintenance. Alternatively, they may be classified as those applications used for rendering oral care and those which are useful for increasing patient compliance.

2.3 Direct or Clinical Applications of Intraoral Camera

It is a common practice for the dentist to examine the oral cavity, perform required investigations, and explain the condition of the oral cavity and various treatment modalities to the patient, along with the advantages and disadvantages of the same. In many participants, the scope for understanding the concepts and conditions of the oral cavity and knowledge may not be adequate. This could be challenging for the oral health care provider to convince the patients for available treatment options. Use of IOC can be effective in familiarising the patients with various aspects before, during, and after the treatment.

Diagnosis and treatment of caries and monitoring of restorations:

Studies have shown that caries can be identified reliably with the use of simple

IOC. In-vitro studies using videos, recorded by an IOC and simultaneous

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Department of Medical Instrumentation Techniques Engineering Final Year Project histological validation showed that IOC examinations significantly increased the detection of occlusal caries.8 Another in-vitro study evaluated visual examination, IOC, and operating microscope for detection of occlusal caries, which concluded that IOC and operating microscope improved the detection.9 Both of these in-vitro studies reported a rise in false positives. Similarly, treatment decision making for restorations was compared with a visual examination, IOC, and operating microscope. [7] It concluded that IOC significantly increased correct treatment decisions compared to unaided visual examination and operating microscope. Boye et al, compared IOC photographs with visual caries assessment and found no significant difference in the caries scores and concluded that photographic assessment could have advantages like reduction in examiner bias, repeatability of assessments, remote screening and can be a permanent record. [8] However, there can be an increased cost, time taken to capture images, and might need additional software and hardware requirements to digitally archive. A study evaluated children's views on the experience of a visual examination and intra-oral photographs for the diagnosis of dental caries. It concluded that IOC was highly acceptable among children in epidemiological studies. [9] Recently, an LED camera fitted with light-induced fluorescence evaluator (VistaCam, Soprolife, and Soprocare) was developed and clinically validated. The device is not a replacement, but a supplement for the clinician to enhance the diagnostic capabilities. These IOCs have a unique feature called "Cario" mode that provides different colors for healthy, infected, affected active, and arrested dentine. It provides a magnified view of the tooth along with an auto-fluorescent image of the carious enamel and dentin and helps in diagnosis, treatment (excavation), [10] monitoring of the lesions and restorations. histological validation showed that IOC examinations significantly increased the detection of occlusal caries.8 Another in-vitro study evaluated visual examination, IOC, and operating microscope for detection of occlusal caries, which concluded that IOC and operating microscope improved the detection.9 Both of these in-vitro studies reported a rise in false positives.Similarly, treatment decision making for restorations was compared with a visual examination, IOC, and operating microscope. [7] It concluded that IOC significantly increased correct treatment decisions compared to unaided visual examination and operating microscope. Boye et al, compared IOC photographs with visual caries assessment and found no significant difference in the caries scores and concluded that photographic assessment could have advantages like reduction in examiner bias, repeatability of assessments, remote screening and can be a permanent record. [8] However, there can be an increased cost, time taken to capture images, and might need additional software and hardware requirements to digitally archive. A study evaluated children's views on the experience of a visual examination and intra-oral photographs for the diagnosis of dental caries. It concluded that IOC was highly acceptable among children in epidemiological studies. [9] Recently, an LED camera fitted with light-induced fluorescence evaluator

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Evaluation of dental restorations in terms of marginal defects, fractured restorations, a partial or total loss can also be done using IOC. Signori et al validated the technique of intraoral digital photography captured with IOC against the clinical assessment of the restorations. [11] There was a fair to moderate agreement for anterior and posterior restorations with higher detection of defects with IOC method. This method has added advantages like permanent archiving, repeatability of the assessments,

