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TELEMEDICINE SYSTEM DESIGN: REVOLUTIONIZING REMOTE HEALTHCARE DELIVERY

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Abstract: The need for e-health systems in countries like ours cannot be over emphasized as there is a serious Medical Practitioners brain drain. Medical Practitioners for lack of conducive work environment, lack of facilities, unpaid dues among other basic needs go in search for greener pasture thereby decreasing the WHO defined doctor-to-population ratio of 1:600 to 1:4000-5000 representing a difference of 3400-4400 population burden on a doctor. This means that the few Medical Practitioners available will be over stressed and therefore giving attention to quality number of patients would be impossible hence this study. This telemedicine system is developed to fill the gap created by the result of Medical Practitioners brain drain. This is to say that with the adoption of telemedicine, foreign medical experts including the Nigerian emigrated doctors can be reached and be of help to the medical sector while they fix the cause of brain drain in the country. It is one major means to bringing to the doorsteps of the Nigeria populace that falls short of the WHO recommended doctor-to-population ratio of 1:600. This telemedicine system was implemented using Spyder ->Python, Microsoft Visual Studio Code -> JavaScript, PHP, AJAX, CSS

Keywords: Telemedicine, e-health, WHO, Brain-DRAIN

1. Introduction

Telemedicine is the remote delivery of health care services through telecommunication technology. A situation whereby the participants (medical care givers and recipients) are not "physically present but via telecommunication". Telemedicine is a word coined by World Health Organization (WHO) in the 1970s[1]. WHO coined this word to fit and describe the services medical practitioners and health givers render off their physical zone through telecommunication tools. With these telecommunication tools, diagnosing a disease, giving treatment plan, carrying out surgeries, and a lot more are practiced today. Telemedicine brings the services of medical practitioners to patients' door mouth, therefore over-coming the problems of medical doctors' brain drain in third world countries. Telemedicine should not be understood to mean a specialty in the medical field but rather a tool to disperse traditional medical practice beyond the walls of the typical medical practice.[2],[3]. Telemedicine could be between two medical doctors or more working as a team or between patient and doctor.

1.1 The Practice of Telemedicine in Nigeria

In Nigeria, use of telemedicine started far back in 2007 when the National Space Research and Development Agency and Federal Ministry of Health inaugurated their first project in six Federal Medical Centers and two teaching hospitals across the country[4]. Between when telemedicine started in Nigeria and now, its' adoption wasn't significant for known reasons such as illiteracy, access to internet, awareness, etc.

In respect of internet access, a survey conducted by the Alliance for Affordable Internet (A4AI) at nine low- and middle-income countries (Colombia, Ghana, India, Indonesia, Kenya, Mozambique, Nigeria, Rwanda, and South Africa), reported that only one in every ten people in these countries have meaningful connectivity[5]. A4AI defined meaningful connectivity as regular access with fast speeds, enough data and sufficient devices which billions of people in its focused countries of research lack. A4AI from its findings, concluded that 81 percent meaningful connectivity gap exists in Nigeria, in which they claimed that only 6.6 per cent of the rural population and 16.4 per cent of the urban have meaningful connectivity. From A4AI report, it can be concluded that telemedicine is out of the reach of a large number of Nigerians as it is access only through meaningful internet connectivity. And for the number that has internet connectivity, the problem of bad internet quality poses as a challenge to accessing telemedicine.

Inadequate information and communication technology (ICT) infrastructure is also another barrier to the effective adoption of telemedicine in Nigeria as revealed in a study by Sani *et al*[6].

Femi Obikunle published an article in The Guardian: Successes, challenges of telemedicine adoption in Nigeria clinical settings, where he listed 8 barriers to the adoption of telemedicine in Nigeria, among which he mentioned high-speed Internet, which is in agreement with A4AI[7].

Femi Obikunle also wrote on lack of education and skills to appreciate telemedicine by rural inhabitants. Obikunle did not fail to mention the fact that Nigeria lacks locally trained experts, and training facilities on how to develop telemedicine platforms. Obikunle concluded by saying that if the barriers to telemedicine adoption are not given serious consideration, it may spell an immeasurable healthcare doom for Nigerian future inhabitants.

1.2 Benefits of Telemedicine

Ojoma Akor published an article on DailyTrust on the report from the maiden Nigerian medical association (NMA) annual lecture series in Abuja where he said the association president, Professor Innocent Ujah stated that Nigeria lost over 9,000 medical doctors to the United Kingdom, Canada and the United States of America between 2016 and 2018[8]. The author in his article said Professor Innocent Ujah, quoting WHO data, said Nigeria has a doctor-to-population ratio of about 1:4000-5000, which falls far short of the WHO recommended doctor-to-population ratio of 1:600.

In a critical situation like the mentioned above, telemedicine with its benefits is one sure way to closing the wide gap created. Telemedicine operates upon the platform of ICT. This is to say that with the adoption of telemedicine, foreign medical experts including the Nigerian emigrated doctors can be reached and be of help to the medical sector while they fix the cause of brain drain in the country. It is one major means to bringing to the doorsteps of the Nigeria populace that falls short of the WHO recommended doctor-to-population ratio of 1:600.

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William *et al* in their paper said telemedicine will allow the underserved a better opportunity to receive the quality care they deserve[9]. The authors in a narrative review discussed the benefits of telemedicine in postoperative care. Some of the benefits listed are increased accessibility along with reduced wait times, excellent clinical outcomes, enhanced patient satisfaction, and cost savings for patients and health care systems.

