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Research Article

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Application of digital medical techniques on interdisciplinary talent education of stomatology and mechanical engineering

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ABSTRACT

Digital techniques including computer tomography (CT), 3-dimension (3D) reconstruction, digital design and 3D printing are widely used in medical research, as well as clinical application, which promotes the cross and integration of fields on medicine and engineering. The requirements of interdisciplinary talents on the two fields are increased rapidly in recently years. In order to satisfy the social requirements on talent, some training methods, including group studying and joint seminar, have been performed around theories and techniques on stomatology, digital image processing, digital design and advanced manufacturing, and more than 20 students have graduated and been accepted by some companies in medical or engineering field, which proved the validity of adopted measures.

Keywords: Digital medicine, Interdisciplinary, Stomatology, Mechanical engineering.

INTRODUCTION

The development of any disciplinary is not an isolated procedure, which is always involved in other related disciplinarians. Cross and integration of different disciplinarians are normal state in modern disciplinary development process [1]. Accompanying with advanced engineering techniques including data (image or point) scanning such as CT (computerized tomography) scanning on body and laser scanning on part surface, image processing and 3D reconstruction of tissue, digital design and manufacturing on customized implant or surgical tools, modern medicine including surgical tools, implants, and clinical operation have been changed significantly, which increases the requirements of medical application on engineering techniques and promotes the cross and integration on the fields of medicine and engineering [2].

Six years ago, we changed our research direction from traditional mechanical engineering to interdisciplinary field of digital medical engineering, mainly in stomatology, including digital guided dental implanting, complex precise maxillofacial surgery, digital orthodontics and other surgeries. Later, we founded the Digital Medical Engineering Research Center of Zhejiang University of Technology (DMERC-ZJUT) in 2008, and totally three professors and 5 associated professors are included. Cooperated with dentists from Dentistry Department of Zhejiang University, DMERC has undertaken several projects about biomedical research on dentistry. During these projects performing, some students including undergraduate and postgraduate students are involved, and some dentists cooperated with us on joint research work, as well as student supervision. On the other hand, the dentists cooperated with us also performed some researches related engineering techniques, their students also wanted to study and use techniques on engineering, so the cooperation between students of the two different majors have been implemented too. In order to normalize the talent training and education procedure on interdisciplinary, we cooperated with the Dentistry Department, Medical School of Zhejiang University, and a full training system has created. Based on these experiences on research and talent training of cross fields, some methods and conclusions are drawn to share

1. Outline of Involved Techniques for Education

Modern methods in stomatology, from diagnosis, plan design, to clinical operation, are evolving and have changed much with engineering techniques developing and introduced in. The accuracy of clinical operations based on guide or template designed from virtual plan in computer and fabricated via 3D printing is improved much from conventional free hand operations, and guided operation is accepted by more and more dentists. The purpose of education in this interdisciplinary is that train dentists to know about techniques of advanced manufacturing, and to learn modern methods for diagnosis, plan design and guided operations, as well as train mechanical engineers to know about dentistry knowledge, and learn medical tools design and fabrication. These trained talents have knowledge on two fields of dentistry and engineering, and can worked as dentist in hospital, or engineer in medical appliance factory or service firm for dentistry, which must promote the development of modern dentistry.

