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Dental Service System into Blockchain Environment

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***Abstract*—A platform that enables users to schedule appointments and connect with dentists is called the Dental Services System. The bulk of appointment slot orders are placed through more traditional channels, such phone calls, texts, or clinic entrances, prior to obtaining treatment. When staff members are unable to alter their status or take too long to provide information, schedule a time, or complete an assignment, this might be troublesome. Blockchain technology is a distributed ledger system that makes use of mathematics, algorithms, encryption, and financial factors. Blockchain's high-security design makes it safe, and the immutability of the data stored there helps to increase public confidence. Data storage databases that use blockchain technology and include security features that permit the exploitation of exposed user data are the main subject of the study. The blockchain may be integrated into a dental service system because of its excellence. The goal of this implementation of blockchain technology into a Dental Service System is to guarantee complete confidentiality while enabling authorized users to quickly create and get permanent records when paired with an application layer. The goal of this project is to create a tool that allows users to schedule appointments while utilizing a blockchain for safe data storage. In the end, this application will facilitate user appointment scheduling while limiting third parties' access to user data.**

***Keywords*—Dental Service System, Blockchain technology**

I. INTRODUCTION

A healthy life is the foundation of an active and happy lifestyle, and contemporary society has greatly profited from the enormous advances in medical research [1]. With each new technology advancement, there are more hints available for understanding the health issues impacting humanity. Some difficulties may be surmounted, such as the fact that some dentists still utilize an antiquated system that requires them to manually record and save all patient data in paper files. In order to schedule an appointment for treatment, the patient or dentist must also send or receive a private message. Therefore, educating patients, providing information about required treatments, and streamlining doctor-patient contact are the most effective ways to create beneficial dental applications. Blockchains are distributed ledger systems that keep track of transactional information in an encrypted digital ledger with linked blocks. Since data is spread throughout a network of replicated, synchronized databases, it provides unequalled protection. Updates are broadcast across the network, and users may only make changes to the blocks to which they have access. Each entry is time- and date-stamped. Satoshi Nakamoto defined the first blockchain in 2008, and it was used as the underlying technology for Bitcoin [2, 3]. It has been shown that blockchain technology enables the creation of trustless systems in which no one authority prevails, while also generating a traceable data provenance that can automatically detect any data alteration and giving an immutable ledger that is accessible to all stakeholders [4].

A blockchain-based dental service system is an application that will assist with the upkeep of dental records, the provision of high-quality patient care, and the monitoring of the offered

treatment. Additionally, this will contribute to an improvement in practice revenue, patient happiness, operational efficiency, and visitation frequency. The storing of user data by an enterprise is more securely done when blockchain technology is included into mobile applications. This strategy is superior than utilizing a normal database since it is difficult for unauthorized parties to access current user data.

Practitioners have used computerized patient health records more frequently recently. Effective patient and dentist communication, long-term management of oral hygiene, and regular dental visits are all requirements for traditional dental care. When management chooses manual or traditional data input, it becomes ineffective. Patients who need to make an appointment can walk in, use WhatsApp, or phone the dental clinic's customer care line. It is inconvenient for patients to schedule appointments when they have to search the whole platform to find a time slot that is open for a certain month. Then, information on the clinical examination, diagnosis, and course of therapy is frequently included in dental records for patients. Following treatment, the dental assistant finds it difficult to manually schedule visits and enter patient information.

It is also inefficient when a patient has to visit a different dentist office without a record to follow their treatment. For the provision of high-quality medical treatment, clinical staff must be able to gather and maintain accurate dental records. In order to give the greatest patient care and track the patient's subsequent treatments, it would make it easier to maintain dental records. The purpose of this project is to develop a dental services application that automates data security and stores patient records securely using blockchain technology.

II. LITERATURE REVIEW

Dentistry currently has a good chance of defining the standards and technologies it will use in the future and deciding how to apply them. According to the EHR standard, a totally electronic patient record is referred to as an "electronic health record." Automated Patient Record, Computerized Medical Record, and Computerized Patient Record are a few examples. The idea of an Electronic Health Record, however, is not dependent on any particular technology or modes of presentation, such as a flowchart or screen.

Electronic Medical Records (EMR) and Electronic Dental Records (EDR) are collections of patient information that are arranged to provide knowledge to the practitioner, other authorized users, and, in certain situations, the patient. Additionally, non-EHR data such as the standard values for laboratory tests may be uploaded by individuals. Another way to think about the EMR and EDR ideas is to mix EHR extracts with other crucial data. EHRs frequently make use of a range of technologies or standards since the healthcare system need a specific, long-lasting structure.

Moreover, it also has to be able to transfer data or information to network organizations, such as screenshots or pictures as well as connect with the interfaces required to produce, administer, and store electronic health records [5]. The dental record includes comprehensive descriptions of the patient's symptoms, medical examination, diagnosis, treatment, and care. It appears to be a legal requirement for the delivery of high-quality patient care that clinical practitioners be able to establish and maintain accurate dental records.

Interest in this novel idea has grown significantly with the creation of blockchain technology as a distributed ledger system in 2008. Experts have noticed a rise in interest in its uses outside of cryptocurrencies in recent years since it is well-known as the foundation of the Bitcoin cryptocurrency [2, 3, 6].

Blockchain technology is composed of a few fundamental concepts that have distinct qualities and are strongly tied to pressing healthcare challenges. Distributed ledgers, such as blockchains, are used to record and keep track of consecutive transactions. By using this structure, the data is protected from potential hacker attacks and tampering by blockchain users. According to [7], each chain record contains random data in addition to accurate information about its creation date and the cryptographic signature of the chain record that came before it.

Each block's data may be encrypted, making it accessible only to those who have the relevant cryptographic keys. Every digital object has a signature, also known as a hash, which is a string of letters and numbers formed cryptographically and has a specific length. Any digital item may be uniquely recognized by its signature, which is a string of characters and integers formed cryptographically and has a predetermined length.

This system development includes a number of current apps in an effort to lessen the burden at the dental clinic. In order to establish the safe approach in this system and make it trustworthy and realizable, there are a few observations on present apps that highlight their differences and the security provided in those applications. The advantages and drawbacks that are essential for the business to develop this project are included in this comparison. These techniques have been used to maintain delicate medical data and test result characteristics [8].

The systems were designed to do away with the problems with paper health records and offer a workable substitute to revolutionize the healthcare sector [8, 9]. Technology improvements that optimize the use of current technology to streamline workplace operations and increase efficiency have made some sectors, including healthcare, more convenient and productive.

Every dental office experiences the same issues, such as a lack of a system to maintain patient data and make appointments. Many of them maintain documents in files the conventional way and do not employ paperless work since everything must be recorded on paper. The effectiveness, security, structure, and flexibility of this electronic health record system were all lacking. As there were several copies of the patient's medical records at each facility where he received treatment, it also had to cope with redundant and duplicate data. A patient must spend a lot of time and go through several steps in order to check his medical data. In this situation, many methods are created in order to enhance the healthcare sector, improve security, and save costs. According to [10, 11], the system is a crucial part of the healthcare sector because of its broad functioning.