Telemedicine has recorded successes in developed nations like America where diagnosis and treatment of a range of urological conditions achieved success. Medication follow-up, metabolic kidney stone counseling, kidney stone and cancer surveillance via telemedicine platforms have also recorded successes[10].

Young *et al* also carried out a study on the impact of telemedicine in pediatric postoperative care[11]. The study came out with findings that patients reported pretty high satisfaction with virtual visits and benefitted from reduced wait times, yet, received care of comparable duration and quality. The authors concluded with a remark that virtual visits provide an efficient way to conduct postoperative visits, reducing wait times and increasing physician efficiency while retaining high satisfaction and quality of care.

Finkelstein *et al* compared virtual visits with conventional in-person visits with respect to clinical outcomes, family experience and costs in a pediatric urology surgical population in a study and concluded that pediatric postoperative care virtual visits are associated with shorter wait times, decreased missed work and school, and clinical outcomes similar to those of in-person visits. Telemedicine appears to reduce the costs associated with these brief but important encounters[12].

2. Related Works

A lot of articles on telemedicine applications flood the internet some of which are not necessarily doctor/patient give and receive but to transfer beneficial information about diseases. Nikniaz *et al developed* a Persian-language application for patients with Celiac disease (CD) which focuses on increasing the knowledge of patients with CD through a Smartphone application. In this study a three-month educational intervention delivered via smartphone application was compared with standard care on gastrointestinal symptom rating scale (GSRS) score in patients with celiac disease and the study recorded a significant positive effect on indigestion symptoms compared with routine clinic education[13]. Baalharith *et al* did a systematic reviewed on Telehealth and Transformation of Nursing Care in Saudi Arabia, aimed at examining the technological impact on nursing in Saudi Arabia[14]. The authors from the benefits of telehealth in their findings came up with three key recommendations: "the need to integrate telehealth into the nursing curriculum, telehealth training, and reskilling among HealthCare Workers (HCWs) in Kingdom of Saudi Arabia (KSA) and further primary studies focusing predominantly on telenursing." Alghamdi *et al* developed a Physical Unclonable Function (PUF) which operates as a challenge-response authentication protocol, where a server presents a challenge to a client having a PUF implemented on its side, which in turn responds to the server with a response that is unique to itself. The client could be any electronic device which has a PUF implemented on it, and this could be as part of a microcontroller or microprocessor or on a field programmable gate array (FPGA)[15]. The authors ensured security of the protocol of their system preventing attackers by using Automated Validation of Internet Security Protocols (AVISPA) tool which made theirs better security-wise compared with other schemes.

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3. System Implementation Tools

Both hardware and software tools were employed in the design and implementation of this system. They both played their significant roles to make the telemedicine system a success. The software and hardware systems included:

a. Software Requirement

1. PHP: PHP is an abbreviation that initially stood for Personal Homepage. But now it is a recursive acronym for Hypertext Preprocessor. Recursive in the sense that the first word itself is a combination of two words coined by Ted Nelson[16], so the full meaning doesn't follow the abbreviation. PHP is both an open-source server-side scripting and general-purpose language that is employed by developers[17]. In this study, PHP was used as a server-side scripting language for the web development and as a general-purpose language for Graphical User Interfaces (GUIs). The popularity of PHP over the years is due to its advantages like its cross-platform nature where it can run on every OS platform be it Windows, Mac, or Linux. PHP's original code is made available for people to build upon which also makes it an easy to learn programming language. PHP was also used in this study to connect all databases as it supports a variety of database management systems be it relational or non-relational.
2. CSS: CSS stands for Cascading Style Sheets. It is a language used to design markup languages like HTML elements. CSS was used in this study to give the appearance of the markup language document with some styles like the layout of the document, the colour, text alignment, font size, etc. The use of CSS solved the problem of the bulky, hard-to-comprehend, difficult-to-manage Hyper Text Markup Language (HTML) codes as well as the use of duplicate HTML tags.
3. JavaScript. JavaScript is one of the powerful tools for web design[18]. We used JavaScript both on the client-side and server-side of the web development to give interactive ability to the various web pages.
4. AJAX: It stands for Asynchronous JavaScript and XML is a combination of; o "JavaScript and HTML DOM to display data or use data as the case may be

o XMLHttpRequest Object to request for data from a web server"

We used AJAX in the implementation of this system to ease updating of a part of web pages without necessarily reloading the "whole page".

a. **Spyder**. Spyder is an open-source cross-platform integrated development environment (IDE) for scientific programming in the Python language[19]. We choose to use Spyder IDE for its "Diverse functionalities such as easy debugging, editing interactive execution" among others.

4 Results and Discussion

This section outlined the results of the implementation. The telemedicine application as illustrated in a Use-Case-Diagram in Figure 4.1 is developed with a singular objective to provide patients a seasy access to medical doctors irrespective of geographical location. A database is created to store patients' diagnostic and personal details.