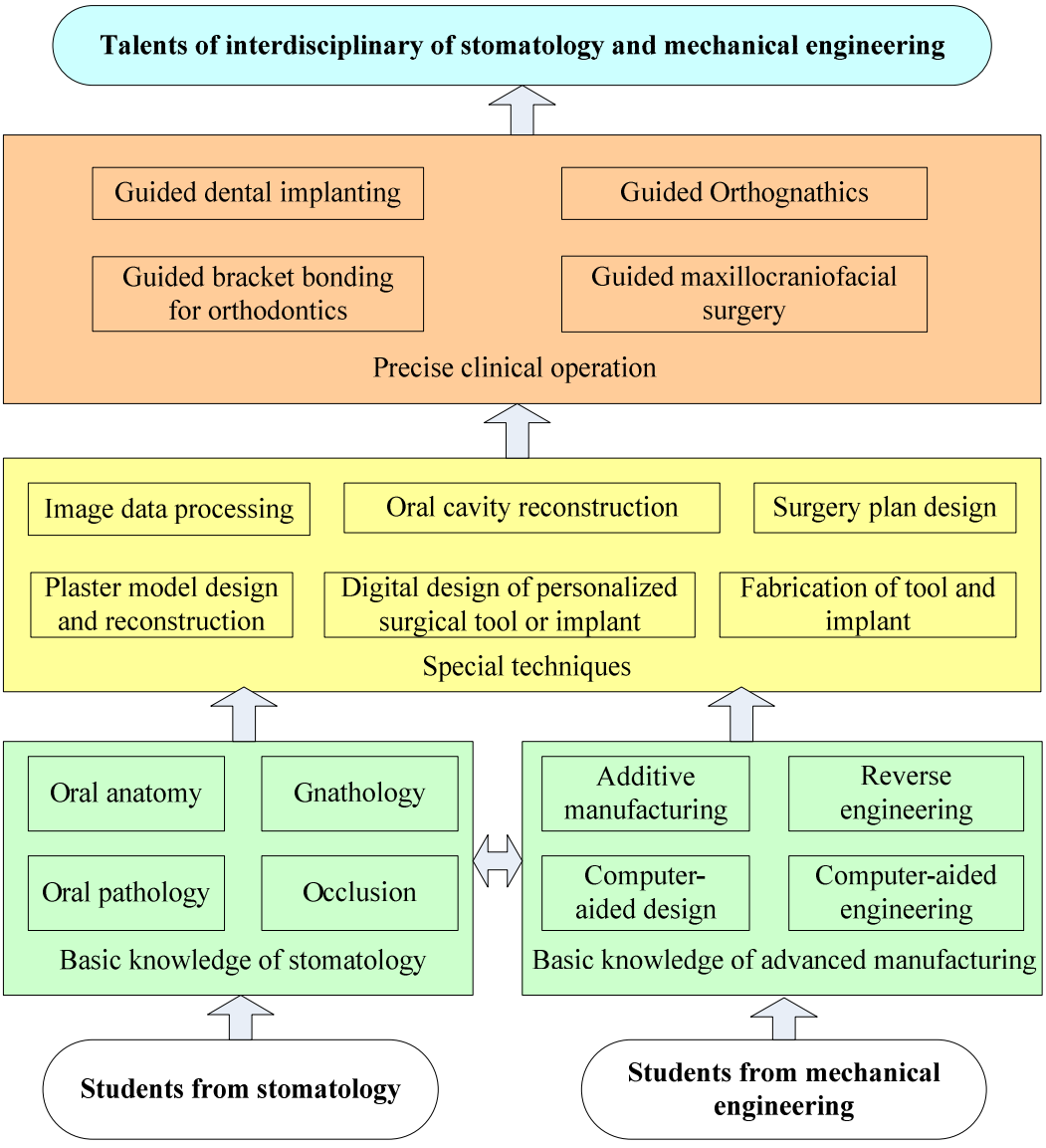

Fig. 1. Involved techniques for education

In the interdisciplinary of mechanical engineering and stomatology, the talent training is performed based on more and more modern techniques, as shown in Fig.1. Totally three parts of knowledge are needed be known about or mastered: basic knowledge, special techniques, and operation skills. For dental students, they have basic knowledge of oral medicine, including anatomy, gnathology, pathology and occlusion. And for mechanical engineering students, they should master advanced manufacturing techniques, including additive manufacturing (AM), reverse engineering (RE), computer-aided design (CAD) and computer-aided manufacturing (CAM). But as a talent in interdisciplinary, knowledge on both fields, including basic theories, some software tools, and fabrication appliances, should be known or mastered.

Based on basic knowledge in stomatology and mechanical engineering, the students in two majors can study some special techniques for modern dentistry, including medical image processing, oral tissue reconstruction, plaster model scanning and reconstruction, plan design, and tool design and fabrication. These techniques also can be divided two parts for dentist or engineer, for example, the surgical plan design generally is implemented by dentist, such as Simplant™ (previous owner Materialise NV, Belgium, now is owned by Densply Implants) [3-4] or Nobel Clinician™ (Nobel Biocare, Sweden) [5] for dental implant plan design, as well as a similar tool from China named 6D Dental™ implanting software [6]. The design and fabrication of surgical guide or customized implant are commonly implemented by engineer, but in recently years, some dentists are involved in customized implant design, such as titanium implant for mandible repair, and some dentists like doing some research work related to biomechanics via finite element method (FEM), so the need to learn some advanced tools for tissue model dealing.