A. Oral Health System

For a population to be promoted, strengthened, and maintained in good health, healthcare measures are crucial. A professional health service can identify risk factors for future sickness and illness, educate people about probable illnesses so they can help with their treatment, and help them understand how controlling these factors may help them retain a high quality of life. Modern technologies may also be available in these institutes or clinics. Health services in underdeveloped nations are mostly concerned with providing emergency treatment or age-specific therapy. The ideal approach will allow communities to foster healthy settings [12]. The principles and recommendations of the top national and worldwide public health organizations would be followed by a perfect oral health care system.

It would also include the most recent findings in clinical and public health research. The amount of data that healthcare organizations currently possess is enormous, and in order to provide value-based patient care and to digitize the environment, automated data storage is required rather than file systems. Medical information includes electronic health reports with patient data, medical records, advice from physicians, analytical documents, therapeutic images, pharmaceutical data, details on health insurance, and content from media platforms and treatment journals [13]. It is typical to think of oral health systems as completely functional and structured. Massive databases are continuously created by the collection of health-related data, and real-time application access occurs at breakneck speed [14].

Dental professionals and experts have started utilizing smartphone applications, just like the majority of other medical specialties. Many dental care facilities now use smartphone technology in their operations and treatments. It's not surprising that there are currently a number of outstanding applications available for dentists and other dental care providers that provide remarkable value and use. Dental care providers will also use mobile applications to provide products to patients more quickly, more affordably, and with consistent supply availability.

B. Dental Care with Cloud Services

A new application that is dependable, competent, and useful across a wide geographical region was produced by combining the mobile device solution with cloud services. Because they allow for contact between patients and their referral sources, mobile technologies, cloud services, and cloud networks are essential. Medical information needs to be appropriately protected in addition to the security issues already stated in order to maintain the reliability of the healthcare system. Patients won't favour cloud-based apps if they are unsure about the security of their medical data, which may be useful for some patients. Instead, their data will be stored locally.

The great majority of cloud service providers carry out their own security assessments to safeguard their systems and data [15]. Health-related information is regarded as private as it is thought that personal information about persons is sensitive. It has been shown that speed is an important factor to take into account when evaluating the performance of cloud-based technologies in order for a system to work successfully with cloud-based apps [16].

C. Implementation of Blockchain

Blockchain technology has applications in the health sector since it offers a high level of security, prevents data loss, and can win over the public's confidence. A blockchain is a system of interconnected blocks that grows as more transactions are added. This platform provides a decentralized method for the dissemination and joint ownership of information. According to [17], it is allowed to store patient medical data on electronic devices since recent developments in technology have made patient data security a major focus in the healthcare sector. Blockchain-based systems are supported by decentralized peer-to-peer networks that store batches of hashed transactions to increase their security. Blockchain technology might work best in the healthcare sector [18]. According to [17], since technology advancements in the healthcare industry have elevated medical data security to a top concern, it is preferable to retain a patient's medical records on blockchain.

The blocks that make up the blockchain network are joined to the genesis block via broadcast or current blocks. The blocks are transmitted to the network after the gathering of event data. An ever-expanding list of blocks of ordered transactions that are routinely reconciled to guarantee data accuracy is maintained on the blockchain, a decentralized computer architecture. Only one block may only be added to the blockchain at a time in order to maintain consensus throughout the whole decentralized network, and each block is mathematically verified using cryptography to ensure that it matches the sequence established by the preceding block. [18]. After that, the blocks are joined together and become immovable. Events are parts of blocks and represent the time between the generation of a request and the broadcast of the block onto the blockchain [19].

D. Current System Analysis

Smartphones and applications have contributed to the growth of healthcare technology in recent years, altering research techniques, information availability, and professional-patient communication [20]. An extensive record of the patient's condition, medical assessment, recuperation, and administration is kept in a dental system. The study's findings showed that specialists were mostly focused on figuring out how practically to utilize, produce, and assess this cutting-edge dental equipment, especially that which was meant for clinical usage [21].

Law requires dentists to keep accurate medical records on file. Due to the public's perspective of healthcare-related legal concerns and the worrisome increase in malpractice lawsuits, every physician has to have a complete understanding of the challenges associated with dental records. Every planned appointment must include open communication between patients and dentists, especially for those who have just had an expensive dental prosthesis fitted. Legally, clinical practitioners

must be willing to establish and maintain correct dental records in order to provide high-quality medical treatment.

By providing adequate care on time, it assists patients in avoiding needless travel, increases the effectiveness of dental time, and reduces the failure rate of the dental prosthesis [22]. Today's use of dental appointment scheduling software is demonstrated by a number of systems, including Dental Calendar, Dentrix Ascend, and Dental Monitoring. Although each of the three strategies has pros and downsides, this one has less factors to take into account. The software package offers various chart types in addition to applications for scheduling, reserving, obtaining medical histories, performing physicals, and monitoring treatment plans.

The Dental Calendar app is a mobile application that allows patients and dentists to keep track of their appointments. It can be installed on their smartphones or tablets. The app automatically contacts patients one week prior to each appointment to check their availability and remind them of their appointment [22]. Through the app, patients can take a photo of their oral cavity and send it to the dentist via cloud services, and get confirmation whether they will come to the clinic on time. Dentists can reschedule the appointment for patients if they are unable to come to their appointment.

A cloud-based dental care service called Dentrix Ascend provides dental treatment. The software package includes programmes for scheduling, reserving, getting medical histories, performing physicals, and monitoring prescription regimens in addition to new chart designs. The user may add clinical notes and choose a pop-up message to display on the chart when it is opened. The appointment scheduling for benefit assessments is made easier by the software used for treatment planning.

A dental practice management solution is beneficial for a number of factors, such as the availability of support through a variety of channels, the capacity to streamline front-end procedures like check-in and check-out, and the capacity to generate personalized performance reports that give clear insight into a practice's success and potential improvement areas [23]. Each user has access to their payroll, subscriptions, and needs for payments, insurance, and collections. It will keep an eye on the various medical payments, including Medicaid and healthcare reimbursement, as well as the perks.

Users can control access for particular people or groups using a permission model. The platform is compatible with eClinicalWorks, Epic, and Allscripts, among other services. Dentrix Ascend provides three unique channels for customer service: internet messaging, text messaging, and the telephone. Pricing structures vary depending on the choices of clients. Benefits would accrue to a variety of facilities, including surgical facilities, small local community healthcare facilities, state correctional facilities, and larger institutions (government) facilities, that are large enough to offer a range of services and are aiming to reduce costs to facilitate maintenance.

Dental Monitoring is the official application for administering their practice, collecting patient information and appointments, and maintaining health records. The function includes schedule recording, customer database formation, patient reminders, and a financial statement. Additionally, this app lists the services offered in the dentist office so that the customer is informed of the cost and may bring enough cash to cover a specific amount of time. The most entertaining means of providing interactive oral care are these applications that help people create dental care routines. They also have a sizable market share. The dental assistant also provides a complete patient history, details on the patient's diagnosis, and details on any prior treatments. It also makes it simple to track the medical equipment and diagnostic data used during dental appointments. As a result, more people are regularly utilizing dental care applications to check on or otherwise enhance their oral health [24]. Table I provides a comparison of existing systems.

