# การวิเคราะห์และออกแบบระบบสารสนเทศในการทำงานทางทันตแพทย์

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บทคัดย่อ

ในประเทศไทยการใช้ระบบข้อมูลทันตกรรมทางทันตกรรมในการรักษาประวัติทางทันตกรรมยังคงมีข้อจำกัดอยู่ ภายใต้กฎระเบียบของกระทรวงสาธารณสุขประเทศไทย ที่กำหนดให้ผู้ประกอบวิชาชีพต้องรักษาเอกสารทางการแพทย์และทันตกรรมที่ถูกต้องและครบถ้วน เพื่อวัตถุประสงค์ในการออกใบอนุญาต รวมถึงการบันทึกข้อมูลเหล่านี้ต้องได้รับการดูแลเป็นเวลาอย่างน้อยห้าปีนับจากวันที่จัดทำข้อมูล ระบบบันทึกข้อมูลทางทันตกรรมที่มีประสิทธิภาพสามารถอำนวยความสะดวกภายใต้ข้อกำหนดนี้ได้โดยการตรวจสอบเอกสารและการประมวลผลข้อมูลทั้งหมด งานวิจัยนี้มีจุดมุ่งหมายเพื่อปรับปรุงกระบวนการจัดเก็บข้อมูล โดยใช้ระบบสารสนเทศเพื่อแก้ไขปัญหาเฉพาะด้านข้อมูลทันตกรรม ซึ่งดำเนินการในสามขั้นตอน การศึกษานี้ได้พัฒนาขึ้นตามวัฏจักรการพัฒนาระบบงาน (SDLC) มีวัตถุประสงค์เพื่อพัฒนาและออกแบบโปรแกรมประยุกต์ทางคลินิกเพื่ออำนวยความสะดวกในการจัดการข้อมูล รวมถึงการปฏิบัติการทางทันตกรรม การศึกษานี้เกี่ยวข้องกับการประยุกต์ใช้เทคโนโลยีสารสนเทศเพื่อการรวบรวมข้อมูลทางคลินิกทันตกรรมในด้านที่เกี่ยวกับประวัติผู้ป่วย การรักษาทางทันตกรรม การติดตามผลและการรายงาน เพื่อที่จะช่วยในการปฏิบัติทางคลินิก ระบบข้อมูลทันตกรรมต้นแบบนี้เป็นรูปแบบเทคโนโลยีสารสนเทศสำหรับการทดลองทางคลินิกที่กว้างขึ้นและการดำเนินการเพื่อสนับสนุนโมเดลทางคลินิกต่างๆ ซึ่งผลการทดลองใช้งานพบว่าผู้ใช้รายงานว่ามีความพึงพอใจในระบบสารสนเทศทันตกรรม โดยมีคะแนนเฉลี่ย 4.44 (พอใจมาก) (คะแนนเฉลี่ยความพึงพอใจ 4.70) ส่วนด้านที่ได้คะแนนน้อยที่สุดคือความยืดหยุ่นของระบบในการตอบสนองความต้องการเอกสารของผู้ใช้ (คะแนนเฉลี่ย 4.20) ระบบสามารถพัฒนาการเชื่อมต่อและการเชื่อมโยงข้อมูลเพิ่มเติมกับระบบข้อมูลรังสีวิทยา (PACS) ฐานข้อมูลทางพยาธิวิทยาหรือฐานข้อมูลเวชระเบียนเพื่อนำเข้าและแบ่งปันข้อมูลการใช้งานได้ง่ายขึ้น

**คำสำคัญ**: สารสนเทศทางทันตกรรม/ วัฏจักรการพัฒนาระบบงาน/ สารสนเทศทางคลินิก

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# Analysis and Design Information System in Dentistry