Modern clinical operation is based on guide or positioning tools for more accuracy, including guided dental implanting, orthognathics, and other surgeries. In order to let engineering student know about the operation process for better design of guide and other tools, these students should enter clinic to watch dentist's operation even aid dentist as an assistant.

2. Technical basement for talent training on interdisciplinary

Conventional diagnosis is performed on 2D x-ray image, which often results misunderstand of oral tissue and defect. For modern dentistry, 3D data of CT images are used more and more. For students from mechanical engineering and stomatology, some advanced techniques and tools are necessary to learn, including CT image processing, 3D oral model reconstruction, surgical plan design and others.

To learn these modern techniques and tools, studying group is created by 5 to 8 students from two majors, and there different knowledge background from stomatology or mechanical engineering can be complementary. In each group, there are 2-3 graduate students as leaders, and others are undergraduate students. The studying content and target of each group is assigned to different area according to research projects, such as dental implanting, orthodontics, maxillofacial surgery. Each group has a teacher or researcher as director, who can guide their study and discussion. Of course, usual communication proceeds via web, phone and seminar, which can promote rapidly mastering on knowledge of dentistry, mechanical engineering, and software.

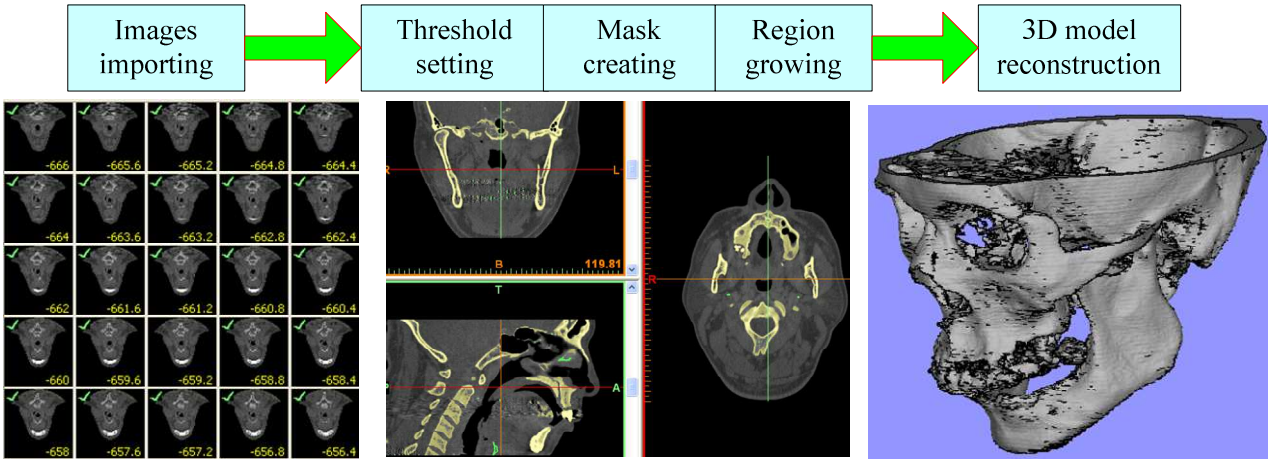

Fig. 2. Procedure of 3D medical model reconstruction

2.1 Basic tools for modern dentistry, image processing and 3D model reconstruction

3D model of oral tissue as the necessary data for modern dentistry is used for diagnosis, biomechanics, simulation, and surgical plan. To get 3D medical model, CT images are needed and processed, and special software platforms are needed too. Cooperated with some companies, a series software tools are supplied to educate and study, including MIMICS/Magic/3-matic (Materialise) and 6D dental implant design software (6D Dental).

The image processing and 3D model reconstruction are easy for mechanical engineering students, but hard for stomatology students, and medical analysis is contrary. The group can study together and make rapid progress. The procedure of image processing and model reconstruction is shown in Fig.2. This procedure is common for 3D medical model reconstruction via any software platforms, and each student need to master, which can make easily understanding to image processing and model reconstruction.

