Medical Service System Innovation of Small and Medium-sized Dental Clinics Supported by Digital Dental Design and Service

Jianliang Lei
Fuzhou Jin an AN@KA Dental Clinic, China
N133788460@qq.com

Abstract

Targeting the service demand of small and medium-sized dental clinics in the medical big data era, this paper studies the application of the digital dental service platform and explores ways to build a new oral health service model with existing resources. The new model allows efficient medical resource sharing and ensures that small and medium-sized dental clinics and patients can access intelligent and quality services tailored to their needs.[1] The focus of the research is how the Dental Medical Service System (DMSS) is influenced by the standardized service processes and treatment specifications in the establishment and application of the Digital Dental Design and Service Central (DDDSC). The paper will be a useful guide for demonstrating how small and medium-sized dental clinics can build a new digital dental service model.

Keywords: digital dental design and service, dental medical service system, dental care quality management

The concept of artificial intelligence (AI) was first introduced at the Dartmouth Conference in 1956. "AI is the science of knowledge--how to represent knowledge and how to obtain and use knowledge," according to Stanford professor Nils J. Nilson. In simple words, AI is the use of intelligent machines to simulate human intelligence for judgment, reasoning, learning, problem-solving, and other related activities, i.e. AI simulates the laws of human intelligent activities. After decades of development and evolution, especially when computer hardware and software soar in

the new century, people's lives are growing more and more digital, and AI is updated and redefined too. "Artificial intelligence is an interdiscipline that brings together computer science, cybernetics, information theory, neuropsychology, philosophy, linguistics, and other disciplines, and its goal is to make the machines behave intelligently like people". As smart wearables become more popular and bio-detection and IT technologies advance, it becomes even more convenient to collect, summarize, and analyze big data for the medical sector. All this has driven the fast introduction of AI into the health care industry.[2] AI has been seen in pre-hospital management, in-hospital treatment, and post-hospital rehabilitation of patients, as well as clinical research, drug development, industry management, hierarchical treatment, and medical education and training, to name just a few. The future of medicine is impossible without AI.

AI technologies are reaching the core area of the dental industry. Imaging diagnosis technology built on the cone beam computed tomography (CBCT), computer-aided design (CAD) and computer-aided manufacturing (CAM) for dental restoration, 3D scanning, and 3D printing are finding their way into all dental subspecialties.[3] Take conventional restoration of tooth defect as an example: the complex process may involve such steps as tooth preparation, alginate/silicone rubber impression, plaster filling, visual colorimetry, plaster model trimming, waxing, prosthesis casting/cutting, staining, modification, and placement. In addition to the clinical diagnosis and treatment time, the patient's final dental placement may take one to two weeks. Digital technologies have brought about a whole different treatment model. Except for the teeth preparation and placement that still need to be done by a clinician, the entire process can be completed with digital equipment: digital impressions through 3D scanning and CAD/CAM-powered chairside design and fabrication. Going digital minimizes the time required for a single restoration, which usually takes only 2-3 hours in one day. With the above technologies, the treatment time has been sharply reduced, treatment efficiency and accuracy greatly enhanced, and patient comfort notably improved.

Compared with traditional fixed and movable restoration of abutment teeth, implant prosthesis boasts some unmatched advantages: no damage to adjacent natural teeth, good stability of the prosthesis, high chewing efficiency, aesthetic and lightweight properties, etc. Among all the dental subspecialties, implant treatment sees the most extensive use of digital technologies: from the pre-consultation data acquisition to the digital surgical design and execution, and to the digital restoration, the entire process can be designed and executed with the support of digital technologies and AI. Low-dose, high-resolution, reconstructible CBCT can find out the quality and quantity of the hard tissue in the implantation area and its relationship with important anatomical structures around it. The software allows the virtual design of the implant position within the bone tissue. By scanning the intraoral teeth and soft tissues directly or the plaster model indirectly and fitting the scanned data to the hard tissue data obtained from CBCT, a more precise virtual model of the hard and soft tissues of the implantation area can be prepared and used to support surgical navigation or surgical guide fabrication in the future. Supported by the virtual model, the placement position, angle, and direction of the implant (or future prosthesis) can be designed through CAD and AI, which can help make surgical guides via 3D printing or enable dynamic surgical navigation. In this way, the implant can be precisely placed into the corresponding site in the minimally invasive surgery (a flapless or minimal flap procedure), which can reduce tissue trauma, accelerate bone-implant contact, and facilitate the healing of adjacent soft tissue. Face scanning allows doctors to know the patient's skin tone, lip shape, facial shape, and the relationship between the pupil plane and the teeth, which enables a more detailed design of the shape, size, and color of the prosthesis, adding to its personalized features aesthetically. By tracing the digital facebow and mandibular movement trajectory, and matching the data of the virtual model, virtual articulator, and jaw position, the ideal bite position and bite trajectory of the patient can be precisely designed on the virtual articulator, which can minimize or eliminate the needs for occlusal adjustment after wearing the prosthesis. By combining the digital facebow and digital bite relationship