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## Abstract

In Thailand the use of dental electronic data systems to maintain dental records is still limited. The Ministry of Public Health in Thailand regulation requires the practitioners to maintain accurate and complete documentation of all medical and dental treatment. For the purpose of licensing these records must be maintained for at least five years from the date of preparation. A robust dental record system can facilitate this requirement by ensuring that complete documentation and data processing. The research aims to improve these processes by applying information systems to address specific issues for dental information and was performed in two phases. This study was developed in accordance with the System Development Life Cycle - SDLC, using the following three steps. The goal of this study was to develop and design a clinical application to facilitate data management in dental clinical practice. The study involved the application of information technology to the process of gathering clinical dental information pertaining to patient history, dental treatment, follow-up and reporting in order to facilitate clinical practice. This prototype dental information system is to serve as an information technology model for wider clinical trials and implementation to support various clinical models. The users reported a general level of satisfaction with the new dental information system with average score 4.44 (very satisfied). The specific aspect that was more highly appraised was the ability to create clinical and administrative reports (average satisfaction score 4.70) whereas the area least scored was system flexibility in addressing user documentation needs (average score 4.20). The system can be developed additional connectivity and data linkage to radiology data systems (PACS), pathology databases or medical records databases for easier information importation and sharing.

**Keyword:** Dentistry information system/ System Development Life Cycle –SDLC/ Clinical information

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## Introduction

Information and computer technology has gained widespread use in dental medical practice as more dental practitioners are using computer systems to record and store data[1]. Dental software applications have been developed in various countries to facilitate clinical workflow[2] and as learning tool for dental training. Many of the software applications have been integrated with dental information systems[3] to allow access to patient medical history data and integration with dental digital media[4]. These systems allow dentists to more easily collect patient dental history, which can then be used for a variety of clinical procedure and in non-clinical practice such as the identification of individuals in forensic dentistry[5, 6]. A personal dental history can be maintained by recording an individual's dental treatment history[7]. Dental information systems also facilitate record keeping as dental records can be more directing and accurately accessed from pre-existing databases. Clinical practice is further enhanced as digital image processing can be performed with greater efficiency and accuracy than manually processed films[8].

In Thailand the use of dental electronic data systems to maintain dental records is still limited[9]. The Ministry of Public Health in Thailand regulation requires that practitioners maintain accurate and complete documentation of all medical and dental treatment. For the purpose of licensing these records must be maintained for at least five years from the date of preparation[10]. A robust dental record system can facilitate this requirement by ensuring that complete documentation and data processing.

Several factors must be considered in developing a clinically useful dental information system. Foremost is consideration for the data structure which should be standardized across different platforms. The American Dental Association (ADA) has promoted an initiative whose objective is to standardize the data structures used in dental patient records. The initiative is to extend or modify the existing electronic health record architecture to include the structure, formats, and relationships of novel information elements and protocols to facilitate information exchange among varying stakeholders[11]. Along these lines, preparing a database for dental workflow necessitates the development of a robust data management software system to manage the dental histories and other data collected as a routine part of dental care. The database navigation system should increase the efficiency of database preparation and data

management, resulting in greater information accuracy and utility in dental clinical practice.

Information collected from patients in dental practice describes various character-istics and can be in a variety of data formats including x-ray films and raw data files. Current collecting methods often result in incomplete records which lead to difficulty in correlating data from different treatments [12]. This also hinders data migration between practitioners, should patients need to change dentists during their treatment. Reimburse-ment processes are also hampered due to missing or duplicated information resulting in increasing expenditure of public funds[13]. Incomplete or inaccurate records com-promise the value of information analysis for research and as a guide to health-care and economic policy makers[14] as well as manu-facturers of dental products[15]. Surveillance and prevention of dental disease is also jeopardized which leads to higher public health spending.

## Background of Information & Data

Information is the result of processing raw data to reveal its meaning. Data processing can be as simple as organizing data to reveal patterns or as complex as making forecasts or drawing inferences using statistical modeling[16]. Data management is a discipline that focuses on the proper generation, storage and retrieval of data. Management information systems combine computer science theory and research related to applications for the creation and utilization within a specified system[17]. Management information systems exist on multiple levels. The operation level of information is used to support and control operational processes. To be useful, this information has to be presented in a timely and accurate manner. Knowledge level systems organize and support the data to be used by systems agents and officers. This level functions to collect new knowledge for organizing and controlling the movement of document within the system. Managerial information includes tactical planning and policy implementation data, while strategic information is used to determine the long-term planning and policy goals for senior executives. All levels of information must be available in appropriate formats to be useful[17]. The process of the system analysis and design will focus on identifying (what?) and solving (how?) problems. The design process will consider the modes of data input, the report design (output design), the monitor interface, system flowchart, the database design and prototype design[18]. The analysts then create the system by programming

