Digital Dentistry: When dental sciences encounter Industry 4.0, what should we learn about it?

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Abstract

Due to the technology innovations in Industry 4.0, digital dentistry has become an iconic transformation in modern dental sciences. Facilitated by Industry 4.0, the ever-advancing technologies like 3D printing, computer-aided design (CAD) and computer-aided manufacturing (CAM) have significantly transformed all fields of dental sciences, and contribute to the optimization in clinical treatment. In spite of the new era in dentistry, what should we learn about the technology innovations as a patient, researcher or clinician? In this article, the technical concepts of digital dentistry and CAD/CAM systems are introduced as an example to discuss the necessary skills for the career development in modern dentistry.

Keywords: digital dentistry, dental CAD/CAM systems and Industry 4.0

Introduction

As in many other industries, automatic production has gradually introduced to dental technology. A series of innovation about computer-aided design (CAD) and

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computer-aided manufacturing (CAM) have applied to both clinical dentistry and academic dental research [1,2]. During the process of industry 4.0, enormous fields of technology were created or significantly improved, including machine learning, artificial intelligence, 3D printing, computer vision, 3D reconstruction [2–4]. Instead of their direct usages on the industrial manufacture, social media, and commercial services, the field of dentistry is also influenced by the trend of Industry 4.0 innovation [4–9]. The term 'CAD/CAM' has frequently used in the field of digital dentistry [8].

According to [10], all CAD/CAM systems consist of three components:

1. A digitalization tool/scanner that transforms geometry into digital data that can be processed by the computer.
2. Software that processes data, and depending on the application, produces a dataset for the product to be fabricated.
3. A production technology that transforms the dataset into the desired product.

Trends in Digital Dentistry

CAD/CAM systems for dental prosthesis: an example of the industrial transformation in modern dentistry

With the aid of CAD/CAM systems, many dental treatments have been optimized, which provides better health care quality [1,8,11,12]. For example, conventional dental prosthetic restoration usually takes several weeks to design dental dentures, but the current 3D scanning and printing technology can shorten this process less than 1 day [9,13]. Traditionally, dental prosthesis requires the cooperation between a dentist and a dental technician to record the oral impression with wax [13], design the surface structure of dental dentures, and implant into patient's gingiva. The whole process usually takes several weeks (Table 1.). To say, patients have to attend to a dental clinic several times for the treatment [13,14]. However, if the designed dental denture isn't accurate, the treatment will require more time and effort of both patients and dentists to accomplish [15].

The improvement of dental prosthetic restorations is the combination of 3D scanning and printing technology [5,7–9]. First, a patient's oral 3D structure is scanned by an optical scanner and reconstructed to 3D DICOM image (Digital Imaging and

Communications in Medicine). Second, a dental implant is designed based on the 3D structure of neighbor teeth. Third, the computer-designed dental implant can be produced by a dental specialized 3D printer within 1 hour. And finally, a dentist can complete the implant operation within a day [14] (Table 1.).

What do CAD/CAM systems of dental implant inspire us about the modern dentistry? First of all, the conventional process of dental implant production was separated into two different professions and locations. One is a dentist and dental clinic, and the other is a dental technician and dental implant factory. Traditionally, these two professions can cooperate and accomplish the treatment in weeks. However, with the aid of 3D technology, the whole process can be conducted by one person, one location and even only one day.

To sum up, the dental CAD/CAM systems have shortened the process and requires minimum experts in the treatment of dental prosthesis.

The transformation of dental occupation: an overview of the influences of dental CAD/CAM systems

One positive perspective of Industry 4.0 is that the value is created from the gains in optimized efficiency, but technology transformation may have pros and cons. One of the challenges is the restructuring of occupations, and some of them may quickly disappear [10].

1. *Compensation effects*: The new treatment is improved by the use of smart technologies which may secure the dentists' job and boost consumer demand with additional income.
2. *Redundancy effects*: The use of CAD/CAM systems may also destroy jobs like the dental technician.
3. *Technological unemployment*: There are concerns that the redundancy effect from Industry 4.0 will retire some conventional skills, leading to technology unemployment.