TABLE I. THE COMPARISONS BETWEEN THE EXISTING SYSTEM

	Dental Calendar	**Dentrix Ascend**	**Dental Monitoring**
Appointment Management	Yes	No	Yes
Confirmation/ Reminder	Yes	No	Yes
Patient Record Management	Can record and not secure	Can record and not secure	Can record and not secure
Star Rating System	No	No	No
Information	Yes	Yes	Yes

There are differences between the system that is in place and the system that will be built, such user-requested services and features. These features and functions illustrate the distinctions between the system's functions and can facilitate the development of a more user-friendly system.

E. Digital Technologies on Dental Practise

The use of digital dental technology and the manner in which it is used have an impact on oral health care. The timeliness and application of digital advances in dentistry are influenced by dental procedures, dental practitioners, and patients' experiences with oral treatments. This section examines the impact digital technologies have on dental practice. The dentist's ability to adapt to innovation and the impact of technology use is significantly influenced by his core beliefs about the dental profession.

Due to technology improvements, this basic part of professionalism will be reconstructed. Dental professionals, dental procedures, dentists' perspectives and actions, and the features of users' acceptance of new technology may all be impacted by technological aspects. These impacts must be considered and discussed when bringing innovations and applying new technology in dentistry. For the development of the Dental Service System, the following technologies are suggested: Flutter, Android Studio, Android Emulator, Solidity, and MetaMask.

Across creating natively built, visually pleasing apps from a single source of code for mobile, web, desktop, and embedded platforms, Google offers the Flutter SDK. Flutter offers a

framework, native performance, adaptable user interface, and rapid development. It may also be easily customized. The Dart programming language will be used in this Flutter for both desktop application development and application development. The open-source project Flutter is hosted on GitHub and is developed by Google and the community [25]. The Flutter framework is composed of the Dart programming language, the Flutter Engine, and the Foundation Library, which offer the application's fundamental classes and functions. Google provides visual widgets and guidelines for human/system interfaces and Material Design.

An Integrated Development Environment (IDE) called Android Studio assists in designing an application's user interface. It provides a real-time glimpse of the 16 designs that are created for each screen. A computer may simulate or run an Android application using this Android Studio's Android emulator. The creation of this system is made possible by Android Studio's wide range of tools and quick application execution.

It incorporates the integrated development environment's code editing and developer tools and is based on IntelliJ IDEA, a Java-integrated programming environment for software development. Android Studio is a tool used to create Android apps. It integrates with GitHub and includes code templates, an emulator, and a Gradle-based build system. Every Android Studio project should include at least one mode with source code and resource files. This category includes modules for Android apps, libraries, and the Google Application Engine.

Android Emulator emulates Android devices, which is useful when developing javascript-based applications because it permits the usage of several device kinds and Android API versions. In the emulator, nearly all the functionality of an Android smartphone is available. This programme includes hardware sensors, Google Play Store connections, a graphical user interface for managing incoming calls and texts, and more.

A smart contract is a contract that is legally binding and written in computer code between a buyer and a seller. The smart contract is available through flutter and implementable on the Ethereum testnet. Using the Remix IDE platform, a simple smart contract may be developed in solidity.

MetaMask is an app-accessible wallet that provides access to the Ethereum Node or blockchain. The wallet's private key stores information on a distributed ledger, and the private key grants ownership of the digital asset or tokens.

III. METHODOLOGY

System development methodology was a framework for constructing an information system that required planning, structure, and controls. Depending on the numerous technical, organizational, and project tasks, each of the available techniques must be adapted to this project in order to ensure its smooth progression.

For the app development stage of an iterative and quick software life cycle, the agile SDLC methodology uses progressive and iterative methodologies with an emphasis on adaptability and user loyalty. This strategy includes a comprehensive action plan for initiating, planning, sustaining, and enhancing system development and modification in order to enhance the specific system.

The project management employed a conceptual model to specify the steps that were involved in knowledge creation, beginning with the original design process of the framework and continuing throughout the framework's existence. Each step had its own conceptual model. The best development framework for this system was the agile methodology. The agile technique provides for process repeat in the case that an issue arises within a loop. This was necessary to make sure that every activity was carried out completely and perfectly. The plan might make it easier to implement the system such that each stage reduces the likelihood of errors occurring as the programme advances. Agile focuses on producing work in manageable chunks with the goal of improving responsiveness to changing needs.

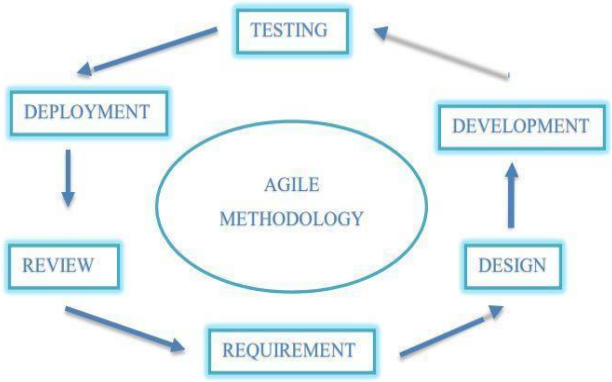

Fig. 1. Agile Methodology

A. *Phase 1: Requirement*

In this agile method for project formulation, the development process started with the requirements phase. Its goal was to collect data from stakeholders on the requirements necessary to construct the product in line with customer expectations and to develop a user story-based vision. The functionalities, performance standards, and other criteria that the product must meet in order for the client to accept it are established during the requirements phase.

These specifications act as the basis for the next steps of the expansion process and as criteria for client acceptance. The requirements-gathering document was built using the data acquired during the requirements phase as the basis.

In this project, it would be necessary to design and pinpoint the user-required features in order to make sure that the application being created is appropriate for the given circumstances. Data was gathered to determine if this Dental Service System was required, as well as whether users and practitioners would find it helpful and efficient. Additionally, this phase would result in a plan outlining the completed tasks and the deliverables with a suitable anticipated completion date, identifying potential products that might support the project's progress.

B. Phase 2: Design

After acquiring the necessary data to answer the stated problem, the system was designed based on the specified criteria once the requirements had been met. Both patients and dentists were intended users of this programme. The dental service system should be developed throughout this process based on the user's requirements and preferences, enabling the user to make optimal use of this feature. This Design phase would include the design of an intuitive, built-in user interface that demonstrates the system's functionality. Then, during this step, a UML diagram must be designed to visually represent a system in order to comprehend the system.

C. Phase 3: Development

This stage was essential to the creation of an application that was generally well-designed. The translation or implementation of the dental service system created during the design phase depended on this. The framework might then be evaluated as a programming language and computer code. In order for the developed system to perform correctly, it must be error-free and adhere to the stakeholder's specifications. The development phase would contain three components. These three elements might be used to build the framework for this dental service system, taking into account user stories and customer expectations in order to meet the system's priorities and objectives as well as the needs of the users. Database development, application programming, and system testing are the three components.