instruction based on the design specifications. Software tools used in the development process should be appropriate to the technologies in use. High level programming languages have been developed in the format of 4GLs (Fourth generation language), which along with CASE tools (Computer Aided Software Engineering) facilitatea wide range of functionality. Finally the system is tested prior to deployment to verify system operations, efficacy and accuracy. This final step ensures that the system matches end-user requirements. The maintenance phase is a process of improvement after the system has been installed and implemented[19].

**Techniques and tools on information system development**

This model of the information systems development cycle is similar to the traditional system development (Traditional SDLC) methodology in many ways. Another similar approach to system development, created from SDLC is a called the prototype model. Prototyping is more user-centric in that the intended user trials prototypes of the application during the development stages and provides input that guides the design process. Components of the prototype system can be separated into, identifying the preliminary requirements of the user, creating the initial prototype, the

prototype implementation, and the process of improving the prototype. Alternative development strategies include End-user Development in which the end-user is primarily responsible for the development process, while Outsourcing uses an external organization and is appropriate when internal personnel lack the relevant skills. Using application software packages is another way of developing systems such as payroll, accounts receivable systems or inventory control systems. If the software is instant to response organizational demands to system would not need to develop their own. These software packages have been designed and tested thereby reducing cost and setup time, while allowing for easier customization and maintenance of the system. This type of programming uses data structured into objects which include data fields and their functions. The class of an object defines related data elements with their related functions or behaviors that can be reused during the development process without needing to alter or redefine their content or meaning of the class. The development of this model allowed for faster and better quality system development that was possible with the traditional systems development method. The application software tool assists with system

development by defining client demands, using a systematic design process, and altering the system appropriately[20]. A database is a set of related data that are stored together to facilitate more rapid and efficient use[16]. The data elements can thus be assumed to be meaningfully related towards a shared objective that can be applied to a work system to update and verify the accuracy of the system database.

**Material and Method**

We used Microsoft Visual Basic 2008 Express Edition and phpMyAdmin Database Management in the development of the dental information application. The computer device specifications and software used in the development process are detailed in Table 1. The development period was from May 1, 2015 to March 31, 2016

**Table 1.** Development hardware and software specifications

| Specification | Description |
|---|---|
| 1. Hardware | |
| 1.1 CPU Intel Core 2 | Duo 2.26 GHz |
| 1.2 RAM | 3 GB |
| 1.3 Hard Disk | 320 GB |
| 1.4 CD ROM | Drive 32 X of speed |
| 1.5 monitor | 16.4 inch |
| 2. Software | |
| 2.1 Operation system | Windows 10 |
| 2.2 Microsoft Visual Basic 2008 | Express Edition |
| 2.3 phpMyAdmin | Version 5.1.18 |

**Subjects**

This research field study was conducted through semi-structured interviews with a convenience sample of 9 general dentists and 7 dental assistants on routine work of the Dental Department of Ananda Mahidol Hospital in Lopburi province area during clinical hours.

**Study design**

The goal of this study was to develop and design a clinical application to facilitate data management in dental clinical practice. The study involved the application of information technology to the process of gathering clinical dental information pertaining to patient history, dental treatment, follow-up and reporting in order to facilitate clinical practice. This prototype dental information system is to serve as an information technology model for wider clinical trials and implementation to support various clinical models. The research aims to improve these processes by applying information systems to address specific issues for dental information and was performed in two phases. The previous study[21] on analysis of requirements in dental health informatics for clinical application was the first phase of the study. The second phase of the study involved using this information to design a dental information system application. This study was developed in accordance with the System Development Life Cycle - SDLC, using the following three steps.

**Step 1 System analysis**

In this step the developer performed a systems and procedural analysis of the existing system to determine scope of the development.