blinding of the evaluators or outcome assessors, the possibility of the single examiner to evaluate all the restorations even in multicentric studies. Monitoring and evaluation of pit and fissure sealants have not been much evaluated. Ferrazzano et al evaluated experimental two-part system (dental arch support and high definition IOC) for capturing standardized images to monitor sealants over a period of time. They concluded that it could be used as standardized and useful methods for sealants retention over time. [12] Alassaad et al, [13] used transillumination and IOC for the diagnosis of incomplete cusp fractures, which are mainly diagnosed based on patient symptoms. A technique was proposed to diagnose the incomplete fractures, capture photographs which can be archived and shared with patients. Similarly, they can also be used to diagnose incomplete cuspal fractures and other high-risk areas. Other potential applications of IOC include the ability to diagnose pulpal exposures, pulp polyp, tooth wear for which efficiency has not been evaluated. Diagnosis of plaque, calculus, and gingival inflammation: Very few reports have shown the applicability of IOC for the diagnosis of plaque, calculus, and gingival inflammation. These reports have used IOC remotely to diagnose these conditions, along with the many limitations. The use of a plaque disclosing solution is often required as a direct assessment of immature and/or minimal plaque accumulation is difficult to perceive through IOC. Besides, the disclosed immature and minimal plaque may not be seen due to the color clipping Evaluation of dental restorations in terms of marginal defects, fractured restorations, a partial or total loss can also be done using IOC. Signori et al validated the technique of intraoral digital photography captured with IOC against the clinical assessment of the restorations. 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A study compared SLR camera and IOC preferences for the assessment of plaque using image analysis. Considering the factors like reliability, simplicity, and flexibility, SLR camera with an image analysis system and the custom frame was more reliable than IOC. [14] Staudt et al introduced a reproducible, standardized image analysis system for the evaluation of dental plaque using an IOC. It has relatively convenient access to the lingual surfaces, increased objectivity, sensitive to a minor reduction in plaque and can be useful in clinical trials. [15] Soprocare IOC has a unique feature called “Perio” mode, which helps in overcoming the limitations with conventional IOC. It can immediately highlight the soft and hard deposits around the tooth with different color schemes and magnification levels. It also highlights the marginal inflammation of the gingiva. In a study that evaluated the efficiency “Perio” mode of Soprocare IOC for detecting the plaque and gingival indices, plaque scores using Soprocare were higher and gingival scores were lower than conventional clinical examination. [16,17] However, these differences were not significant and concluded that “Perio” mode of Soprocare IOC is a reliable tool. Many advantages have been highlighted, such as scoring can be repeated on the pictures, images can be used for patient education, motivation and can be compared

with subsequent recall visits to know the effectiveness of treatment and self-efficacy. Shakibaie and Walsh used VistaCam IOC system for comparing calculus and caries fluorescence readings. [18] Fluorescent readings were significantly higher for calculus than root surface caries and are not affected by saliva and blood, which suggested that VistaCam can be used as an adjunct to clinical examination. The clinician should take into account that there was an overlap in the fluorescent readings for subgingival calculus and root caries. effect of the LED lights. Due to the disclosing solution, the early signs of gingivitis can also be masked. A study compared SLR camera and IOC preferences for the assessment of plaque using image analysis. Considering the factors like reliability, simplicity, and flexibility, SLR camera with an image analysis system and the custom frame was more reliable than IOC. [14] Staudt et al introduced a reproducible, standardized image analysis system for the evaluation of dental plaque using an IOC. It has relatively convenient access to the lingual surfaces, increased objectivity, sensitive to a minor reduction in plaque and can be useful in clinical trials. [15] Soprocare IOC has a unique feature called "Perio" mode, which helps in overcoming the limitations with conventional IOC. It can immediately highlight the soft and hard deposits around the tooth with different color schemes and magnification levels. It also highlights the marginal inflammation of the gingiva. In a study that evaluated the efficiency "Perio" mode of Soprocare IOC for detecting the plaque and gingival indices, plaque scores using Soprocare were higher and gingival scores were lower than conventional clinical examination. [16,17] However, these differences were not significant and concluded that "Perio" mode of Soprocare IOC is a reliable tool. Many advantages have been highlighted, such as scoring can be repeated on the pictures, images can be used for patient education, motivation and can be compared with subsequent recall visits to know the effectiveness of treatment and self-efficacy. Shakibaie and Walsh used VistaCam IOC system for comparing calculus and caries fluorescence readings. [18] Fluorescent readings were significantly higher for calculus than root surface caries and are not affected by saliva and blood, which suggested that VistaCam can be used as an adjunct to clinical examination. The clinician should take into account that there was an overlap in the fluorescent readings for subgingival calculus and root caries.