During this phase, Ethereum smart contracts written in the Solidity programming language will be constructed. Then, a MetaMask wallet will be built for a dentist in order to connect with an Ethereum smart contract and conduct a record transaction.

D. Phase 4: Testing

This step served to confirm that the programme was bug-free and compliant with all previously discussed elements. This executed a set of tests to confirm that the code was error-free and that the business objective of the solution was met. During iterations, testing expanded to encompass system integration, interoperability, and user acceptance testing in addition to functional testing. The purpose of testing the dental system was to validate the functionality of each component. If a fault was detected during the servicing of the system, it may be changed, fixed, and retested. Patients as well as dentists were testing out this device. There are two techniques to assess the system's user requirements:

i. Technical characteristics of the system are evaluated.
ii. Evaluation of features that are both functional and non-functional.

This might be stressed to make sure the tool is user-friendly and fits their needs. This stage of testing is very important since it establishes if the normative requirements, such as Dental System Integration Specifications and Device Design Specifications, actually suit the demands of the customers.

E. Phase 5: Deployment

The procedure needed to bring the dental service system into production was the deployment phase. The Dental Service System had been introduced and was ready for release at this point. In other words, this ensures that the commodity is immediately accessible to everyone who requires it. After completing a comprehensive analysis of all requirements, it is necessary to follow a number of implementation processes to guarantee that the code and technologies have been appropriately deployed.

F. Phase 6: Review

The final part of the agile technique was the Review phase. After the completion of the preceding phase, it would examine the progress made towards meeting the requirements. This phase was crucial to the development of a Dental Service System since it helps to uncover problems after implementation. During this phase, it was determined that the established requirements could be transformed into a comprehensive system based on the specified characteristics.

IV. REQUIREMENT ANALYSIS AND DESIGN

A. Requirement Analysis

Requirement analysis entails a technique for gathering information about the user's desired services and the system's operation prior to creating and deploying the system. To determine the overall design, the architectural requirement analysis was required. Determining an appropriate requirement analysis would lead to a good design definition, and system design should be sufficiently precise to guarantee that all project needs are testable, quantifiable, and able to be stated with the precision needed for system design [26]. For each component of this Dental Service System architecture, multiple diagrams were presented. Use case diagram and class diagram are examples of these diagrams. The significance of this picture is in its capacity to aid the user in comprehending the varied patterns of functionality.

i. Use Case Diagram

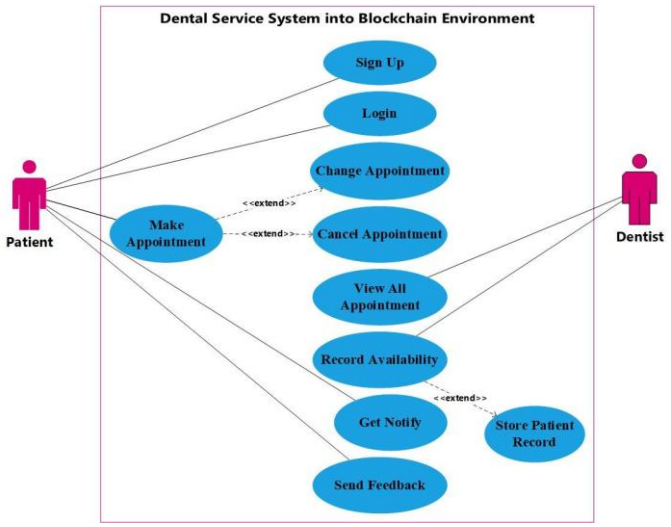

Fig. 2. Overall system features and actor involvement

ii. User Class and Characteristic

Table II provided specifics on each user's attributes inside the Dental Service System. The patient, dentist, and dental assistant were among those who used the Dental Service System.

TABLE II. USER CLASS AND CHARACTERISTICS

No	User Classes and Characteristics
1	Patient Descriptions Appointments can be made for patients using this method. The patient may easily choose a comfortable day and time for scheduling with this system since they can explore all of the available time slots. Patients may receive information from a clinic on costs and protocols for receiving medical care. The patient will get a message alerting them that the booking was successfully completed when the appointment is confirmed. Function Used 1. Book an appointment 2. Check available times and dates. 3. Notification 4. Give feedback
2	Dentist Descriptions All appointments made by Patients are visible to the dentist. Additionally, the dentist could be able to record and save the patient's therapy. Function Used 1. Check the Appointment list. 2. Record Availability

iii. Class Diagram

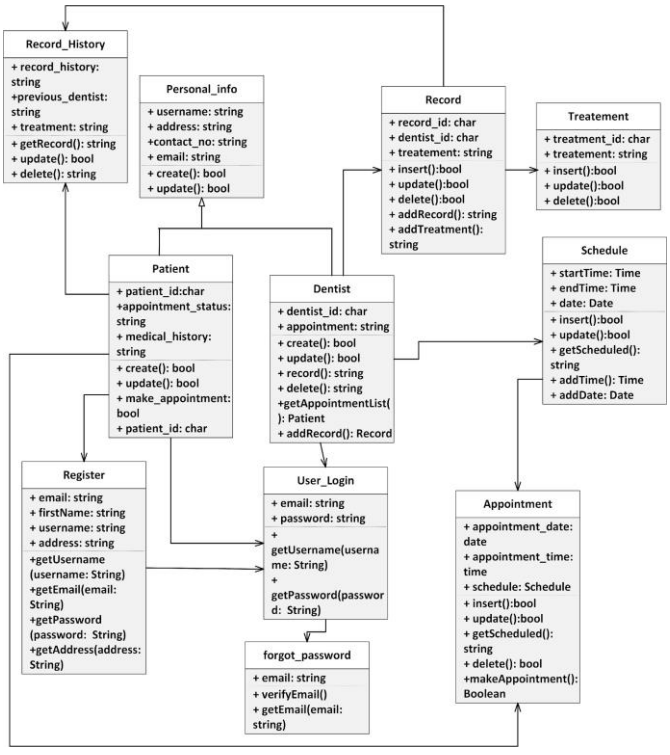

Fig. 3. Class Diagram

This system's class diagram is depicted in Fig. 3. This system's class diagram served as a structural model, describing the system's objects, attributes, and interactions between them as well as how different object-classes work together.

B. System Architecture and Design

The system's overall architecture will be covered in this section. As can be seen, there is a complete architecture image of the system, and it is possible to determine how this blockchain works and communicates with other applications like database, backend server and etc.