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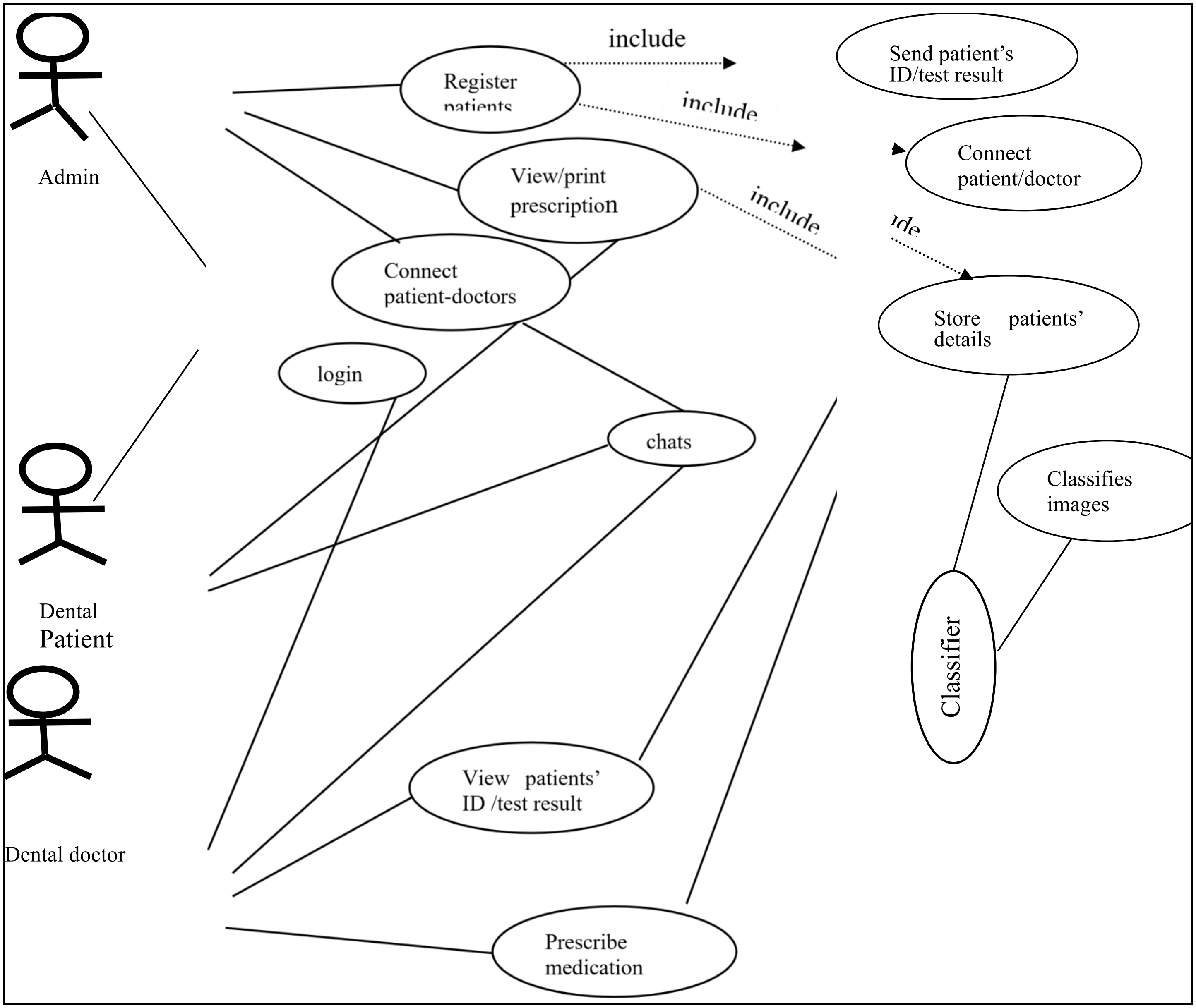

Figure 4.1 System Use-Case-Diagram

Medical doctors who are interested in rendering consultation services are registered with their personal and professional details. Doctor's personal data is captured and registered both for legal and professional record keeping. Doctors' data captured for this system's use are doctor's full name, contact number, and email address. These data undoubtedly are the key information with which a user of this system can contact a doctor. Information such as the email address as it is used is to transfer patient's personal and diagnostic details to doctors.

This application is developed to work in connection with classification models as well where a classification model trained to classify radiographical images connected to it can act as diagnostic tool. Results from the classifier are stored in a database and used as the basis for treatment planning.

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Patients using this system are distributed among registered medical doctors for consultation. Listed and discussed are the outputs of the telemedicine application.

a. **Staff Manager Menu**. Enlisted doctors and staff are registered here. Registration is one of the processes by which dental doctors and patients' interaction is made viable. Qualified

