Chapter 14
Open-Source Technologies and Workflows in Digital Dentistry

Rong-Fu Kuo, Kwang-Ming Fang, and Fong-Chin Su

Abstract The Medical Device Innovation Center (MDIC) at the National Cheng Kung University has developed a complete and professional digital dentistry design workflow with cutting-edge equipment and software. MDIC certified with ISO13485 can provide total solutions in digital dentistry. An "Intelligent Manufacturing Systems Center" (IMSC) has been established using dental open technologies toward providing digital dentistry training and restoration design services. This digital dental laboratory is able to control the entire digital process from digital impressions to the CAD/CAM creation of the restoration and model milling. An intraoral scanner is used to make digital impressions for 3D geometric models from the chair side or from traditional impressions. In the design phase, three different commercial software packages are considered for the design portion. After importing the digital impression STL data file, one or more of these packages are used to design the restoration. The design is then sent to a five-axis milling machine for production. The CNC machines are chosen for machining or milling of the prosthetics from various materials including wax, PMMA, zirconia, chromium cobalt, resin nano-ceramics, glass ceramics, lithium disilicate, silicate ceramics, and titanium. As a cloud base solution, these design packages allow a connection to a remote manufacturing site. Our R&D team built a web-based cloud solution that can be deployed to each pertinent location. All data from the design package is stored on a private cloud which is then automatically synced to the remote public cloud. Work orders from various sources are then processed by any remote technician. Through the above settings, we may produce several common digital dentistry products including crowns and bridges, veneers, inlays and onlays, temporary crowns, and virtual diagnostic wax-ups. This digital dentistry laboratory is also equipped to handle advanced clinical cases such as implant planning, digital smile design analysis and customized surgical guides, custom abutments, implant bridges and bar designs, and orthodontics. Digital animation is applied for patient education and communication. For academics and training, a comprehensive digital technology training program has been developed to help dentists and dental technicians.

R.-F. Kuo • K.-M. Fang • F.-C. Su (✉)
Medical Device Innovation Center and Department of Biomedical Engineering, National Cheng Kung University, 1. Ta-Shueh Rd., Tainan 701, Taiwan
e-mail: fcsu@mail.ncku.edu.tw

K. Sasaki et al. (eds.), *Interface Oral Health Science 2016*,
DOI 10.1007/978-981-10-1560-1_14

Keywords Intelligent manufacturing systems • Restoration • Digital dentistry • Cloud base solution

14.1 Cloud Base Solution for Intelligent Dental Clinic and Manufacturing System

Industrial technologies are growing rapidly in recent years. Dental industry is toward a digital revolution as shown in Fig. 14.1 which causes traditional dental industry to face a serious impact and revolution [1, 2]. Dental clinics also transform gradually toward an intelligent environment illustrated in Fig. 14.2. In order to face this challenge, MDIC presents an innovative dental full-chain model focusing on digital design phase as a core concept plus the utilization of open-source technologies. This model based on an ecosystem platform provides a variety of services corresponding to the demand of dental clinics and dental labs. These needs may cover a variety of customizable dental products and services which are closely connected to dental design and manufacturing processes.

Integrating design and manufacturing for digital dentistry as a complete chain to provide custom service is the core in the model. In order to achieve high competence, MDIC established a mobile interface APP platform based on cloud computing and mobile ecommerce. Cloud computing provides a lot of advantages including high flexibility, low cost, mass storage, and parallel computing capacities to the