This step provided the development team with important information about the user requirements in the following areas of the structure and form of the dental workflow within the clinic, the current diagnostic and treatment procedures, the current system specifications to allow the developer to address specific system and procedural deficiencies, and the specific requirements of the system users, in this case the nine dentists and the seven dental assistants. In fig.1 we see a typical setup of dental information for recording of a variety of data formats including x-ray films and raw data files.
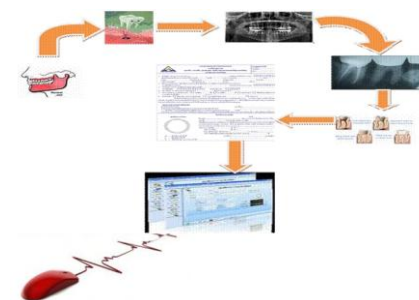


**Figure 1**. The usability dental information

**Step 2 System design and development**

The results from Step 1, which consists of sub-systems, were analyzed and used to in the design of the new information system which more accurately met the needs of the target users. The design process involved the following steps on workflow diagram, context diagram, and Dataflow diagram.

For database, the system design was follow by Entity-relationship diagram or ER-model, Data dictionary, and Database design using a relational database. In the part of recording data and report of the patient we were analyzed about of input-out design, selecting the programming language, and management for database design (Figure 2).
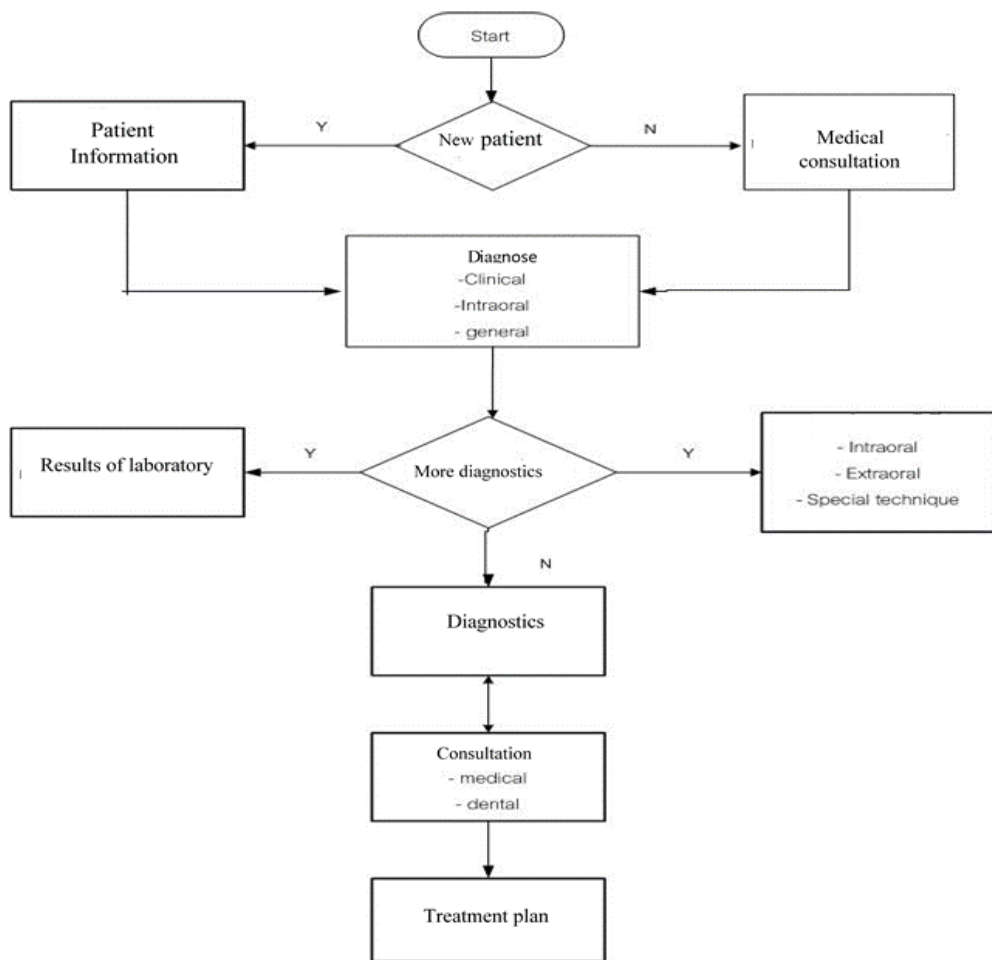