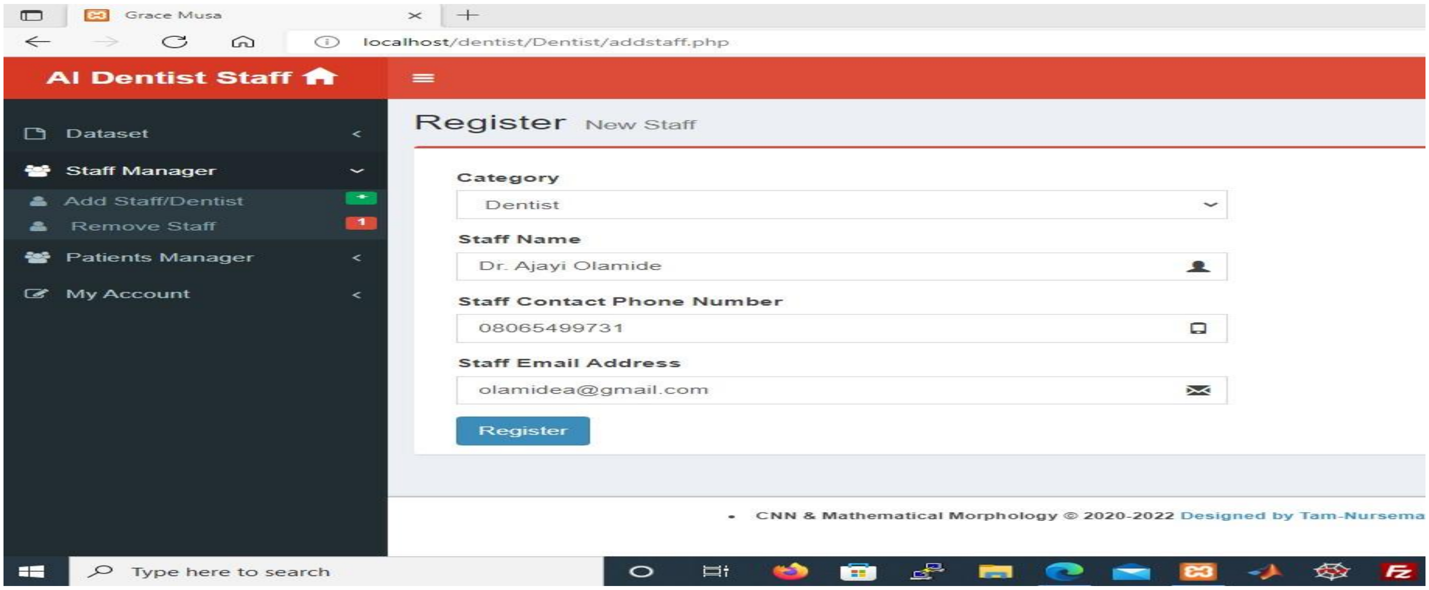

Figure 4.2 Dental doctor registration

As seen in Figure 4.2, the staff manager menu is where, besides registering staff/dental doctor removes staff/dental doctor. A user no longer in the organization is removed and therefore has no access to the system.

b. **Staff/Doctors' Page:** Figure 4.3 displays a page with a list of registered prospective end users of the telemedicine application. Users account can also be removed in this page

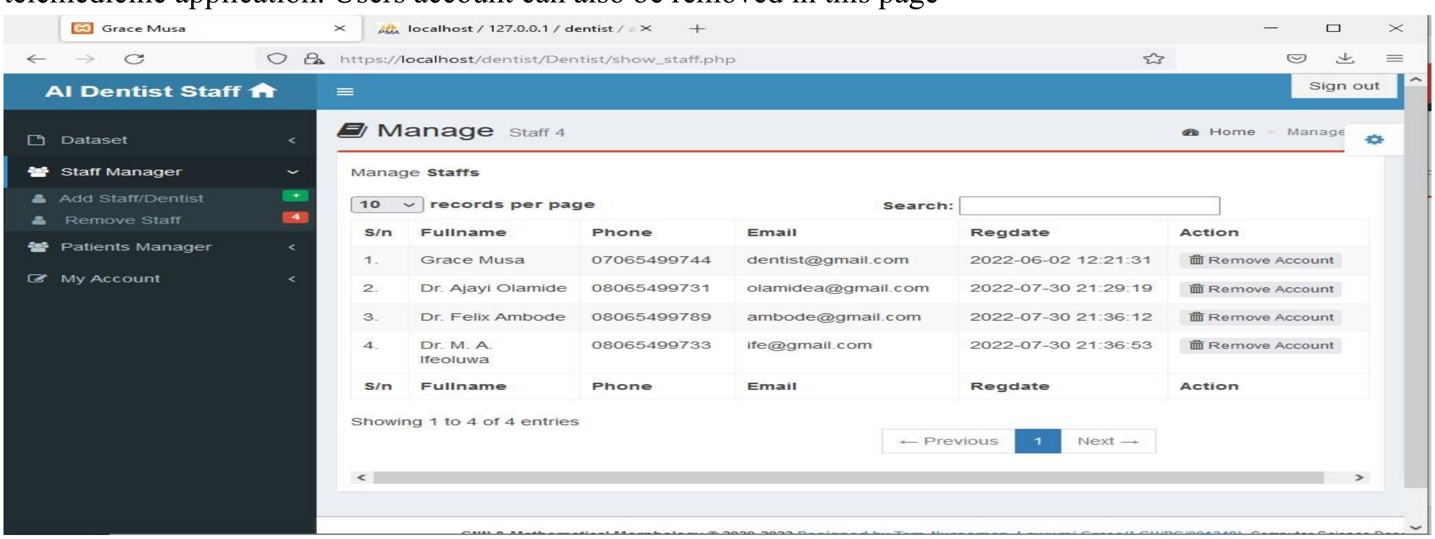

Figure 4.3 Staff/doctor's list

c. **Patients' Manager Menu.** This page is where an avenue for consultation is created. Here, the doctor of preference is chosen from a dropdown menu that contains the list of doctors available for consultation illustrated in Figure 4.3. Patient's personal and diagnostic details including patient Identification Number (ID) are captured

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and sent across to the preferred doctor as displayed in Figure 4.4 and Figure 4.5. A good number of doctors can be accessed by different patients. This makes the system robust. Patients are assigned to the number of doctors registered for consultation.