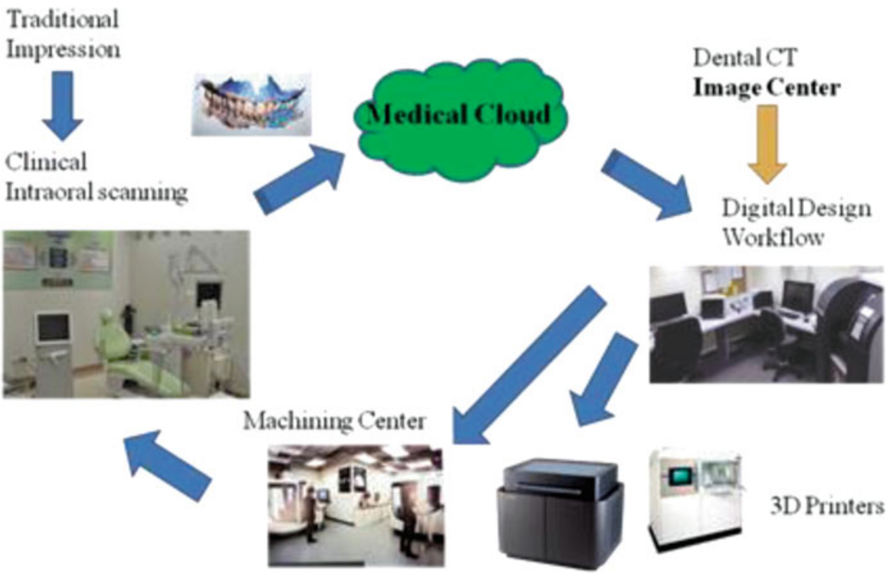

Fig. 14.1 Dental digital workflow

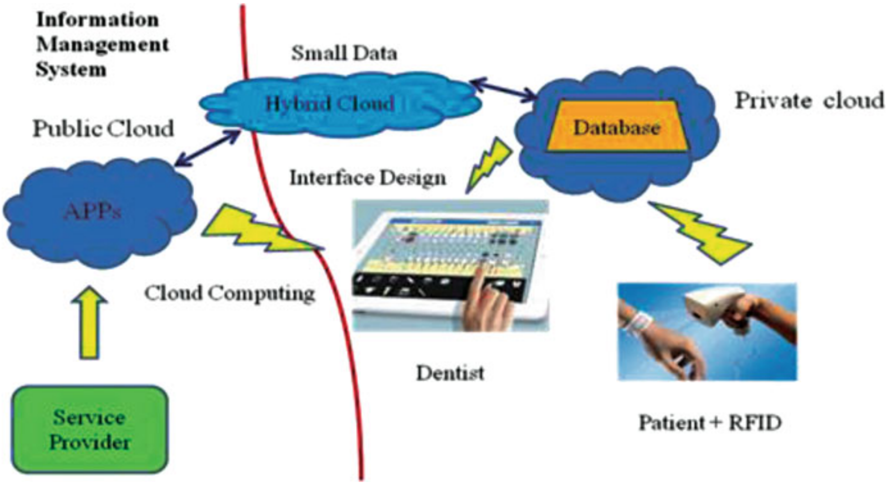

Fig. 14.2 Intelligent dental clinic

proposed architecture [3, 4]. Further, mobile services provide customers with ubiquitous services and shorter response time to quickly respond to customers' demand. Moreover, a lot of customer messages can be aware and collected by the sensors of mobile devices to continuously improve service quality [5].

The platform provides further features including flexible communications on geometry and color shading, the customizable dental order, and global data analysis. Moreover, the platform offers a variety of connecting services for various mobile devices such as smartphones and tablet PCs to connect to the system and communicate with global partners.

14.2 Integration of Digital Information

In the dental clinic, there are quite a lot of data produced on a regular base including information of extraoral impression, intraoral impression, CBCT dental medical image, occlusion and TMJ analysis, and tooth shade matching. The development of tooth shading device is discussed in the following.