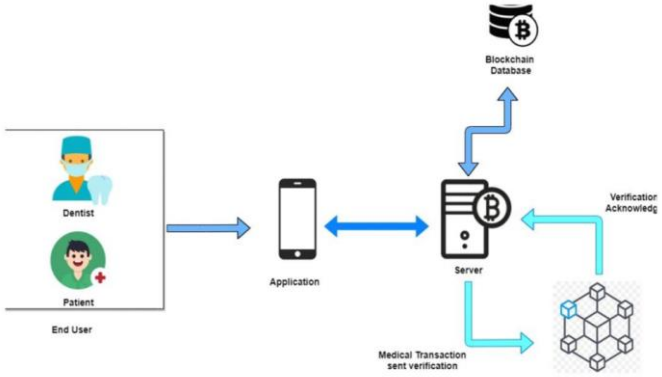

Fig. 4. Overall System Architecture

This system's general system architecture is depicted in Fig. 4. Two users, a dentist and a patient who served as the program's end user, had access to it. Sensitive data would be sent or entered into the system by the end user, and it would be safely stored in the database. In conclusion, the blockchain is a decentralized ledger that included a variety of services capable of validating and committing fresh blocks. The application backend server was in charge of maintaining proper records and protocols, which contributed to the data's validity and security. As a result, disagreements amongst parties prevented them from coming to a consensus. A hash is automatically included when a block is created, and any modifications to the block also modify the hash. Hashes therefore help in the detection of block tampering.

C. Ethereum Smart Contract Design

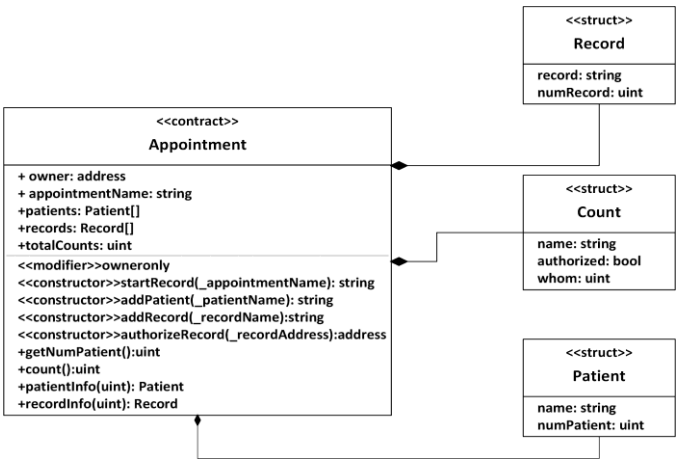

Fig. 5. Class diagram for the Solidity Smart Contract

Fig. 5 depicts the UML diagram for the Solidity Smart Contract, which consists of four components: the contract named Appointment, the struct Record, which is related to the contract because it contains an array of objects of type Record, the struct Count, which is related to the contract because it has a function with the type count, and the struct Patient, which is related to the contract because it contains an array of objects of type Patient.

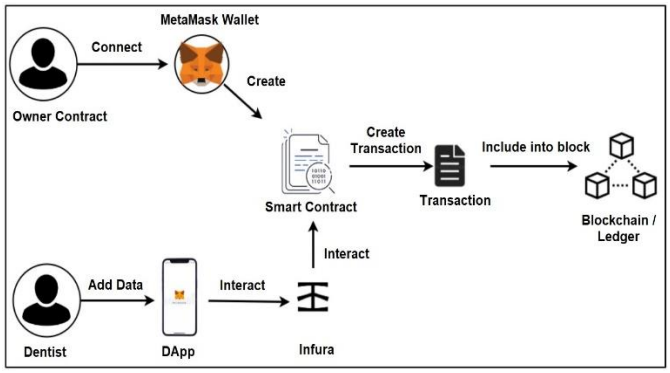

Fig. 6. Flow Diagram for Deploy Smart Contract and Dentist Add Data

The overall structure of how the contract owner deploys a smart contract and how the dentist adds data to the blockchain is depicted in Fig 6. Before the contract can be used, the transaction must be signed by the contract owner who will connect to the MetaMask wallet to inject the JavaScript library web3.js. Next, the contract owner will use Remix IDE to construct a smart contract in the browser, compile it, and finally deploy the contract. A contract that has been successfully deployed exposes transaction data and a transaction hash to the Remix IDE terminal. By passing the contract through Etherscan, the contract owner may verify that it has been uploaded to the blockchain. As the contract contains an array of objects of type Patient, the contract is related to the struct called Patient.

Additionally, dentists can add information to the blockchain, such as patient records. The diagram depicts the interaction and flow of data processing in a blockchain. In the beginning, the dentist will enter the data into the application, which has been linked to the dentist's MetaMask wallet. Infura will be utilized as the interaction between the Smart Contract and the Decentralized Applications (DApps). When the dentist delivers the data, the smart contract is updated and a new transaction is added to the blockchain.

Although this system are using Blockchain, the Blockchain network used is private network whereby, the data ledger is not share to all like a public network. Only invited user can see the ledger.

V. IMPLEMENTATION AND TESTING

A. User Interface

The interface design of the system to be constructed is determined by the outcomes of the system analysis and the variety to be constructed. The following are menu layouts created on the Dental Services System.

Fig. 7. Welcome Page

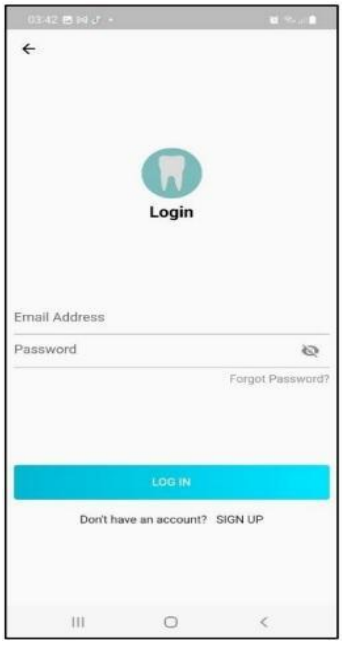

Fig. 8. Login Page

Fig. 7 displays the interface of the Welcome Page. Before dentists and patients may log into the system, they must pass through this phase. This page is the primary user interface. This interface will appear when the patient and dentist select the Denteeth icon.

Fig. 8 illustrates the login page. Both dentists and patients will utilize the login interface. After clicking the login button, the dentist and patient will be taken immediately to the login page. In this section, the dentist will use the provided email address, and the patient will log in using the email address that was entered during the prior registration process. The option to toggle password visibility is shown on the right side of the password text field.

Then, if the patient forgot the password for the registration portion, the lost password button would be located at the bottom of the password text field. Patients will then see a login button that will take them to their homepage.

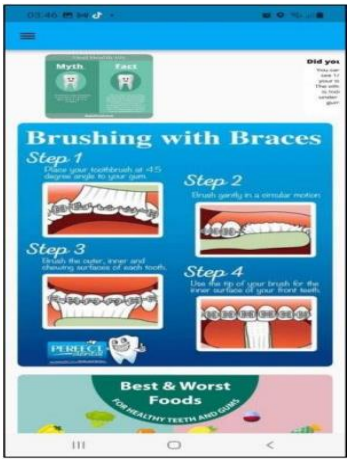

Fig. 9. Homepage

This application's patient and dentist homepage is depicted in Fig. 9. On this website, readers may find a variety of dental care-related information and advice. Users can scroll down to peruse the available information. On this page, the user can see the menu button icon on the left, and by clicking the icon, the menu bar will appear, displaying all the application's functions.