**Figure 2.** Chart of workflow for dental data

From figure 2, New Patient Registration: Patients presenting for routine oral care or acute dental care, such as acute dental pain or Oral facial swelling are questioned about their medical and dental histories. Their dental and medical treatment history is elicited and recorded onto an outpatient card. Examination: After obtaining the history, a dentist performs a detailed dental exam to include the teeth, gums and other surrounding soft tissues, focusing in the area of chief complaint. The exam involves instrument assisted visual inspection, percussion and palpation of the entire oral cavity. The extra-oral examination involves inspection of the face, cranium, neck and a general medical exam. The dentist also elicits any past medical history, particularly as relates to dental health. Any serious medical conditions are referred for medical attention prior to proceeding with dental care. Additional diagnosis: Additional diagnostic tests are appropriately applied, including oral radiography and laboratory testing. Diagnosis: The dentist will first establish a preliminary diagnosis from the history and physical examination. This diagnosis is the most likely from a differential diagnosis list and

is further clarified with confirmatory testing. The definitive diagnosis, thus obtained is recorded on the patients' outpatient card. Treatment planning: Once a diagnosis is confirmed the team formulates an appropriate treatment plan which necessarily includes dental preventive measures. Acute conditions will warrant urgent or emergent care with appropriate follow-up care.

Summary of procedural deficiencies, an evaluation of the survey responses and observation of the clinical processes highlighted the following system deficiencies. Lack of consistency of information: The current system was based on data collections specific to the requirements of individual units such that patient records were incomplete. This required the dental staff enquire about and update patient medical histories which are necessary for diagnosis and treatment. Deficiency their cross-linking of Information: The current data collection system lacked the capability to cross-reference information across databases which would facilitate medical and dental history taking by allowing data such as prior dental treatments, dental imaging and laboratory test, to be imported into the patient's record. The

present storage system lacks an appropriate database that would make this possible. Instead the dental clinic continues to use paper based data storage which can result in patient data loss. Information medical history and deficiency of consistency: Patients are sometimes required to visit other dental clinics to continue their therapy, for instance in the case where implant radiographs are required to be obtained in a remote clinic.  The records from different clinics may have incompatible formats such that clinicians cannot rely on dental information to identify patients or verify authenticity.

For the redundancies for collecting patient information: Patient information collected during different clinical visits or by different clinicians, even if seen for continuation of therapy, may be mismatched and stored as separate unrelated records. This could result in incomplete or redundant patient records.

Operational: Difficulty in reading dental staff writing can result in delays or errors in medical care. The Management: The deficiencies in the collected data may hinder or delay management information services such as information analysis for planning and productivity.

## System Analysis

We analyzed the three categories of concerns and used the results to guide design of the new system in three steps, logical design, user interface design, and database design.