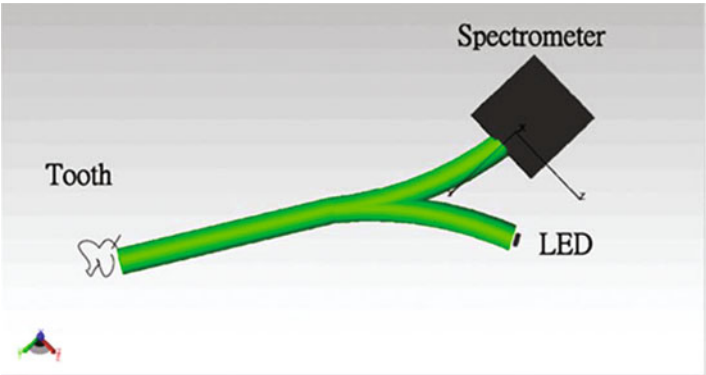

Fig. 14.3 Experiment setup using Y-shaped bifurcated fiber cables with a source leg to carry light from a light-emitting diode (*LED*) to a tooth surface and a spectrometer leg to carry light reflected by the tooth to a spectrometer

14.3 A Shade Guide Development Based on Open-Source Technology

Dental color matching is a challenging aspect of prosthetic dentistry. A dental shade guide is an essential tool used in dental labs and dental clinics to determine the color of natural teeth [6–13]. Color measurement apparatus consisted of a spectrometer and fiber bundles fixed on an optical table as shown in Fig. 14.3 with probe bundles with round bundle light source and single-fiber spectrometer legs with SMA connector. The bifurcated fiber cables with a source leg to carry light from a light-emitting diode (LED) to a tooth surface and a spectrometer leg to carry light reflected by the tooth to a spectrometer. The probe tip is in contact with the tooth surface and the height of the tip raised from tooth surface to 0.5 mm and 1 mm, respectively.

14.4 3D Printing Applications in Digital Dentistry

3D printing, also referred to as "additive manufacturing," has become one of the most well-known technologies since the twentieth century. Comparing to the conventional manufacturing, 3D printing has several remarkable advantages, such as overcoming the limitation of machining to make complex structures, high resolution, being simple for manipulation, and being easy for customization. Moreover, some 3D printers are small and economic enough for public to afford. Ideas and products can be made without sending into the workshop, which reduces the criteria of designing and fabrications at present; medical applications for 3D printings can be briefly catalogued into several uses, such as a means of manufacturing prototypes rapidly, or models for clinic, teaching, and surgical guides, or implants and prosthetics, or bioprinting [14, 15].

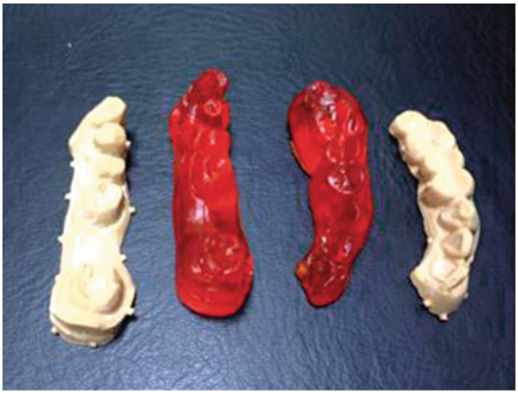

Fig. 14.4 RP model products from FDP and milling machine

IMSC has established a 3D printing production line to assist industries and clinics in dental areas. Among different methods of 3D printing, "projection-based stereolithography apparatus" (PSLA) has additional advantages of economic and relatively smooth finished textures. In Fig. 14.4 which shows that two tooth models (colored in red) were manufactured for a dental technology company. In contrast to conventional manufacturing of making tooth models, the advantages of using PSLA manufacturing are higher resolution provided by digital files and less relaxation occurring in the PSLA material. The manufacturing procedure of PSLA requires .stl files to regenerate geometries, and these .stl files are often obtained by either intraoral or extraoral scanners [16]. Despite the improvement of resolution of scanners from macros to micros, one of the major reasons that this technique has not yet been largely used in practice is due to its loose accuracy and inconsistency, especially when it is applied to those assemblies requiring high precision. The accuracy of a finished component is influenced by many effects, from a preparation process [17], operating conditions [18, 19], a post-process [20], and other manufacturing processes with specific chemical reaction [21]. A standard operation procedure is defined to overcome these issues making loose accuracy and inconsistency to allow a printed model fitted with a manufactured zirconium denture, as shown in Fig. 14.5 below. It is believed that once accuracy and precision are repeatable, 3D printing cannot only be used in making models for teaching or guiding but also explores more applications, for instance, making orthodontic braces and quality control in the production line of tooth manufacturing.

