System for Archiving, Communication and Analyzing of 3D Dental Cast Model

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Abstract—Dental cast model is necessary tool for orthodontic procedure where the clinician requires displaying and analyzing for the appearance of the patient's teeth before and after treatment. However the dental casts made from plaster of Paris require annual maintenance to check if there are any damages and proper storage for at least 10 years. Therefore, our system for archiving, communication and analyzing of 3D dental cast model has been developed for archiving, delivering and manipulating electronic dental model to the end users. The method combines with the electronic 3D dental model being generated by scanning a dental cast that made from plaster of Paris before storing the electronic dental models in STL and VRML formats in the database which connected to a server-based computing system. Next the 3D electronic models are delivered to a remote client computer over a distributed communication networks, which allowed users to access to the 3D electronic data via web browser or mobile device. Finally, users can manipulate the electronic 3D models at remote client computer, and performs analysis on 3D dental casts by the software tool provided by our system. The attitudes of clinicians toward our system for archiving, communication and analyzing of 3D dental cast model (AnaDent3D) through the assessment on the website and software tool by doing post-test questionnaires are positive. It is concluded that the system for archiving, communication and analyzing of 3D dental cast model is effective in recording, delivering and analyzing of the electronic 3D dental cast data.

Keywords—3D dental cast; 3D dental analysis; archiving database; computer-based patient records; orthodontic dental model; digital dental model services.

I. INTRODUCTION

Orthodontic casts are commonly used in dental offices as permanent records of a patient's teeth. The casts are often applied to display and analyze for patient's malocclusion problem. However the dental cast made from plaster of Paris can be damaged and requires annual maintenance with proper storage for at least 10 years to compile with Thailand Health Facilities Act. Therefore this paper proposes the system to help eliminating the use of plaster study models in orthodontic practice while improving the accuracy and efficiency of orthodontic diagnosis and care delivery. There are similar systems available in the market such as 3D Digital Dental Model Services by 3M Unitek, the exclusive distributor of GeoDigm Corporation [1]. GeoDigm is a provider of orthodontic products and services to deliver e-model trade; 3-D Digital Dental models and other services to the orthodontic market in North America. However, high price tags and inconvenience of international delivery for dental model to service center have discouraged dentists to use such a service. Therefore, our system for archiving, communication and analyzing of 3D dental cast model has been developed to handle electronic dental model to remote clients for the dental services in Thailand and South East Asia.

II. PROPOSED TECHNIQUE

This paper presents the method of software development for archiving, communication and analyzing of 3D dental cast model system that can be illustrated in Fig 1, which divided into 3 parts. First, the archiving system for 3D dental model is designed as a web database using PHP and MySQL. Second, the communication system of the 3D dental model has been developed for delivery the 3D data in STL and VRML formats via web browser and mobile device. Third, the analyzing software provided by our system is written using Borland C++ Builder® and OpenGL library for 3D dental model analysis. Since the dental data is in 3D format so the technology applies for developing our system can be shown in Fig 2.

A. Archiving System for 3D Dental Model

To get the 3D digital dental model, the clinicians need to send the plaster model with the patient information to our administrator. Then the admin will scan the model using laser/optical 3D scanner to transform an orthodontic model into electronic form, to display on the WWW and to provide clinician with an accessible source of complete, high-quality
3D dental model. Digital orthodontic records for diagnosis and treatment planning can apply to set up orthodontic diagnostic information in the website and available only for the members of AnaDent3D with the login name and password which have a permission to access only patient’s data that belonged to the login member. The flowchart of our archiving system can be shown in Fig.3.

![Flowchart of the archiving system on 3D dental model.](image)

Figure 3. Flowchart of the archiving system on 3D dental model.