2.4 Indirect Applications of Intraoral Camera

These applications may not be directly linked to the diagnosis or treatment of oral diseases or conditions. Dentists or hygienists can use the IOC to train the patients or individuals to maintain appropriate oral hygiene, proper use of mechanical plaque control aids, demonstration of oral conditions, etc. Alternatively, patients also can use the IOC at home and contact the oral health care providers and seek information in real-time or as store and forward method. It is crucial for the clinician to communicate with the patients about the realistic scenario of the oral cavity and the pros and cons of the treatment proposed. A lot of factors come into play during the process of communication with the patients. Use of pictures and videos captured through IOC of the patient's condition in real-time can reduce the effect of such factors. IOC can help the clinician or oral health provider to communicate with patients and motivate them for treatment, which will increase patient compliance and acceptance that can contribute to the success of the treatment or outcomes. IOC was shown to be an effective and interactive tool to communicate with patients.64 One can use either photograph or live video of the patient's conditions to demonstrate and educate about the oral hygiene and conditions which captures the attention of the patient and understand the pathological processes and boost the correct use of oral hygiene methods. [19,20] Similarly, an attempt to demonstrate various other conditions like potentially malignant disorders, malignancies, periodontal conditions, pericoronitis, fractured teeth and cusps, incipient caries, deep pits and fissures, pulpal exposure, pulp polyp, and impacted teeth will make the patients understand the characteristics and severity of the disease condition. This way, it is possible to incorporate an approach called "codiagnosis," which combines the views of patients and oral health care provider in planning the treatment. [21], Indirect Applications of Intraoral Camera

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2.5 Advantages of Intraoral camera

Intraoral cameras help in the early detection of any dental issues that are gradually developing They are useful for emergency dental treatments , They allow dentists to keep track of any modifications or progress of a treatment plan more easily

By offering better and more precise images of the entire mouth, they help increase the accuracy and results of dental treatments.

Materials and Methods

For making a structure for our project we used a 3D designing application called "SketchUp"

3.1.1 SketchUp

Figure (3-1) shows a suite of subscription products that include SketchUp Pro Desktop, a 3D modeling Computer-Aided Design (CAD) program for a broad range of drawing and design applications — including architectural, interior design, industrial and product design, landscape architecture, civil and mechanical engineering, theater, film and video game development. Owned by Trimble Inc., the program is currently available as a web-based application, SketchUp Free, and three paid subscriptions, SketchUp Shop, SketchUp Pro, and SketchUp Studio, each with increasing functionality. The program includes drawing layout functionality, surface rendering in different "styles", and enables placement of its models within Google Earth.

Figure (3-1): Sketch Up icon.

We made a 3D model containing a handle, a battery holder, a place for gluing the electrical circuit and an enclosure for placing the camera is shown in figure (3-2).

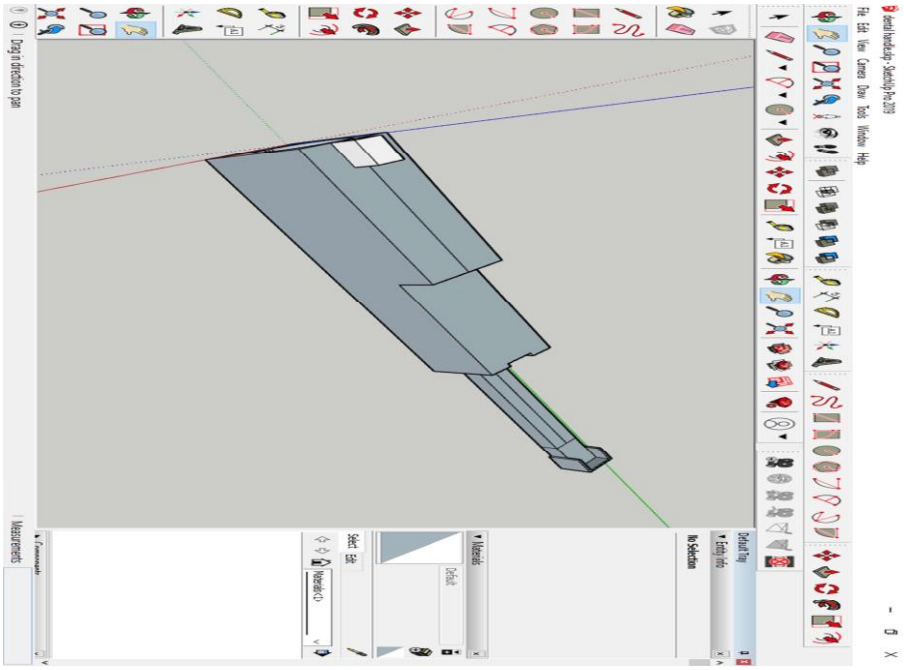

Figure (3-2): 3D design model.