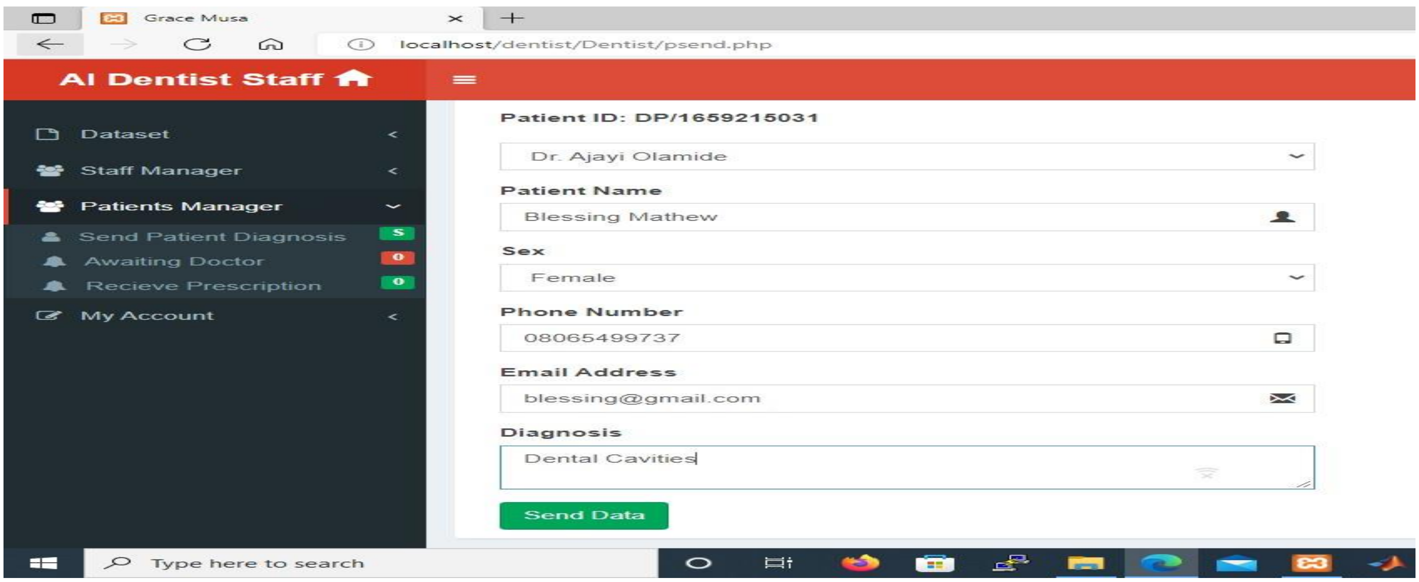

Figure 4.4 Sending Patient personal and diagnostic details to registered Doctor

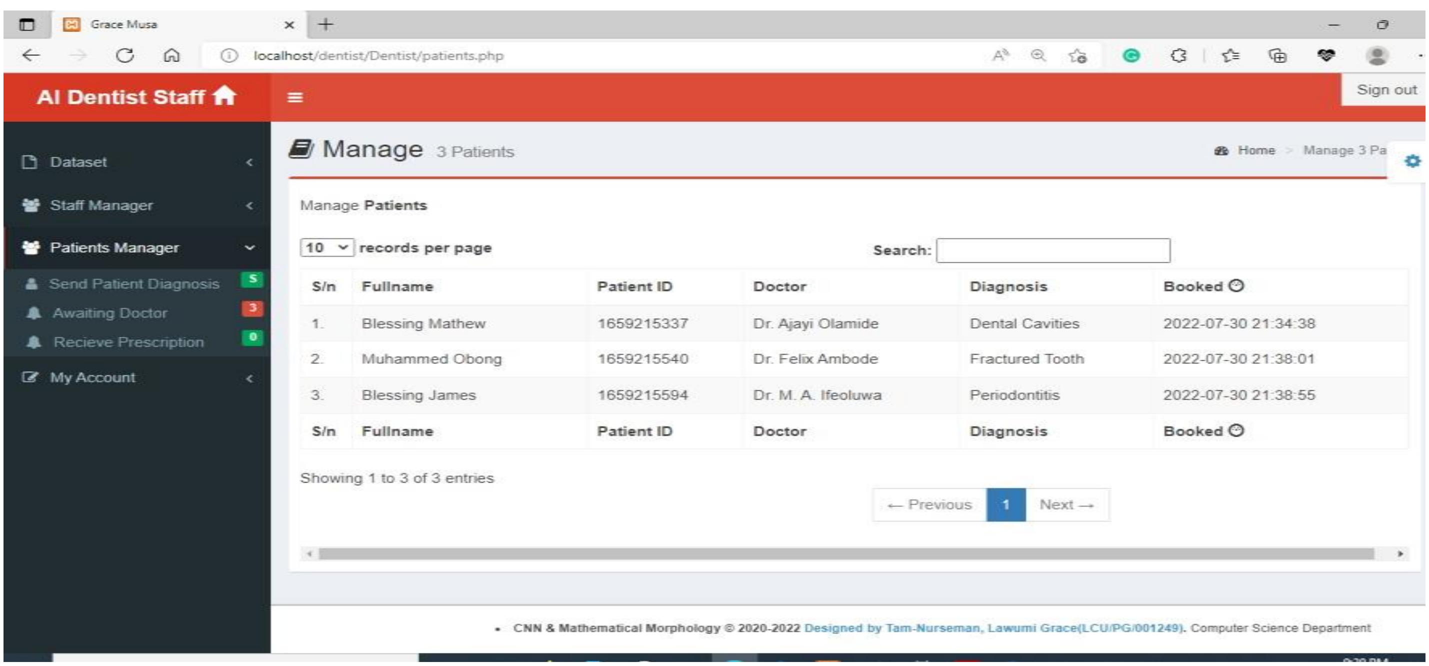

Figure 4.5 Patients' diagnostic list sent to different doctors

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d. Doctor's Dashboard. Figure 4.6 displays a doctor's patient(s) list on queue awaiting to be atteneded to. The number of patients on treatment is indicated. If no patient is on treatment and awaiting queue tends to increase, the admin checks for possible problem and finds solution.