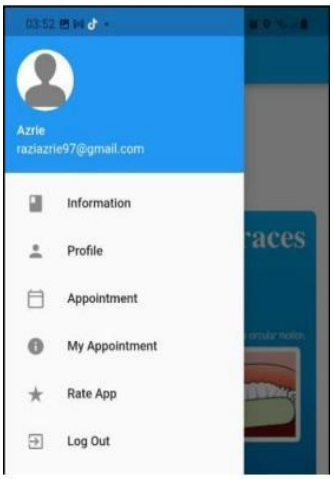

Fig. 10. Patient's Drawer Page

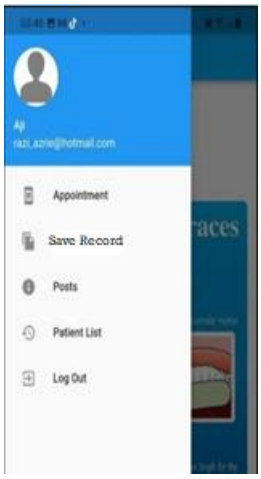

Fig. 11. Dentist's Drawer Page

This Fig. 10 depicts the Patient's Drawer Page. On the top of the page, the user's full name and previously registered email address will be shown. It will display once the current user has logged in. Then, the menu button then includes a button for information that the dentist may want to display, such as a promotion, a button for the user's profile that shows their information and allows them to edit it, a button for scheduling an appointment, a button for their scheduled appointment, a button for rating the app, and a button for logging out of the application.

The dentists' drawer page is shown in Fig. 11. The patient's entire name and email address are visible at the top as additional information to the dentist. The dentist will then have several buttons: Patient List, Appointment, Save Record, Post, and Logout. The Patient List button can be used to check the total number of patients, Appointment button can be used to check the patient's appointment, Save Record button can be used to enter the patient's record and send it to a blockchain service, Post button can be used to send announcements to the user, like a promotion, and Logout button can be used to log out of the application.

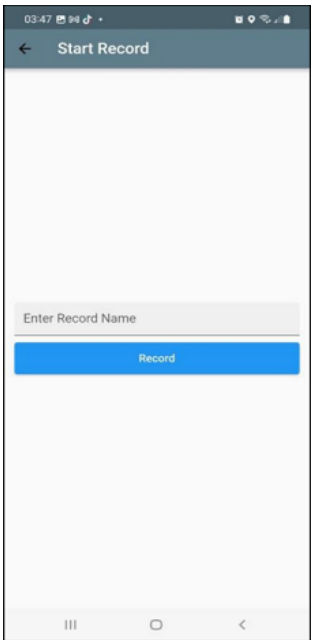

Fig. 12. Dentist's Save Record Page

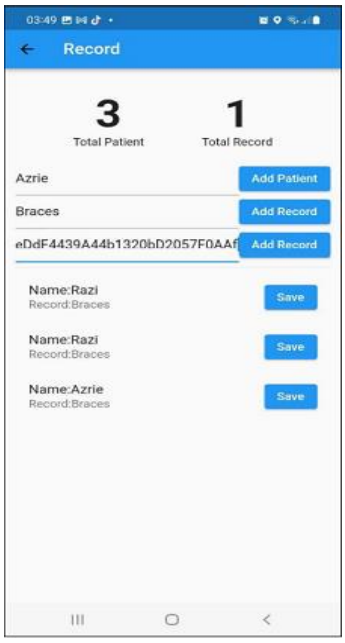

Fig. 13. Dentist's Add Record Page

Fig. 12 depicts a Save Record page. After the dentist has clicked the save record button, this page will load. As mentioned previously, dentists must input the record name, which functions as a folder name. The dentist must then click the Record button in order to go to the Add Record Page.

Fig. 13 depicts the Add Record Page. This page will be displayed once the dentist clicks the record button in Fig. 12. On the top, the dentist will see the overall number of patients and the total number of records kept. Next, on the text box, the dentist must enter the patient's name, the completed treatment, and the contract address obtained from the MetaMask account. The contract address is used for dentist to add the record in blockchain. To add the record to the block via a Goerli Test Network transaction, the dentist must next click the Add button on the right side of the text field. The block will be create based on the data that enter in the current text box. The data then will make a transaction through a solidity to check either the data is valid based on the contract address obtained from MetaMask. After the validation, it will create a block to save the record in blockchain. Therefore, the Save button trigger the total record that has been held before.

B. *Implementation of Blockchain*

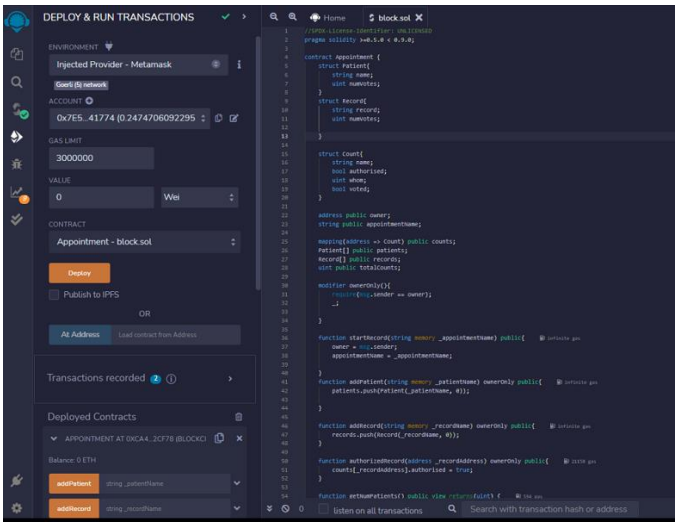

Fig. 14. Smart Contract in Remix IDE

The smart contract in Remix IDE is depicted in Fig. 14. Remix IDE provides an interface where solidity contracts may be authored and subsequently distributed on the blockchain. The first line of pragma solidity >=0.5.0 0.9.0 states that the source code is for a version of Solidity more than or equal to 0.5.0 but less than 0.9.0. A contract is a grouping of information about its purpose and location on the Ethereum Blockchain.

A public state variable of the type string is declared on the line string public. A function that allows access to the current value of the state variable from outside the contract is automatically generated when the term public is used. There is no way for another contract to access the variable without the public keyword. The constructor function is a specific function that is carried out once upon contract formation and cannot be used again. In this instance, it will retrieve the string value, put it in the memory data storage region, and set it to the currently-called value. On the right side of each method, the expected cost of gas is displayed.

The gas costs must be paid to the miner in order for the transaction to be verified once the block is formed. The contract will then be compiled prior to the deployment process, allowing the developer to recheck the programme code and repair any errors that may have occurred. The process of deploying onto the blockchain will then be complete. MetaMask will be used in this procedure to execute contract deployment transactions.

This MetaMask features an ether that functions as a token, thus if a contract is deployed, the transaction fee will be charged to the owner of the device doing the operation. As it will interact with MetaMask, the Injected Provider MetaMask will be selected to link the owner's MetaMask wallet account in order to complete the transaction. The deployment process can then be completed.