After making the design we sliced it in order to make it ready to be printed by using "Ultimaker Cura 4.13.1" software.

3.1.2 Ultimaker Cura

Cura is an open source slicing application for 3D printers. It was created by David Braam who was later employed by Ultimaker, a 3D printer manufacturing company, to maintain the software. Cura is available under LGPLv3 license. Cura was initially released under the open source Affero General Public License version 3, but on 28 September 2017 the license was changed to LGPLv3. This change allowed for more integration with thirdparty CAD applications. Development is hosted on GitHub. Ultimaker Cura is used by over one million users worldwide and handles 1.4 million print jobs per week. It is the preferred 3D printing software for Ultimaker 3D printers, but it can be used with other printers as well.

Ultimaker Cura works by slicing the user's model file into layers and generating a printer-specific g-code. Once finished, the g-code can be sent to the printer for the manufacture of the physical object is shown in figure(3-3). The open source software, compatible with most desktop 3D printers, can work with files in the most common 3D formats such as STL, OBJ, X3D, 3MF as well as image file formats such as BMP, GIF, JPG, and PNG.

Figure (3-3): Ultimate Cura software icon.

After making the gcode file by using the slicer software we used the 3D printing technology to print the model by using "Ender3 V2" 3D printer.

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3.1.3 Ender3 V2 3D Printer

The Creality Ender-3 is an FDM 3D printer is shown in figure (3-4). This means it prints parts by melting and extruding a thermoplastic filament through a heated single extruder equipped with a Bowden feeder system. The extruder module has been designed for printing with generic 1.75mm filaments.

Department of Medical Instrumentation Techniques Engineering Final Year

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We used PETG filament for PETG is an immensely popular 3D printing filament, widely used for its high strength, relative flexibility, and temperature resistance compared to the ever-popular PLA.

It's measured in many of the same ways as ABS but is generally much easier to work with and has the added benefit of being food safe. As a result, it displaced ABS as the second most popular 3D printing filament on the market. PETG is made from Polyethylene Terephthalate (PET), the material you may know from plastic water bottles, but some ethylene glycol is replaced with CHDM (cyclohexanedimethanol) — hence the letter "G" after PET for "glycol-modified". The result is a clearer, less brittle filament that's easier to extrude than PET. However, it does have the unfortunate side effect of changing the recycling process. Although PET is widely recycled, PETG is not – the subtle differences between these materials create a troublesome contaminant in recycling facilities. Still, it's an excellent filament choice for printing objects that need to be sturdy, smooth, and exhibit low shrinkage. It's also popular because PETG is considered food-safe – but you should still read the fine print on any spool you buy to be sure. There aren't many disadvantages to printing with PETG. Of the few, PETG is more prone to scratches and scuffs than PET is. It's also true that, despite being comparable to PLA for its ease of printing, many makers do find PETG a bit trickier to print than other materials. It certainly has its quirks, so you'll need to find the "sweet spot" for your print settings. For example, you'll likely find more clumping at the nozzle and more stringing when compared to PLA. If you're using a glass print bed, PETG is great for releasing after cooling – but mind the easy release during your print and make sure your bed temperature is high enough to keep it stuck. We used PETG filament for PETG is an immensely popular 3D printing filament, widely used for its high strength, relative flexibility, and temperature It's measured in many of the same ways as ABS but is generally much easier to work with and has the added benefit of being food safe. As a result, it displaced ABS as the second most popular 3D printing filament on the market.

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you're using a glass print bed, PETG is great for releasing after cooling – but mind the easy release during your print and make sure your bed temperature is high enough to keep it stuck.

Then we used a WIFI camera is shown in figure (3-8) and glue it to the 3D model, the li-ion battery with the electrical circuit are fixed to the chassis of the device and the antenna are fixed in the bottom near the handle is shown in figure (3-5), (3-6) and (3-7).