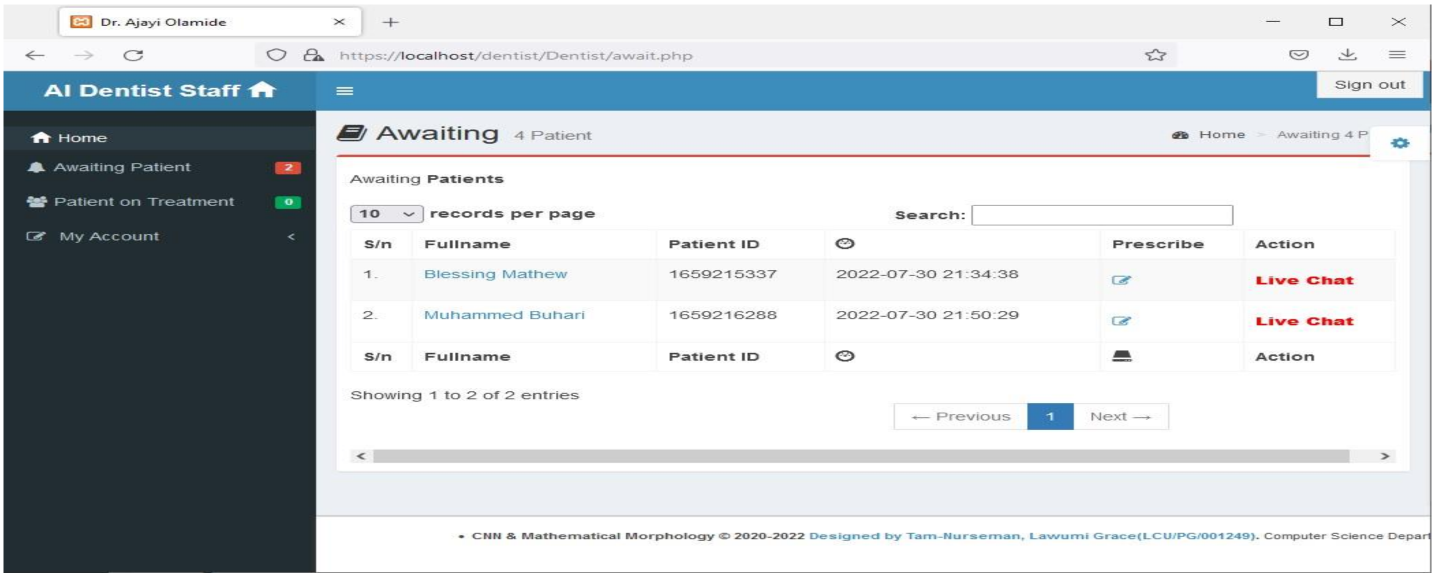

Figure 4.6 Doctor's dashboard

e. Patient's Dashboard. The patient's dashboard page as seen in figure 4.7 indicates whether or not a patient is on chat with a doctor. Whenever a patient is on with a doctor, the next patient to be attended to waits on a queue and as soon as the current chat is over, the awaiting patient is connected.

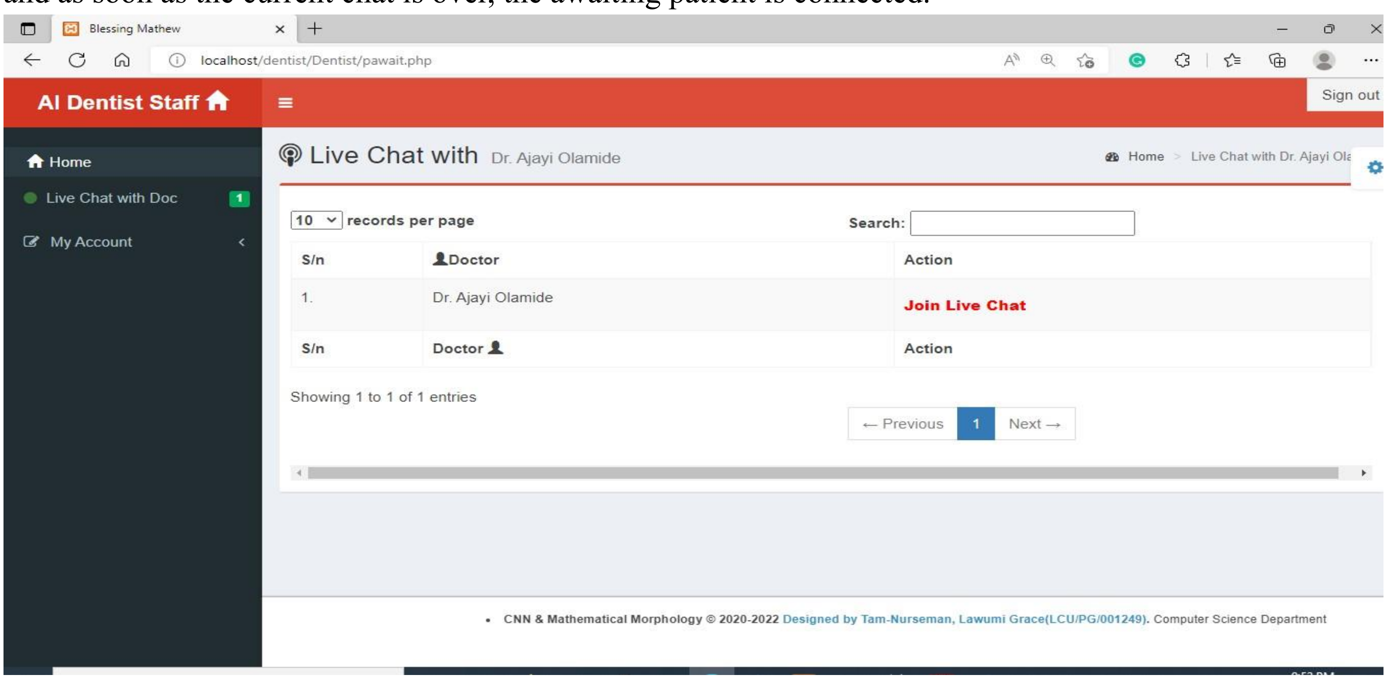

Figure 4.7 Patient's dashboard

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f. Figure 4.8 is a view of a patient-doctor chat. This can be likened to a consulting room. Here the doctor exercises the three elements of diagnosis which are;[20]