The role of organization on the training of digital dentistry

On the other hand, due to CAD/CAM systems, the necessary skill of dentists or dental technicians may be changed. Currently, dental students usually spend most of the time on hands-on experiments, and there is obviously a lack of training of computer-aided procedures [6]. Despite the workflow of advanced dental equipment, the skills of troubleshooting, debugging and computation may be useful. Fortunately, there are commercial organizations working on proposing CAD/CAM systems. CEREC (https://www.dentsplysirona.com) is an educational organization of digital dentistry founded by Dentsply Sirona, a dental equipment company in the US [16]. The organization provides education and training for dentists to understand the hardware and software of CAD/CAM systems.

However, most of the courses cost a lot and the purposes are for advertisement. Another concern is that those skills learned from the commercial organizations are platform-specific. Dental CAD/CAM companies like 3M and Dentsply Sirona provide their products with closed operating systems.

One disadvantage is that there is a lack of integration between those systems. To say, a dentist has better to use products from the same company. Otherwise, the data can hardly transfer from platform to platform. The other disadvantage is that the company has direct control over the software license, update, and data. Therefore, users have to keep buying licenses and catching up software updates which may destroy the system integration [2,15].

High-cost equipment may lead to the centralization of capital in the dental market

The other question of digital dentistry is about the centralization of capital [10]. As many fields influenced by Industry 4.0, the overall production has become decentralized, while the capital is not the case [2]. Traditionally, dentists can earn the majority of interest in dental procedures. However, with the aid of advanced technology, the total interest may be higher in the market (compensation effect), but the interest is more centralized to the provider of dental equipment. That is to say, the accumulation and centralization of capital may lead to the concentration of enormous

wealth in few companies which provides dental materials, and dentists may be replaced by advanced dental devices.

In summary, since the dental CAD/CAM system is not the silver bullet to fix all of the clinical problems, dentists still need to pay effort on the clinical training and money for software licenses. The advantage of using digital devices are becoming promising, which can provide a better quality of dental treatment. However, the downside is that the current platforms of CAD/CAM systems are closed and lack of integration. Also, the costly equipment may lead to the centralization of capital in the dental industry.

The necessary skills for dental career development, adjusting to the world of Industry 4.0

Dental education majorly focuses on diagnosis, usage of dental materials and hands-on procedures [2,12]. However, complete engineering training also requires lots of time to get familiar with operation systems, image processing, and CAD/CAM techniques. Therefore, the education of digital dentistry requires a multidisciplinary discipline of both dentistry and engineering. But what knowledge of engineering can improve the usage of CAD/CAM systems as a dental student remains under debate [3].

Dental students and dentists need to know about

1. The traditional hands-on skills in orthodontics and prosthetics may be replaced or improved by the computer-assisted clinical operation.
2. The training of computer-assisted clinical operation is significantly different from the conventional procedure. Dentists should pay attention to troubleshooting skills, human-machine interaction, and data processing, which have become crucial in the field of dental education. However, these skills are still missing in dental training.

Conclusion

The technological innovations of Industry 4.0 have significantly influenced dental surgery. Digital dentistry and dental CAD/CAM systems (computer-aided design, CAD; computer-aided manufacturing, CAM) became popular in recent years. First, this article describes the influences of the CAD/CAM systems on dental treatment as

an example of the transformation in the modern dentistry. Second, the necessary skill of a dental career may include engineering techniques like data analysis, digital image processing, and operating system. Furthermore, troubleshooting skills and debugging with digital devices are crucial for clinical treatment. And the last, the evergrowing cost of dental devices may result in the centralization effect of capital in modern dentistry.