with the virtual model fitted by the pre-consultation data, a prosthesis whose color, shape, and bite relationship meets the patient's personalized requirements can be quickly fabricated through CAD/CAM. Digital technologies and AI-assisted design and fabrication have penetrated every step of implant therapy. In the future, AI-powered surgical robots will replace traditional clinicians to place implants more precisely through minimally invasive surgery.

Despite the extensive application of digital technologies, implant therapy remains an invasive procedure. There are still a series of problems and challenges: high access threshold and technical sensitivity, the need for soft and hard tissue augmentation surgery due to the tissue condition of the implantation area, frequent postoperative maintenance, and secondary peri-implantitis. In China, implant therapy with lucrative profit has made its way widely into many dental clinics, including most of the private ones. Due to poor technical skills of the medical staff and imbalanced hardware, however, post-implantation problems abound: inadequate preoperative examination and diagnosis, loose control over indications, incomplete preoperative risk assessment, defective imaging analysis, lack of correct intraoperative surgical approach or surgical guide, and lack of reasonable shape and occlusal design for postoperative restoration, etc. In patients suffering the loss of teeth, especially complex multiple ones, the vast majority are the elderly. More factors should be evaluated when implanting for elderly patients. First of all, elderly patients should be assessed concerning previous occupation, literacy, and psychological factors, to understand their expectations for the prosthesis and the restorative process. They fall behind younger ones in both literacy and knowledge of the oral treatment process, which means that disputes may easily arise without knowing and explaining to them properly. Secondly, dentists should ask and record the patient's general conditions and medications. Although implant surgery can be minimally invasive in many cases with the assistance of digital technologies and AI, the surgery duration remains long for some patients with complex loss of teeth, thus bringing high subsequent risks. Learning about elderly patients' underlying health conditions (such as hypertension,

heart disease, diabetes, hematological diseases, thyroid diseases, neurological diseases, and certain infectious diseases) and medication history (such as anticoagulants and antihypertensives) enables dentists to bring under control these underlying diseases and surgery-related risks during the perioperative period. Thirdly, most elderly patients also suffer from such oral diseases as serious periodontal disease, dental tissue loss or pulpal and apical inflammation, disorders of occlusion, temporomandibular joint pain, oral mucosal diseases, and severe loss of soft and hard tissue in the implantation area after long-term failure to restore the missing teeth caused by the above-mentioned diseases. These problems may lead to implant failure or incomplete restoration. Last, elderly patients are bothered by a low metabolic rate and decreasing tissue repair and healing ability. Their postoperative pain, edema, and other inflammatory reactions are more serious than those of younger patients. Combined with systemic diseases, they are poor in psychological endurance, which means the psychological care during the perioperative period needs to be more thoughtful. To sum up, the implant targets real people and cannot be modified or fabricated repeatedly, hence the importance of quality control and risk avoidance during the therapy.

The clinician's little implant experience, insufficient hardware and software of the medical institution, or the lack of or inadequate consideration of the patient's pre-consultation evaluation, systemic/local factors analysis, perioperative care, and post-implant maintenance, all these can be boiled down to the low quality of medical services or uneven development of the sector. The quality of medical services is the lifeline of health providers. National health administrations can regulate and improve the service quality of public general hospitals through a graded accreditation system, to ensure that the public can access quality services. In addition to normal requirements on hardware and software, the system also focuses on a "patient first" service philosophy. The hospitals' quality, service, safety, management, and performance will be repeatedly evaluated to urge continuous efforts in this regard. There lacks such an evaluation system for mushrooming private dental clinics.