The archiving system is developed in three parts. First is the record of patients in 2D images, which can be uploaded, downloaded, edited and kept as 2D patient’s data. For orthodontic case, the 2D patient data consisted of: 1) facial photographs in relaxed frontal view, smiling frontal, and profile view, 2) intra-oral photographs in five views—frontal, left, right, upper occlusal, and lower occlusal, 3) panoramic and lateral cephalometric radiographs, and 4) orthodontic study models in centric occlusion [2]. Second is the record of patients in 3D dental model can be downloaded and edited for orthodontic diagnosis and keeping as an electronic patient’s record instead of the plaster dental model. Third is the record of patient’s information including the analysis result, which can be uploaded from software viewer tool such as Bolton's analysis and dental identification data which clinicians are allow adding their own information to each patient's data. Example of 2D patient’s data in this system and Bolton analysis results from software tool provided by our system is displayed in Fig.4, which all images contain links to the enlarged images.

![Example of 2D patient’s data; all images contain links to the enlarged images and Bolton analysis result from software tool, which provided by our system.](image)

Figure 4. 2D patient’s data; all images contain links to the enlarged images and Bolton analysis result from software tool, which provided by our system.

All information and data are recorded and allowed for searching and accessing the cases with patient's information in the database system as the diagram which can be seen in Fig.5. The system allows members and administrator to
login with different permission levels as shown in Table 1, where the italic word shows the superior level of the administrator over the members.

**TABLE 1.** The database system can be accessed in different levels according to the type of members. The italic section shows the higher level of permission of the administrator over the members.

<table>
<thead>
<tr>
<th>Capable</th>
<th>Admin login</th>
<th>Member login</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile</td>
<td>View/Edit</td>
<td>View/Edit</td>
</tr>
<tr>
<td>Patients</td>
<td>Add/View/Edit</td>
<td>View/Edit</td>
</tr>
<tr>
<td>❖ records in 2D images</td>
<td>Add/View/Edit/Del</td>
<td>Add/View/Edit/Del</td>
</tr>
<tr>
<td>❖ records in 3D dental model (stl, vrml)</td>
<td>Add/View/Edit/Del</td>
<td>View/Edit/Del</td>
</tr>
<tr>
<td>❖ Analysis results from software tool &amp; dental identification data.</td>
<td>Add/View/Edit/Del</td>
<td>Add/View/Edit/Del</td>
</tr>
<tr>
<td>Details of all members (clinicians)</td>
<td>Add/View/Edit/Del</td>
<td>Not Available</td>
</tr>
<tr>
<td>Details of all patients</td>
<td>Add/View/Edit/Del</td>
<td>Add/View/Edit/Del</td>
</tr>
</tbody>
</table>

Figure 5. The diagram shows the way to access the data in the database by clinicians.

**B. Communication System for 3D Dental Model**

The communication system is depended on the 3D data types. The records of 3D dental model data are divides into 3 types. First, STL (Stereo lithography format), a standard format for the industrial CAD/CAM applications, is available from the 3D scanner and uploads to the database. For display this format, users need to download 3D file to their own PC and use the software tool (AnaDent3D Viewer) for analyzing. Second, VRML (Virtual Reality Machine Language) format is also available for displaying on web browsers, which has already installed VRML plug-in for Internet Explorer such as COSMO [3] or Cortona [4]. Since this format is quite big compare to the STL format, so it will use just only for viewing on the internet without downloading to the user’s PC. Third, the STL low resolution is prepared for the users who would like to display on smart phone. This file is design to be a small file but contains enough information when display with the mobile device. Our system also provides the software tool on mobile which operate on Window mobile OS. The clinician can point at a URL and it will download the 3D STL dental data and let the clinician see the 3D object on mobile device. Using the mobile device pad, the user can rotate and pan the 3D models while looking at 3D object from any direction. Fig. 6 (A) displays the 3D dental model via web browser in VRML format while Fig. 6(B) display 3D dental model via mobile device in STL low resolution.

**C. System for Analysis of 3D Dental Model (AnaDent3D Viewer)**

The software tool provided by our system named AnaDent3D Viewer is a window based application for viewing and analyzing 3D dental model in STL and VRML formats. Clinicians can easily access to study or apply as a visual aid during patient consultations. The software tool allows a simple click and drag moves, the models can be completely rotated and viewed in any direction. Full body rotation has been included. Apart from the basic functions on open and display the 3D data, the software tool also provides the necessary functions to perform the analysis of 3D dental...
model used for viewing and analyzing the 3D data of patient's teeth described as following.