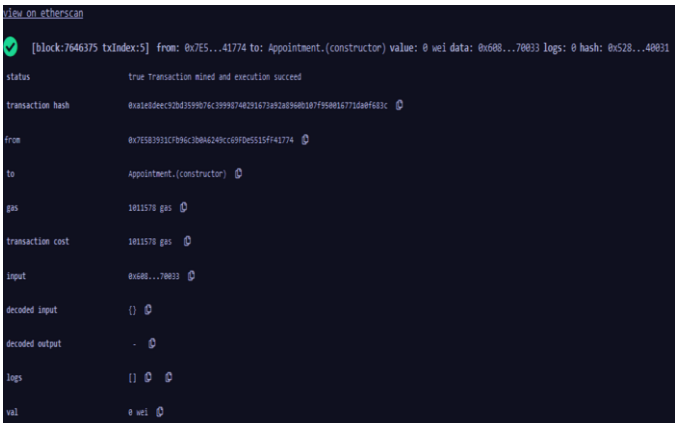

Fig. 15. Creation of contract in the blockchain

Once the contract deployment process has been started using Injected Provider with MetaMask, it should prompt the user to approve the transaction, pay for gas, and wait for the transaction to be mined. In the Remix IDE, the terminal will display information relevant to each transaction result. After the contract has been successfully deployed, it will generate a transaction hash, gas fees, transaction cost, and additional information as depicted in Fig. 15. A transaction hash may be used to determine whether or not the contract was successfully produced into the block.

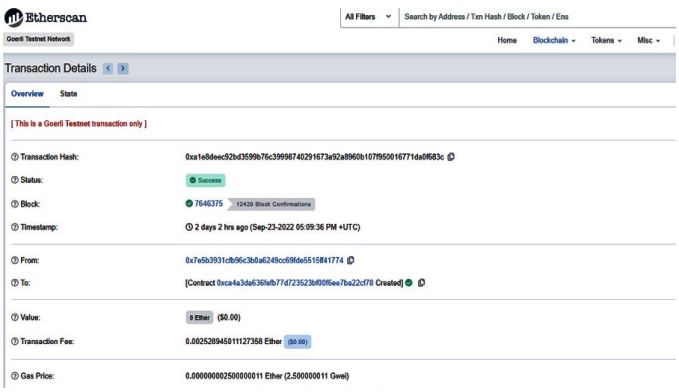

Fig. 16. Transaction Details of Deploy Smart Contract

The Transaction Details of the Deploy Smart Contract are depicted in Fig. 16. A developer starts a transaction through their MetaMask wallet when transferring an asset from their wallet address or contract address. A transaction hash, also known as Transaction ID, is assigned to the transaction once it has been created. This serves as a transaction reference number for all parties involved.

This Etherscan displays the status and details of every transaction. After the transaction has been made, it is broadcast to the network and added to the transaction pool. From this transaction pool, miners select transactions to include in a blockchain block. Once the transaction has been picked up and validated by a miner, it is considered successful and complete. The "Success" status displayed on the Etherscan Transaction

Details Page as shown in Fig. 16 indicates that the transaction has been confirmed.

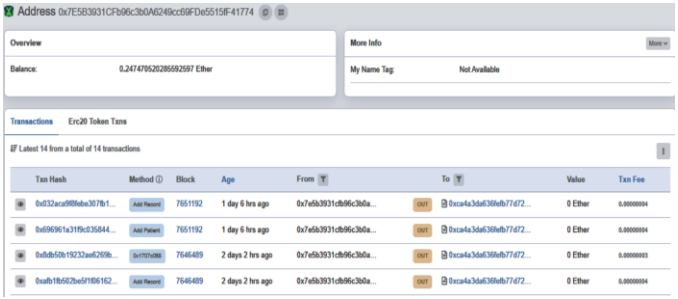

Fig. 17. Transaction Based on MetaMask Wallet Address

The Transaction based on the MetaMask Wallet Address in Etherscan is depicted in Fig. 17. When exploring a wallet address on Etherscan's "Transaction" page, a list of all ETH transactions (Txn Hash) connected with the MetaMask Wallet will be displayed. All transactions associated with this dentist's wallet address are displayed in the above diagram. All of the dentist's transactions will be assigned a transaction hash, a unique string of letters and numbers that identifies a transaction on the Ethereum blockchain.

The "Method" column then displays a description of the transaction's operation. For instance, dentists can add the patient to the smart contract, which will then display the block number for this transaction. The "From" column contains the wallet address of the dentist who initiated the transaction. The "To" column identifies the smart contract that was invoked to execute this operation. The value in Fig. 17 represents the amount of ether that was exchanged. Txn charge represents the cost paid to verify this entire transaction, indicating that the dentist added the patient's information to the smart contract.

C. User Testing

The user tested the system to ensure that it satisfied his or her needs for use. To test the system, A tester who has some information technology experience will be chosen to test the system. They received a user's manual with instructions on how to operate the equipment. Users were given a questionnaire on their experiences with the software, including whether or not it satisfied all of the requirements, after the system had been evaluated. The user has been divided into the patient and dentist groups.

TABLE III. PATIENT AND DENTIST TESTING

No	Test	Expected Output	Result
1	Sign up - Valid email - Valid username - Valid password - Input address - Input phone number - Send verify email	Sign-up has successfully done, and it will show the homepage	SUCCESS
2	Sign in - Enter a valid email - Enter a valid password	Sign in successfully and navigate to the homepage	SUCCESS
3	Forgot password - Enter a valid email - Link sends to valid email - Change password	Password change and update new	SUCCESS

TABLE IV. PATIENT TESTING

No	Test	Expected Output	Result
1	Booking appointment - Select date - Select a time slot - Book Appointment	Successfully booking and updating in the booking list	SUCCESS
2	Display profile image - Edit profile - Input data in the required textbox	Manage to update profile	SUCCESS
3	Information page - View Announcement	Can view the announcement	SUCCESS
4	Delete or cancel the booking	Booking successfully delete	SUCCESS

TABLE V. DENTIST TESTING

No	Test	Expected Output	Result
1	Record - Enter user details - Enter record detail	Successfully upload and do the transaction to the blockchain	SUCCESS
2	Display booking appointment	Successfully show booking appointment	SUCCESS
3	Add information or make an announcement	Successfully send to the user	SUCCESS
4	Display Patient list	View list of patients	SUCCESS

VI. CONCLUSIONS

This project's objective is to develop a dental service application that leverages blockchain technology to automate data protection and store patient records in a secure location. Additionally, blockchain usage is extremely restricted, and the records that will be supplied to patients must be meticulously vetted and maintained so that user data is not exposed to severe dangers. Moreover, this application provides merely a conventional booking application, but there are security weaknesses in this system as soon as it is proposed that are highly harmful if the application intends to continue without the data security component. Besides that, there are a growing number of initiatives to put more and more apps on blockchain, making scalability a significant hurdle to blockchain's widespread adoption in real-world business environment. Nevertheless, despite numerous tries, certain extremely essential objectives which is to improve the record system using Ethereum smart contract using Solidity programming language and deploy it to a blockchain are achieved. The smart contract has generated in the blockchain, which includes transactions for data uploads via MetaMask. The deployment of the smart contract utilizing solidity in conjunction with the MetaMask to generate transactions and Infura as the endpoint was successful. Experiments involving the transmission of a record via an application through MetaMask and the solidity's maintenance of the record within the newly-created block provide more support.