## Logical design:

The logical design of a system involves planning and mapping data flow and can be represented as context diagrams. For our system the data flow was mapped through the patient enrollment process, the treatment phase and the reporting phase (Figure 3).
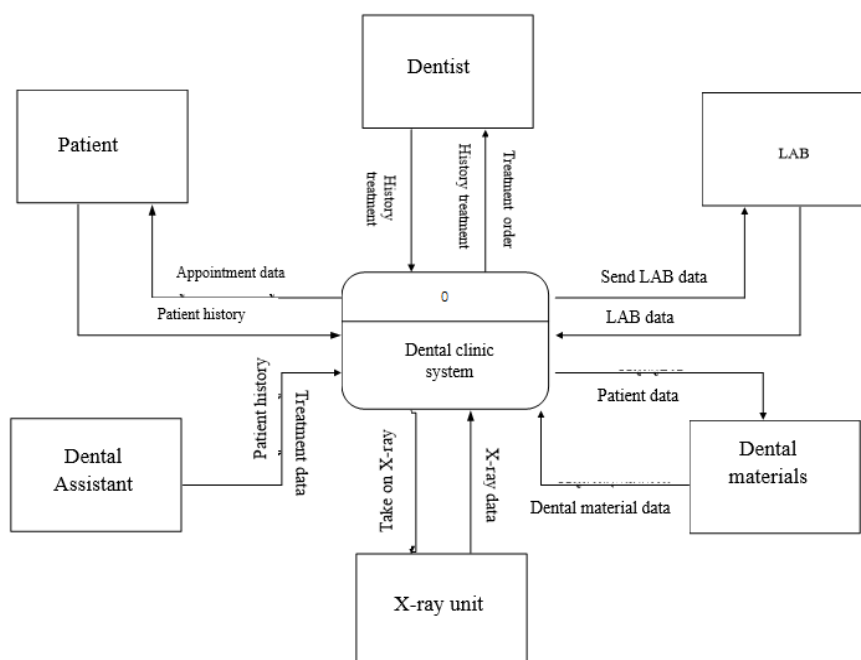
**Figure 3** Context diagram of dental information system

**Design and Development Program**

The dental information system is developed around the dental clinical record. Data recorded in the clinical record includes patient's demographic data, dental services, dental information, provider information, appointment schedules, payment information, and a cost analysis. Figure 4 shows a model of the dental information flow during the treatment course

.
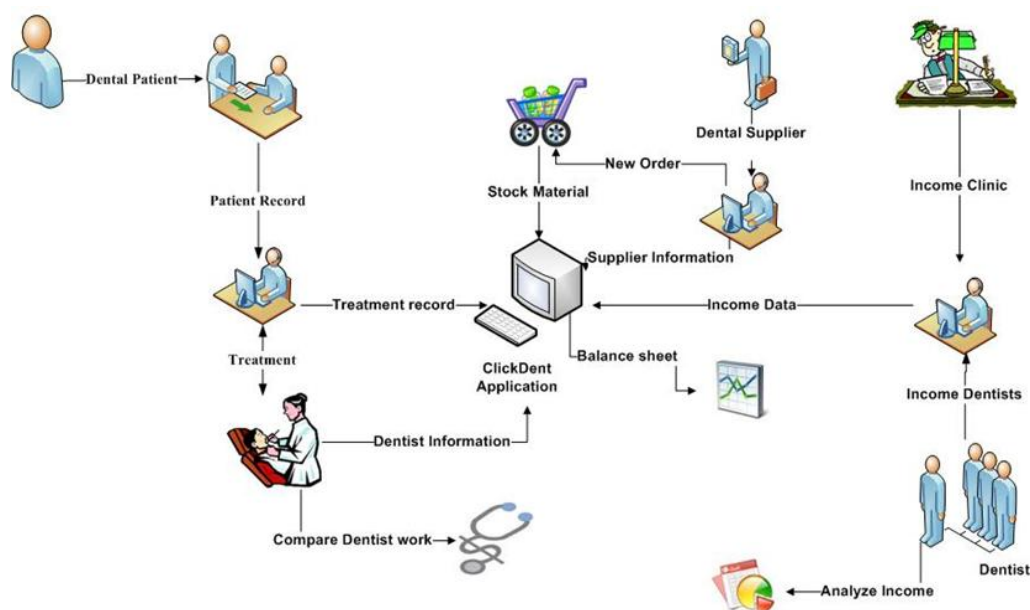
**Figure 4** Process of the dental application

The system ensures that patient data is secured and access to individual records is password protected.  When a system user enters a specific user identification and password combination the system verifies the individual's identification and security access level

The user-interface screen designed for this application used a drop-down menu interaction which was divided into the main menu commands and sub-menu command. The main Menu drop-down list contains 9 options: Patient management, Dentist management, Practice management, Appointment, Billing, Reports, Practice analysis, Inventory, Setting, Security, and

Tools, for patient management menu drop-down list has 5 sub-menu

The practice management menu has 10 sub menu items including medical history, dental history, dental habits, allergies, chief complaints, examination advices, treatment, prescription, referrals, and insurance companies.