1) **Overjet and overbite checking function** [5]

Overjet and overbite checking function is more complicated for measuring the distances of overjet and overbite on the plaster dental model directly. Since overbite is indicated the distance that upper front teeth extend out over the lower front teeth, while overjet is indicated the distance that the upper teeth extend far forward from lower teeth. An algorithm on overjet, overbite checking can be done by cross-sectional plane cutting along the arch form curve. Then the projection of 3D data at the cross sectional area is calculated and displaying into 2D image that allows the user to measure the distance. The result after applying this function is as shown in Fig.7.

![Figure 7. The result of 3D Model overjet/overbite checking function.](image)

2) **Occlusal contact checking function** [5]

Orthodontics and orthognathic surgery needs an occlusal contact checking for diagnostic that the patient has the correct bite after the treatment. For occlusal contact checking, this can be done by using articulating paper mark size to be descriptive of the occlusal load. However, the research by J.P. Carey et.al [6] stated that there is no direct relationship between paper mark area and applied load could be found. The clinicians just assume the size of paper markings can accurately describe the markings' occlusal contact force content. Therefore, the occlusal contact checking function would follow the practice of the bite marking on the paper as follows: the possible area is first determined at three millimeters above and below the occlusal plane. Then the overlap area is checked by determining the dot product between vector from lower to upper tooth and a unit vector on z axis. Next is to paint tooth area that has the contact with the color show the contact depth in millimeter that related to the occlusal contact force. The result of an occlusal contact checking function can be shown as in Fig.8 where the colored –coding of the contact surface can varies on contact strength.

![Figure 8. The image shows the result of an occlusal contact checking function, where the colored –coding of the contact surface can varies on contact strength.](image)

3) **Bolton analysis function**

Bolton analysis is the dental analysis derived by measuring the dental width of the individual teeth before comparing maxilla (upper cast) and mandibular (lower cast) sum of dental widths in percentage invented by Bolton in 1958 [7] for the following dental assessments:

- When the dental ratios are not proportional with standard values, it would indicate where irregularity occurs
- This analysis can be applied for orthodontic treatment and cephalometric analysis to indicate if orthodontists and craniofacial surgeons would either extract the teeth or perform cephalometric surgery along with dental stripes to correct dental positions and space.
- This analysis can estimate overjet and overbite after orthodontic treatment.
- Sum of 12 maxilla and 12 mandibular dental widths could be applied for malocclusion assessments.

The computerized technique is similar to the 2D work by Bholsithi and Sinthanayothin [8], but our function provides tools for measuring the dental and individual teeth widths in 3 dimensional as shown in Fig.9.

4) **Virtual bases construction for orthodontic study model function**

The preparation of dental study model generally relies upon the dental technicians' artistic skills and experiences on mounting dental casts on the bases by manual method, which is difficult, tedious and time-consuming process. Therefore this function proposes the semi-automatic computerized method to perform dental bases for orthodontic study model which requires a few steps for creating virtual upper and lower virtual bases attach to the dental casts. First is to create the virtual bases from the template to be translated, rotated and scaled for getting the appropriate size and
occlusal alignment position. Second is to apply the bridge algorithm using cubic spline technique to connect the bases with the dental casts. Third is to fill the vacant space between the dental bases and casts by creating the ceiling and floor surfaces. Next is to blend and smooth the ramp bridge connections between dental bases and casts and create the curve surface. The final step is to mount the upper and lower bases with the upper and lower casts respectively. The result of the construction virtual bases for orthodontic study model can be seen in Fig.10.

III. RESULT

From the clinician’s viewpoints, the web database and all the functions from this system are giving satisfied and better appearance in comparison to some commercial software/system. Also the attitudes of 20 clinicians toward our system for archiving, communication and analyzing of 3D dental cast model (AnaDent3D), by assessing the website and software tool and doing post-test questionnaires, are positive as well.

IV. DISCUSSIONS & CONCLUSION

The results of database system and all functions have expressed that the system under discussion can perform the archiving, communicating and analyzing of the 3D dental model. Therefore, it is concluded that the system for archiving, communication and analyzing of 3D dental cast model, is effective in recording, delivering and analyzing of the electronic 3D dental cast data.

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REFERENCES