2.2 Advanced techniques of diagnosis, plan design, and digital design based on 3D medical model

The 3D medical model is exported with STL file of triangular meshes, based on it, many other use can be done for research, as shown in Fig.3. For biomechanics analysis, such as the relationship between root resorpition and stress on tooth toot in orthodontics, can be simulated based on 3D models of tooth, periodontal ligament and bone via FEM, and stress on implant for dental implanting and other issues related to biomechanics can be simulated and analyzed too. For surgical operation, such as dental implanting, maxillofacial surgery and orthognathics, 3D medical model can be effective on surgery plan, medical model fabrication and simulation on physical model, surgical guide, and customized implant. Also for tissue engineering, scaffold with customized outer shape and complex internal micro-structures can be design based on 3D medical model of mandible, and fabricated by 3D printing. Till now, many researches are performed by cooperated group from mechanical engineering and stomatology, and many postgraduate students are involved.

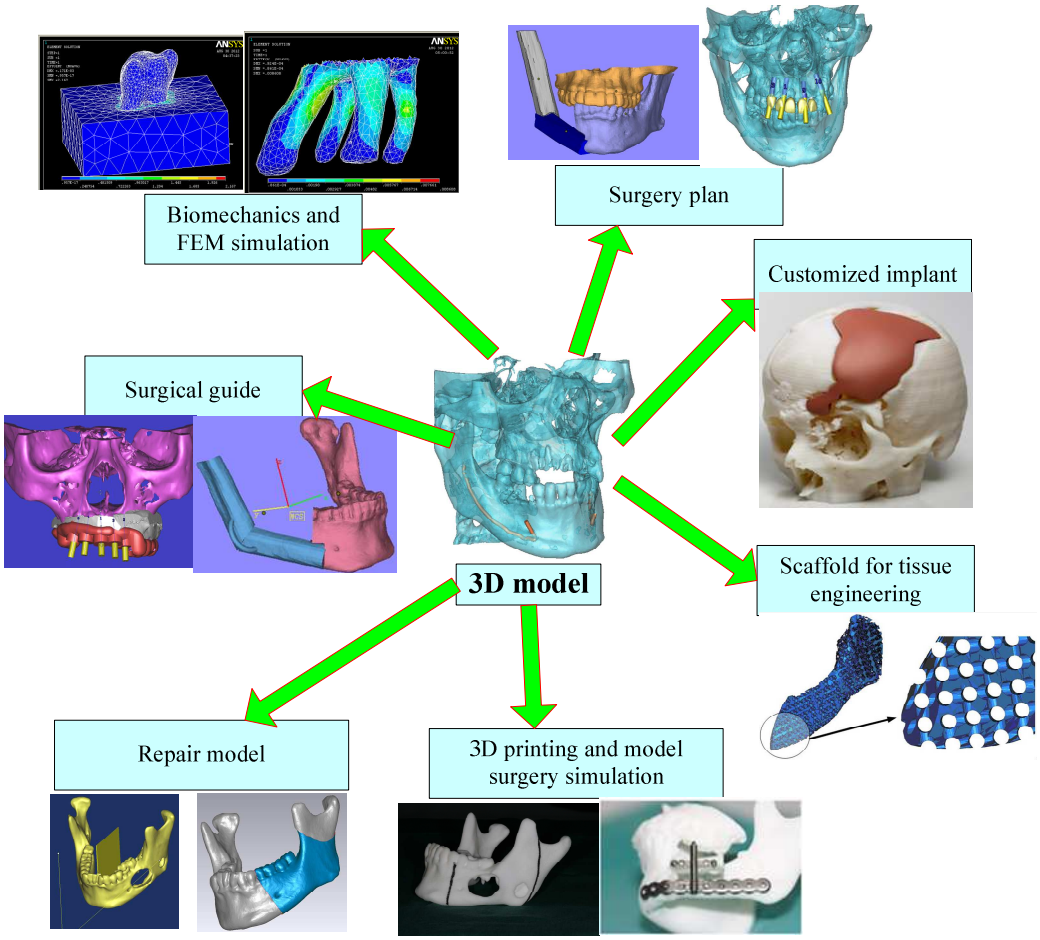

Fig. 3. Procedure of 3D medical model reconstruction

3. Measures for Talent Training on Interdisciplinary

Cooperated with Dentistry Department of Zhejiang University and its affiliated hospitals, we created a system for talent training on field of interdisciplinary, which includes measures of creating studying group, teaching medical engineering knowledge on courses, directing postgraduate students jointly, jointly seminar and discussion, and others. These measures have been very useful on rapid learn of related knowledge for engineering students or dentistry students.