For the database design, PhpMyAdmin software was used to create the database which was named "ClickDent.mdb" and consisted of a series of data tables organized in relational database (Figure 5). The diagram shows the relationships of the tables in dental information system. These tables are created with a data dictionary that lists the table title, a data type and data size.
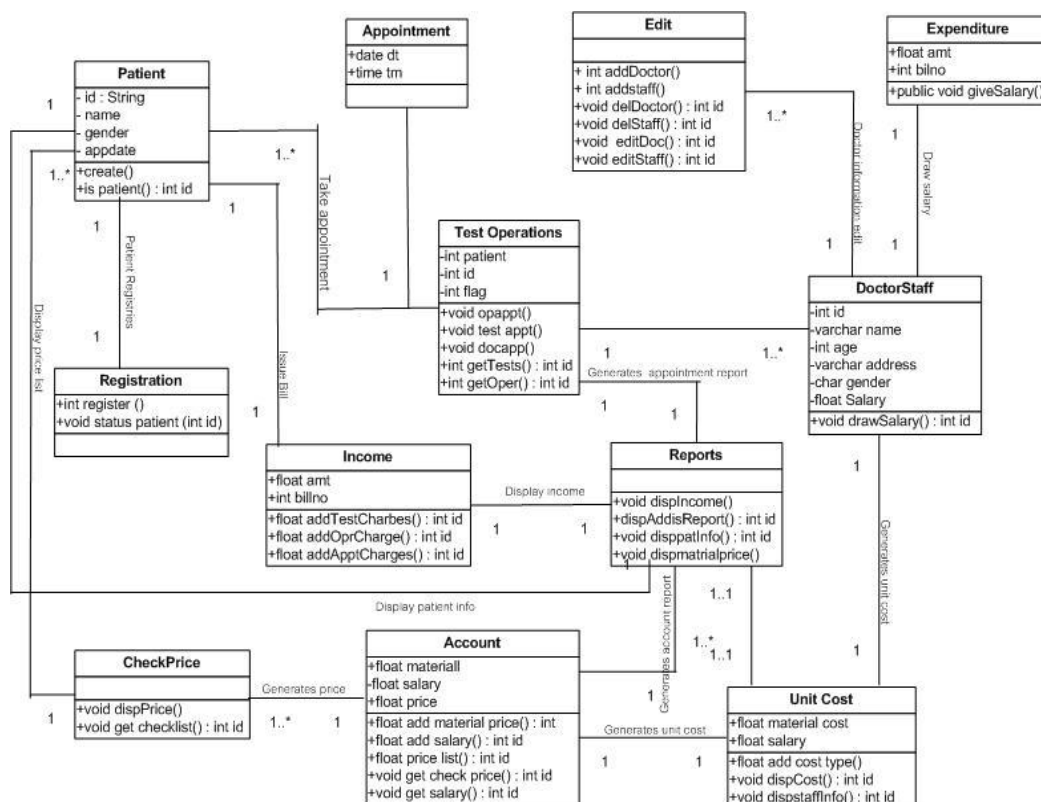
**Figure 5.** Relational Database of Dental Clinic information

### Data analysis

SPSS for Windows version 18.0 (SPSS Inc., Mahidol University, Thailand) was used for statistical analysis. Descriptive analyses were conducted to determine the statistical for levels of satisfaction of group differences

### Results

When the development of the application was completed it was installed on clinic workstations for trial simulation in the dental department of Amanda Mahidol Hospital and the Department of Surgery at Faculty of Dentistry, Mahidol University. It was intended that the software be tested on the target population of dentists and dental assistants whose input guided the software development process.

The respondents from the dental clinic at Ananda Mahidol Hospital which the majorities are male, aged between 31-40 years,

Of the respondents who tested the dental information software, four were dentists and 2 where dental assistants (clerical staff). A questionnaire was used to evaluate the effectiveness of the dental information program. The questionnaire was designed to assess both the input process, and reports (output) generated by the system. The responses were scored as levels of satisfaction as shown in Table 2.