1. History
2. Examination
3. Diagnostic test

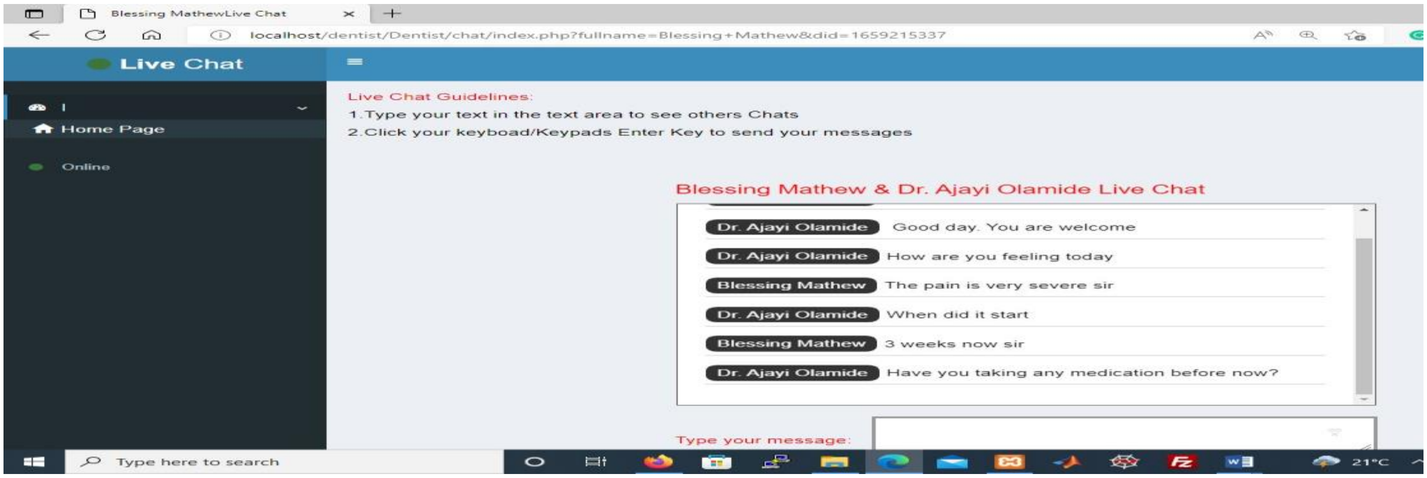

Figure 4.8 Patient-doctor live chat

Having received the patient's personal and diagnostic details, the doctor listens to the patients' complaints and ask some structured questions. At this point, the doctor establishes rapport with the patient to arrive at a provisional diagnosis through direct chat with the patient. Besides the diagnostic report sent from the diagnostic test, the doctor further makes inquiry from the patient to get more details about the history of the present complaint, previous dental history, family, and social history from the patient. Response to these structured questions will give the doctor an idea of the best possible treatment plan.

Figure 4.9 displays a sample page of doctor's prescription after doctor-patient chat. The patient's name, diagnostic reports alongside the doctor's report are seen displayed in the page.

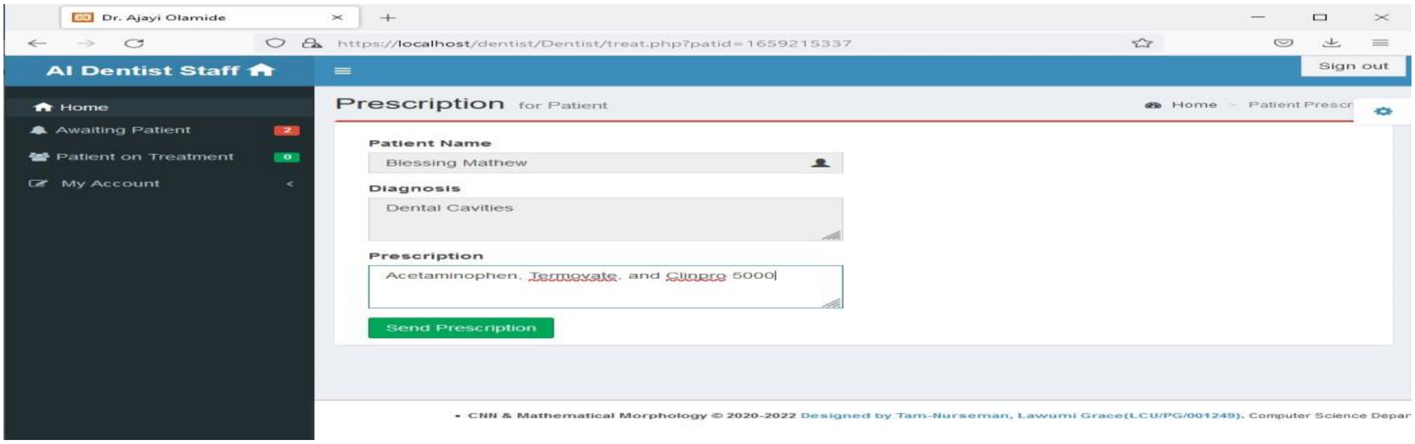

Figure 4.9 Doctor's prescription page

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h. **Doctor's prescription page:** All the prescriptions of the various doctors to different patients are stored in a database for record and reference purposes. Figure 4.10 displays patients' details, consulted doctor's name, diagnostic detail, date of consultation, and prescription.