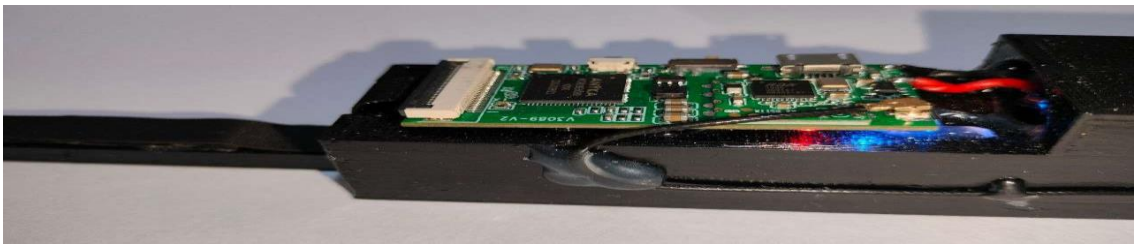

Figure (3-5): Electrical circuit and antenna wire assembly.

Figure (3-6): Antenna and li-ion battery.

Then we used a WIFI camera is shown in figure (3-8) and glue it to the 3D model, the li-ion battery with the electrical circuit are fixed to the chassis of the device and the antenna are fixed in the bottom near the handle is shown in figure (3-5), (3-6) and (3-7).

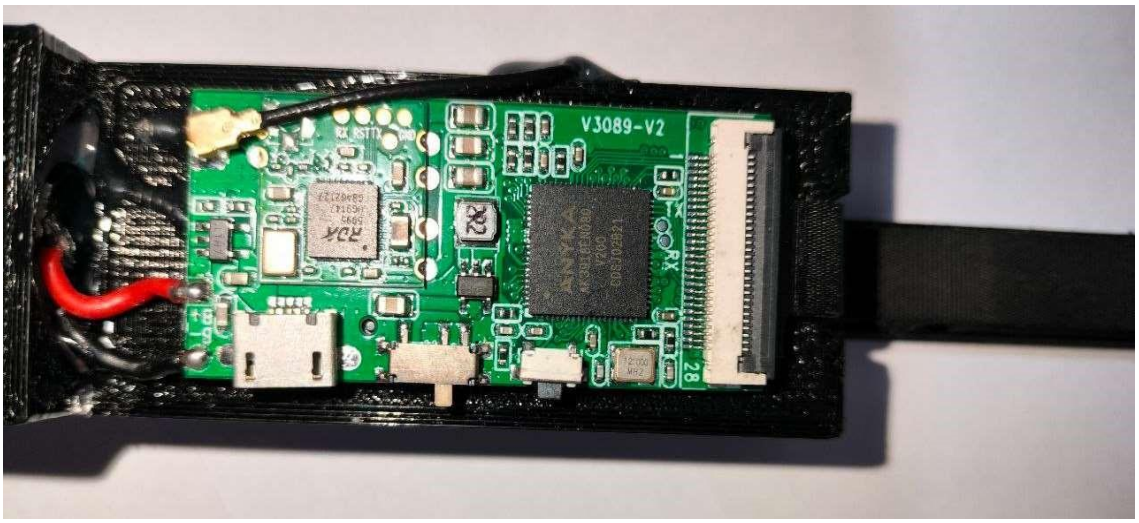

Figure (3-7): Electrical circuit of the device.

Figure (3-8): The Camera.

3.2 Working Principle

The aim of this proposed approach is to design a wireless intraoral dental camera. The objective is to get a benefit of the nowadays technology for making equipment that help the dentists in his daily work.

The required components used in this project include a 3D model, a power supply unit a camera and an electrical circuit that can send the video captured by the camera through WIFI to the receiver smartphone or PC. The working of this device can be explained with the help of a block diagram is shown in figure (3-9).