**Table 2** Evaluation of satisfaction with the Dental Information program

| List of satisfaction | Excellent | Good | Fair | Poor | Improve | $\overline{X}$ | S.D |
|---|---|---|---|---|---|---|---|
| 1. The development of agility program | 2 | - | 8 | - | - | 4.20 | 0.422 |
| 2. The development of automated management features response to requirements of users | 4 | 6 | - | - | - | 4.40 | 0.516 |
| 3. Data entry is convenient and easy to verify | 5 | 5 | - | - | - | 4.50 | 0.527 |
| 4. Manuals to understand the overall system and lead to a subsystem | 4 | 5 | 1 | - | - | 4.30 | 0.675 |
| 5. Manuals to identify functionality of the system | 3 | 6 | 1 | - | - | 4.20 | 0.632 |

**Dental Information System testing**

The second analysis included responses from the group of dentists and dental assistants from Ananda Mahidol hospital in Lopburi Province and the group of dental assistants from the Department of Surgery in the Faculty of Dentistry, Mahidol University. Analysis of variance testing with F-test showed no difference in responses between the two groups. Student t-test analysis of the means showed no difference in the populations, that is $\sigma_1^2 = \sigma_1^2$. Hypothesis testing was performed to a significance level of $\alpha = 0.05$.

## Discussion

In developing the application the researcher evaluated the existing system used in the dental department at Ananda Mahidol Hospital. The existing data collection process consisted of a variety of collection modalities that were often times incompatible resulting in information redundancy and inconsistency. The use of physical paper stores caused additional storage concerns. The completeness of records was a major concern, with records lacking basic demographic data or having incorrect information, such as name spelling errors. Incomplete or inaccurately recorded diagnosis data results in inaccurate search and reporting functionality. The isolated clinical data systems made interdepartmental or inter-system information sharing less efficient, while managerial and executive tasking, such as systems analysis and strategic planning were difficult to coordinate and execute.

After evaluation and analysis the existing system we were able to design a information management system that addressed the specific process needs of the target clinical setting, including the processes for patient registration, diagnosis, treatment, appointments scheduling, clinical billing and reporting. The user interface and database designs were specific to the dental clinical situation to facilitate more efficient and effective practice. We used the phpMyAdmin database manager open source software version 2.10.3 to prepare and manage the relational databases and used Microsoft Visual Basic Express 2008 for software development.

The Dental Information System software was evaluated by four dentists and two dental assistant staff members from the Faculty of Dentistry where the software as trialed. The post-development system evaluation showed general satisfaction with the system which was judged as meeting the needs of the personnel and was appropriate for the clinical setting.

## What is already known on this topic?

This study performed a qualitative assessment of system user needs to develop a dental information system to support clinical dental work flow and process. Song et al. highlighted the importance of clearly identifying clinician's point-of-care requirements, through qualitative analysis, to develop systems that support the diagnosis and treatment of dental disease. While an electronic data management application can greatly improve clinical practice and

patient outcomes, inefficient system development that is not user-centered can result in decreased system usability with resultant reduction in productivity and serve an a significant barrier to system adoption. The development of this dental information system followed a model of extensive work analysis in an interdisciplinary working group to build a system that is intuitive to the target population[22]. This emphasis on the user experience ensures that information systems can be applied to clinical practice in meaningful ways to, not only improve the quality of patient care, but also, facilitate cost savings and oral health promotion efforts[23].

### What this study adds?

The recommendation of dental clinical information systems in warranted and systems can be developed that integrate a wider variety of functionality depending on user needs and requirements. Our system can also be further developed and customized for greater utility. The system can be developed as a web-based application for easier and wider access across systems, allowing for greater flexibility and versatility of functions. The system could further be deployed on handheld mobile devices that clinicians can carry and use in the examination rooms. The system can be developed additional

connectivity and data linkage to radiology data systems (PACS), pathology databases or medical records databases for easier information importation and sharing[24].

### Acknowledgements

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