It is vital to develop and modify functionality in this system to make it more user-friendly. Numerous proposals for future enhancements to this system could be developed in light of

recent developments and user requirements. Some suggestions for increasing the performance of this system include incorporating as many user-friendly features as feasible. To prevent consumers from carrying huge quantities of cash or going cashless, implement an online payment capability.

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REFERENCES

[1] M. Foley, R. Lalloo, A. Spencer, and L. Do. (2022). What are "health" and "oral health"? *Journal of Global Oral Health*, 1-9. Doi: 10.25259/JGOH_23_2022.

[2] S. Nakamoto. (2009). Bitcoin: A peer-to-peer electronic cash system. Cryptography Mailing list at https://metzdowd.com.

[3] K. Wookyun. (2018). Blockchain revolution in healthcare: The era of patient-centered dental information system. *International Journal of Oral Biology, 43*(1), 1-3.

[4] Q. Feng, D. He, S. Zeadally, M. K. Khan, and N. Kumar. (2019). A survey on privacy protection in blockchain system. *Journal of Network and Computer Applications, 126*, 45-58. Doi: https://doi.org/10.1016/j.jnca.2018.10.020.

[5] R. Wutthikarn and Y. G. Hui. 92018). Prototype of blockchain in dental care service application based on hyperledger composer in hyperledger fabric framework. *2018 22nd International Computer Science and Engineering Conference (ICSEC)*, 21-24 Nov. 2018, pp. 1-4. Doi: 10.1109/ICSEC.2018.8712639.

[6] S. Banupriya and K. Kottilingam. (2021). an analysis of privacy issues and solutions in public blockchain (bitcoin). *2021 2nd International Conference for Emerging Technology (INCET)*, 21-23 May 2021, pp. 1-7. Doi: 10.1109/INCET51464.2021.9456350.

[7] A. E. Mark. (2017). Hitching healthcare to the chain: an introduction to blockchain technology in the healthcare sector. *Technology Innovation Management Review, 7*(10). [Online]. http://timreview.ca/article/1111.

[8] G. Jetley and H. Zhang. (2019). Electronic health records in IS research: Quality issues, essential thresholds and remedial actions. *Decision Support Systems, 126*, 113137. Doi: https://doi.org/10.1016/j.dss.2019.113137.

[9] T. Sarwar *et al.* (2022). The secondary use of electronic health records for data mining: data characteristics and challenges. *ACM Computing Surveys, 55*. Doi: 10.1145/3490234.

[10] Q. Gan and Q. Cao. (2014). Adoption of electronic health record system: multiple theoretical perspectives. *2014 47th Hawaii International Conference on System Sciences*, 6-9 Jan. 2014. 2716-2724. Doi: 10.1109/HICSS.2014.352.

[11] A. al-Aiad, R. Duwairi, and M. Fraihat. (2018). Survey: Deep learning concepts and techniques for electronic health record. *2018 IEEE/ACS 15th International Conference on Computer Systems and Applications (AICCSA)*, 28 Oct.-1 Nov. 2018. pp. 1-5. Doi: 10.1109/AICCSA.2018.8612827.

[12] S. L. Tomar and L. K. Cohen. (2010). Attributes of an ideal oral health care system. *Journal of Public Health Dentistry*. https://doi.org/10.1111/j.1752-7325.2010.00172.x.

[13] M. I. Mohd Salleh, R. Abdullah, and N. Zakaria. (2021). Evaluating the effects of electronic health records system adoption on the performance of Malaysian health care providers. *BMC Medical Informatics and Decision Making, 21*. Doi: 10.1186/s12911-021-01447-4.

[14] C. B. Sivaparthipan, N. K. Karthikeyan, and S. Karthik. (2018). Designing statistical assessment healthcare information system for diabetics analysis using big data. *Multimedia Tools and Applications, 79*, 8431-8444.

[15] J. Surbiryala, C. Li, and C. Rong. (2017). *A framework for improving security in cloud computing*. 260-264.

[16] Y. Kravchenko, O. Leshchenko, N. Dakhno, O. Trush, and O. Makhovych. (2019). Evaluating the Effectiveness of Cloud Services. *2019 IEEE International Conference on Advanced Trends in Information Theory (ATIT)*. 120-124.

[17] A. Shahnaz, U. Qamar, and D. Khalid. (2019). Using Blockchain for electronic health records. *IEEE Access*, 1-1. Doi: 10.1109/ACCESS.2019.2946373.

[18] Y. Chen, S. Ding, Z. Xu, H. Zheng, and S. Yang. (2018). Blockchain-based medical records secure storage and medical service framework. *Journal of Medical Systems, 43*(1), 5. Doi: 10.1007/s10916-018-1121-4.

[19] Q. Xia, E. Sifah, A. Smahi, S. Amofa, and X. Zhang. (2017). BBDS: Blockchain-based data sharing for electronic medical records in cloud environments. *Information, 8*, 44. Doi: 10.3390/info8020044.

[20] R. Collado-Borrell *et al.* (2020). Effect of a mobile app for the pharmacotherapeutic follow-up of patients with cancer on their health outcomes: Quasi-experimental study. *JMIR Mhealth Uhealth, 8*(10), e20480. Doi: 10.2196/20480.

[21] I. M. Faria, M. C. Sancas, A. V. B. Pintor, and L. S. G. Primo. (2018). Dental apps for smartphones: New way of providing services and education. *Creative Education, 09*(05), 687-696. Doi: 10.4236/ce.2018.95050.

[22] C.-Y. Lin *et al.* (2014). Improvements in dental care using a new mobile app with cloud services. *Journal of the Formosan Medical Association, 113*(10), 742-749. Doi: https://doi.org/10.1016/j.jfma.2014.02.009.

[23] B. L. Finkbeiner and C. A. Finkbeiner. (2019). *Practice Management for the Dental Team E-Book*. Elsevier Health Sciences.

[24] S. Datta, D. Sybil, and V. Jain. (2020). Teledentistry applications: Potential dental care facilitator amidst a pandemic. *Journal of Clinical and Diagnostic Research, 14*, ZE06-ZE10. Doi: 10.7860/JCDR/2020/46496.14300.

[25] R. Mamoun, M. Nasor, and S. H. Abulikailik. (2021). Design and development of mobile healthcare application prototype using flutter. *2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)*, pp. 1-6.

[26] P. Gunawardhana. (2019), Process of requirement analysis link to software development. *Journal of Software Engineering and Applications, 12*, 406-422. Doi: 10.4236/jsea.2019.1210025.