Table

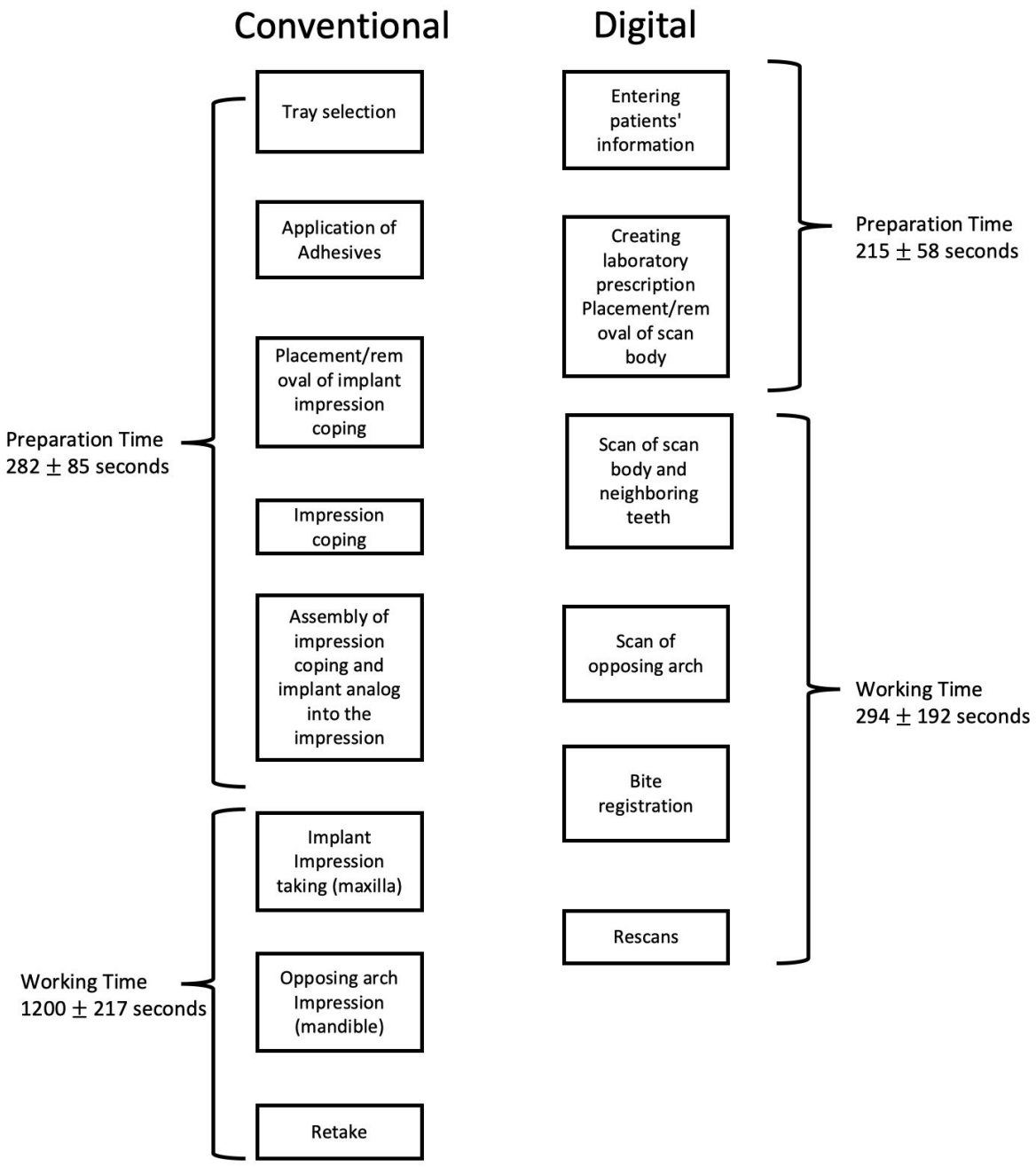

Table 1. Phases of implant impression treatment for timing. The duration of the digital implant impression treatment is significantly higher than the conventional implant impression treatment. The duration of each clinical procedure is listed from top to bottom in the flowchart and separated into conventional implant impression and digital implant impression. The durations are shown with standard deviation. This flowchart is modified and replotted from [13].

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