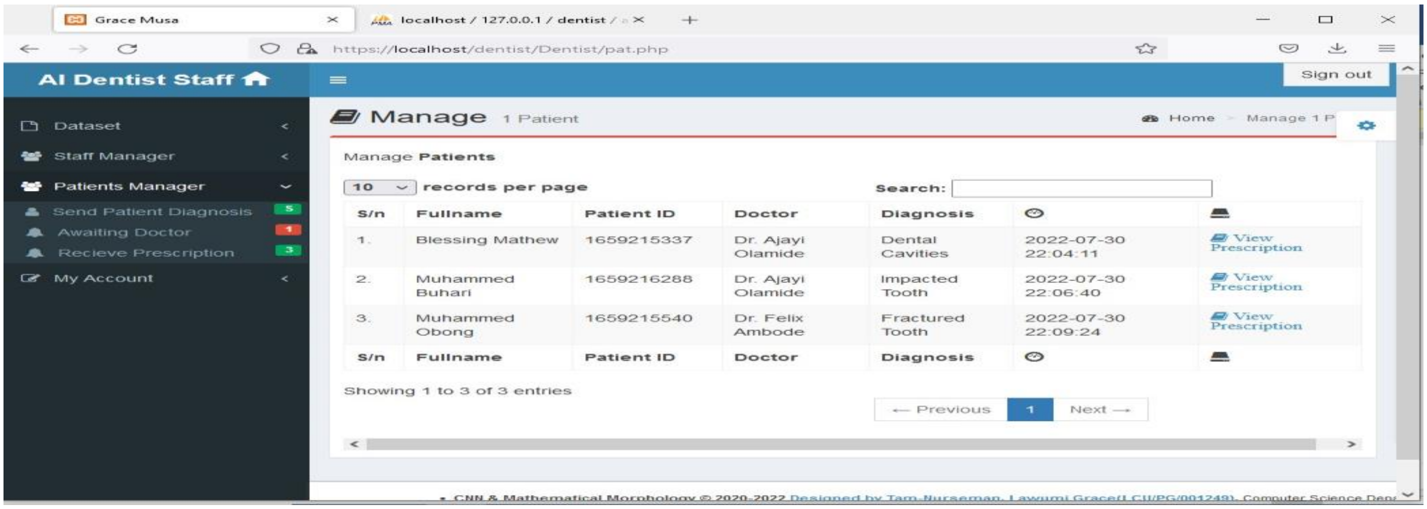

Figure 4.10 Received prescription lists.

Every prescription is sent to the subscribing organization or hospital displayed in figure 4.11. Patients receive a printout copy or soft copy sent to their email address

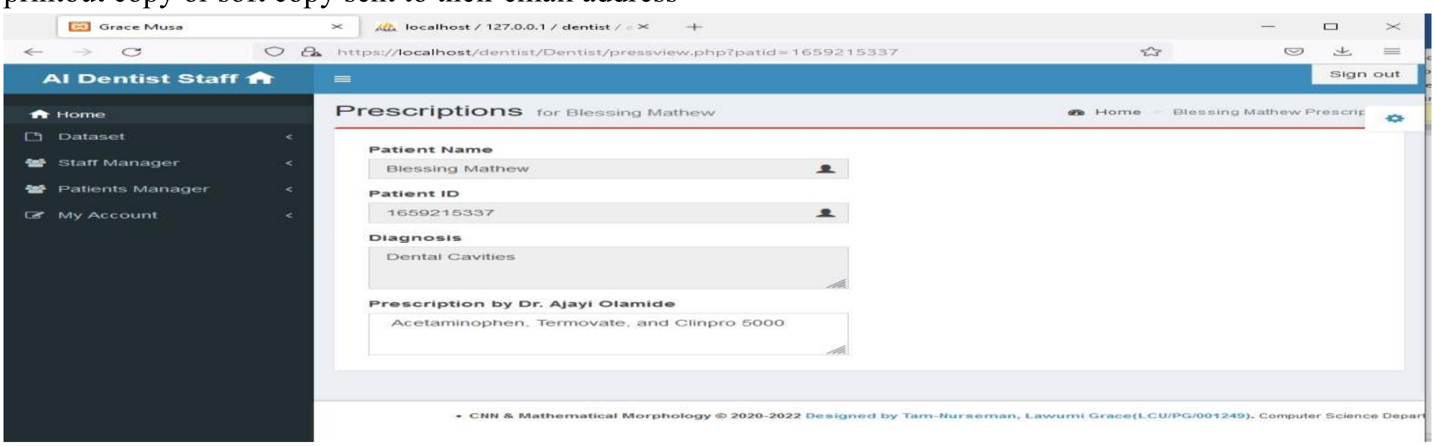

Figure 4.11 Prescription received in hospital

5 Conclusion and Future work

This system is designed and developed to fill the wide gap created by Medical Practitioners brain drain. It is a perfect substitute to the shortage of Medical Practitioners in countries suffering from such and highly recommended for deployment for use in hospitals.

Security of chats between Medical Practitioners and patients should be given attention in future work so as to keep patients' privacy in future work. Video chats should also be included so that Medical Practitioners can have a facial expression of patients. This will go a long way for Medical Practitioners to understand the situation they are dealing with in the patients.

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