3.1 Creating studying group

The studying group is formed by 2-3 students from mechanical engineering and 2-3 students from dentistry. Each group is focused on one research thesis, such as biomechanics in implant, surgical guide, or biomaterials. The complementary on knowledge of engineering or dentistry can promote rapid progress on knowledge learn of interdisciplinary. In DMERC, totally 4 groups exist, and 12 postgraduate students from mechanical engineering and 8 postgraduate students from dentistry are included in.

For each group, a teacher from mechanical engineering and a teacher from dentistry are assigned as the directors. The directors guide the research direction of the group and help to solve the problems in research work. For example, in a group about digital orthodontics, the aim of the group is to develop a new appliance for tooth movement based on shape memory polymer. In this group, the students from mechanical engineering study biomechanical properties, arch wire forming, and force measurement of shape memory polymer (SMP), as well as indirection bonding of brackets, and students from dentistry study medical problems such as bone rebuilt, root resoption, plan design. To measure the force applied to tooth by SMP arch wire, a device based on two sensors of Nano17 (ATI industrial automation), the smallest 6 dimension force transducer in the world, is created. This device is designed by mechanical students, but the orthodontic model for testing is designed by dentistry students.

Another group is studying a new dental implant with analogue shape of natural tooth. The impalnt has two roots, and is designed with serial parametes based on statistical data of large mounts of natural teeth, as shown in Fig.4 [7]. Among this study, the dentistry students supplied more than 100 molars, and performed the animal tests and toxicity tests for the implants; the mechaical engineering students aimed to statistically analyze to the collected molars, and then create the parameteric system of the impalnt construction and optimize them by stress analysis on FEM methods, and farbricate them by 3D printting of titaium powder. Till now, the animal tests are implemeting and the results show good osstoingegration.

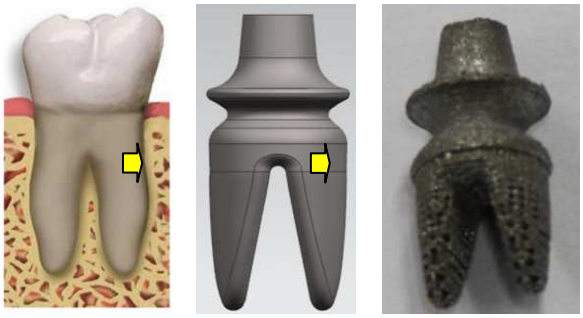

Fig. 4. Analogue dental impalnt with double roots

Fig. 5. A presentation by Professor Chen

3.2 Joint seminar

A joint seminar is performed once time each week. In seminar, each group reports the advances and problems on research of the week, and directors from mechanical engineering and dentistry give comments and suggestions. In the seminar, some presentations by teachers about state-of-art or basic theories of related areas are arranged also, as well as some famous researchers are invited too. Fig.5. shows a presentation in a cooperated seminar by Professor Jie Chen, from Purdue University-Indian University, Indianapolis, with title Predictable Orthodontic Treatment, at Nov. 1, 2012.

CONCLUSION

Students education in interdisciplinary is more difficult than conventional disciplinary, because more knowledge are needed to learn. For dentistry students, it is very difficult to master engineering techniques, but for mechanical engineering students, they are lack of medical knowledge. In recent years, based on some advanced methods for talent training, the interdisciplinary of mechanical engineering and stomatology is developing well in DMERC of Zhejiang University of Technology, and students including undergraduate sand postgraduates are training well. These students are working in medical tool company or medical service company with good professional prospect.

In future, the mature methods for talent training in interdisciplinary will keep, and new methods will be explored and tested to promote the development of mechanical engineering, stomatology and their cross.

Acknowledgement

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