14.5 Conclusions

Change toward digital era is an irreversible global trend. Due to business competition, most medical facilities are designed as a close system. With the gradual opening up of the technology and broad network connection, medical processes will become simplified and efficient. Thus, both dental lab and dental clinics work

Fig. 14.5 PMMA restoration on FDP model

increasingly in a smart way. Based on the development and validation of new technologies, MDIC continuously develops an international digital ecosystem platform that allows patients' clinical satisfaction even higher than before.

References

1. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dent Mater J. 2009;28(1):44–56.
2. Van Noort R. The future of dental devices is digital. Dent Mater. 2012;28(1):3–12.
3. Hashem IAT, Yaqoob I, Anuar NB, Mokhtar S, Gani A, Khan SU. The rise of "big data" on cloud computing: review and open research issues. Inf Syst. 2015;47:98–115.
4. Qi H, Gani A. Research on mobile cloud computing: review, trend and perspectives. Paper presented at the Digital Information and Communication Technology and it's Applications (DICTAP). Second International Conference on. 2012.
5. Alqahtani AS, Goodwin R. E-commerce Smartphone application. IJACSA Int J Adv Comput Sci Appl. 2012;3(8):54–9.
6. Tung FF et al. The repeatability of an intraoral dental colorimeter. J Prosthet Dent. 2002;88(6):585–90.
7. Browning WD et al. Color differences: polymerized composite and corresponding Vitapan classical shade tab. J Dent. 2009;37:p. e34–9.
8. Vichi A et al. Color related to ceramic and zirconia restorations: a review. Dent Mater. 2011;27(1):p. 97–108.
9. Jarad FD, Russell MD, Moss BW. The use of digital imaging for colour matching and communication in restorative dentistry. Br Dent J. 2005;199(1):43–9.
10. Karaagaclioglu L, et al. In vivo and in vitro assessment of an intraoral dental colorimeter. J Prosthodont. 2010;19(4):279–85.
11. Pop-Ciutrila I-S, et al. Shade correspondence, color, and translucency differences between human dentine and a CAD/CAM hybrid ceramic system. J Esthet Restor Dent. 2016;28:S46–55.
12. Gómez-Polo C et al. Differences between the human eye and the spectrophotometer in the shade matching of tooth colour. J Dent. 2014;42(6):p. 742–5.
13. Schwabacher WB, Goodkind RJ. CIE (Commission Internationale del'Eclairage). Colorimetry – technical report. CIE Pub. No. 15, r.e.V.B.C.d.l.C. 2004.

14. Seol Y-J, et al. Bioprinting technology and its applications. Eur J Cardiothorac Surg. 2014;46(3):342–8.
15. Ventola CL. Medical applications for 3D printing: current and projected uses. Pharm Ther. 2014;39(10):704–11.
16. Gibson I, Rosen DW, Stucker B. Additive manufacturing technologies: rapid prototyping to direct digital manufacturing. New York: Springer US; 2009.
17. Canellidis V, et al. Pre-processing methodology for optimizing stereolithography apparatus build performance. Comput Ind. 2006;57(5):424–36.
18. Nee AYC, Fuh JYH, Miyazawa T. On the improvement of the stereolithography (SL) process. J Mater Process Technol. 2001;113(1–3):262–8.
19. Chartier T, et al. Stereolithography process: influence of the rheology of silica suspensions and of the medium on polymerization kinetics – cured depth and width. J Eur Ceram Soc. 2012;32(8):1625–34.
20. Kim H-C, Lee S-H. Reduction of post-processing for stereolithography systems by fabrication-direction optimization. Comput Aided Des. 2005;37(7):711–25.
21. Dufaud O, Le gall H, Corbel S. Application of stereolithography to chemical engineering: 'From Macro to Micro'. Chem Eng Res Des. 2005;83(2):133–8.