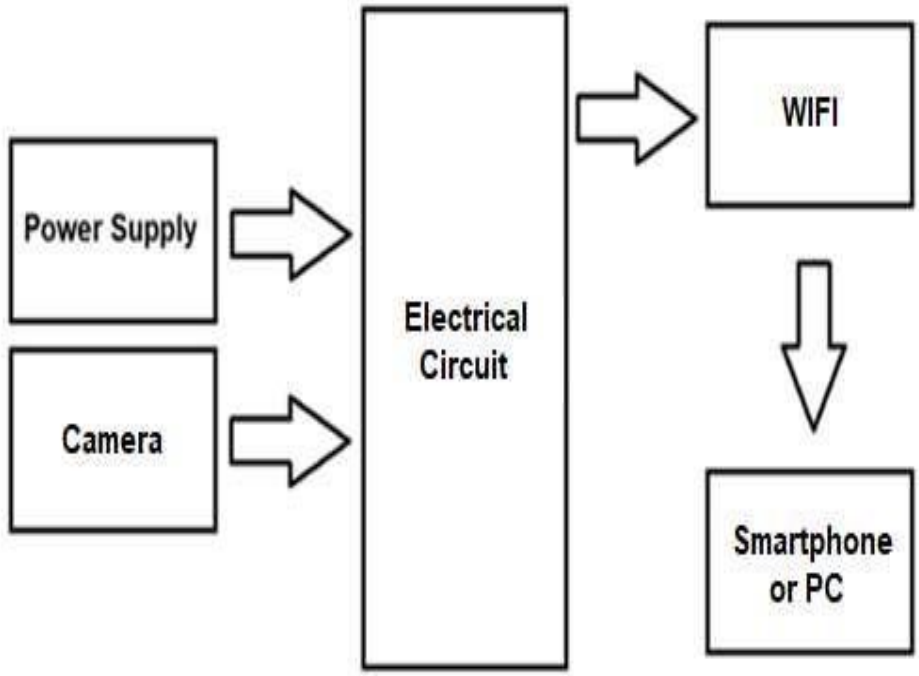

Figure (3-9): Device block diagram.

This block diagram includes a power supply block that supply power to the whole circuit, and a camera which captures the video and sends it to the electrical circuit that sends it to the receiver phone via WIFI.

3.2 Working Principle

The aim of this proposed approach is to design a wireless intraoral dental camera. The objective is to get a benefit of the nowadays technology for making equipment that help the dentists model, a power supply unit a camera and an electrical circuit that can send the video captured by the camera through WIFI to the receiver smartphone or PC. The working of this device can be explained with the help of a block diagramis shown in figure (3-9).

Figure (3-10): The device after full assembly.

Results and Discussion

After powering on the device, the red led in the electrical circuit start to glow up and the blue led start to blink indication that the device starts to broadcast an access point via WIFI called "F621091HDSKL" is shown in figure (4-1).

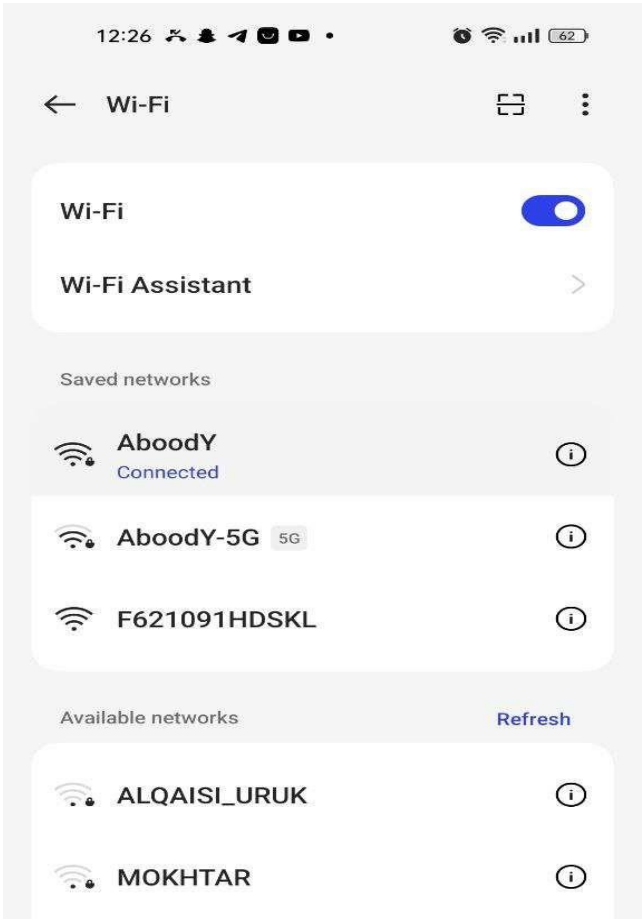

Figure (4-1): Selecting camera SSID.

Conclusion

It can be concluded that IOC has diverse applications in oral health care and can effectively assist dentist, dental hygienists, and oral health care providers. Also, the compliance of the patient can be increased by the use of IOCs in diagnosis, treatment planning, goal setting, oral hygiene instructions, and maintenance. However, studies are scant in this area, and a precise understanding of the mechanisms of IOC by which patient compliance can be increased is not very clear for many other potential applications.

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