Although these private players understand that keeping improving the service is the way to survive the fierce market competition, they remain disadvantaged in terms of talent reserve, experience, and patient loyalty. At the same time, fast yet blind development results in a mismatch between their service quality and their scale and scope of medical services. Take the most popular implant treatment as an example: in addition to the industry regulations and systems that monitor the equipment and personnel qualifications, is there a parallel service provider who can offer guiding constraints and supervision throughout the treatment process and regulate and equalize the therapy quality? That way medical institutions at different competency levels can deliver average medical results while offering patients personalized visual plans and relevant knowledge, thus driving the healthy development of the industry.

DDDSC and **DMSS** built on it may be the solution to these problems.

Definition of DDDSC

DDDSC refers to a dental service organization that provides remote or field assistance to small and medium-sized dental clinics throughout processes such as patient intake, pre-consultation, health information management, AI image diagnosis, clinical decision-making, surgical approach guidance, postoperative complication treatment, and risk prediction, prevention, and control with the help of technologies like Internet+, Internet of Things (IoT), 5G, and AI. It also provides a strict and unified management system that helps these dental care institutions deliver medical services of standard quality, thus promoting the overall development of the regional dental industry. When multiple regional DDDSCs are connected and expanded, an industry-wide big data management center for dental service can also be created.[4] The ultimate goal of DDDSC is to build an industry-wide DMSS that can avoid vicious competition and promote the harmonious and benign development of the industry.

Architecture and Functions of DDDSC

1. Small Dental Unit (SDU) with full dental clinic functions: The SDU can not only act as a normal dental clinic but also provide a venue to carry out relevant

treatment measures formulated on the cloud platform. In addition, it can test the effectiveness of the diagnosis and treatment processes and management systems and help correct existing problems for improvement. The personnel of the medical institutions can also provide off-site medical support for the output of offline ancillary products.

2. Multi-Disciplinary Specialist Platform (MDSP) supported by cloud technology:[5] Through the cooperation with the special committees of the Chinese Stomatological Association (CSA), experts on oral subspecialties can be recruited to analyze the real-time diagnosis and treatment data that small and medium-sized dental clinics upload to the cloud platform through Internet+, IoT, and 5G technologies, offer real-time consultation for patients based on Virtual Reality (VR), and come up with follow-up diagnosis and treatment plans. If a subsequent surgery is needed, the preoperative surgical process (including risk control) can be developed and the surgical guide can be designed virtually online. Corresponding data is transmitted to DDDSC for immediate fabrication through offline 3D printing, and the accuracy of the surgical guide in the model or the patient's mouth can be verified through real-time imaging technology.

3. IT support team: The team includes engineers who are proficient in dental hardware and software technologies. Tasks to be performed by the team include: construction and maintenance of cloud-powered MDSP; port protocol matching and data chain sharing among digital dental imaging equipment, CAD/CAM, 3D scanners, and 3D printers; the connection between the patient health data system and the doctor examination platform; the combination of diagnosis and treatment quality evaluation, cost accounting, and medical cost control system; development of client software or mobile applications; maintenance of digital equipment and troubleshooting of common problems, etc..[6]

4. Customer service center: The center is responsible for promoting and marketing dental design services; promptly responding to and transferring online applications for dental design services, contacting SDU and MDSP to offer real-time

online consultation, create diagnosis and treatment protocols, and offer services offline; responding to, explaining, and giving feedback on problems during the provision of service, and offering timely solutions.

5. Logistics management team: The team is tasked with pooling and allocating resources reasonably; monitoring the effectiveness and quality of services; recruiting and reserving talents; managing finance; and contacting and coordinating with social and public affairs regulators.

Application Scenarios of DDDSC

DDDSC is expected to facilitate dental diagnosis and treatment with comprehensive technical support at different levels. Oral implantology is of greatest promise for DDDSC as it sees the most extensive use of digital and AI-assisted diagnosis and treatment technologies. The diagram below briefly describes DDDSC service flow for difficult and complex implant cases (see Figure 1):

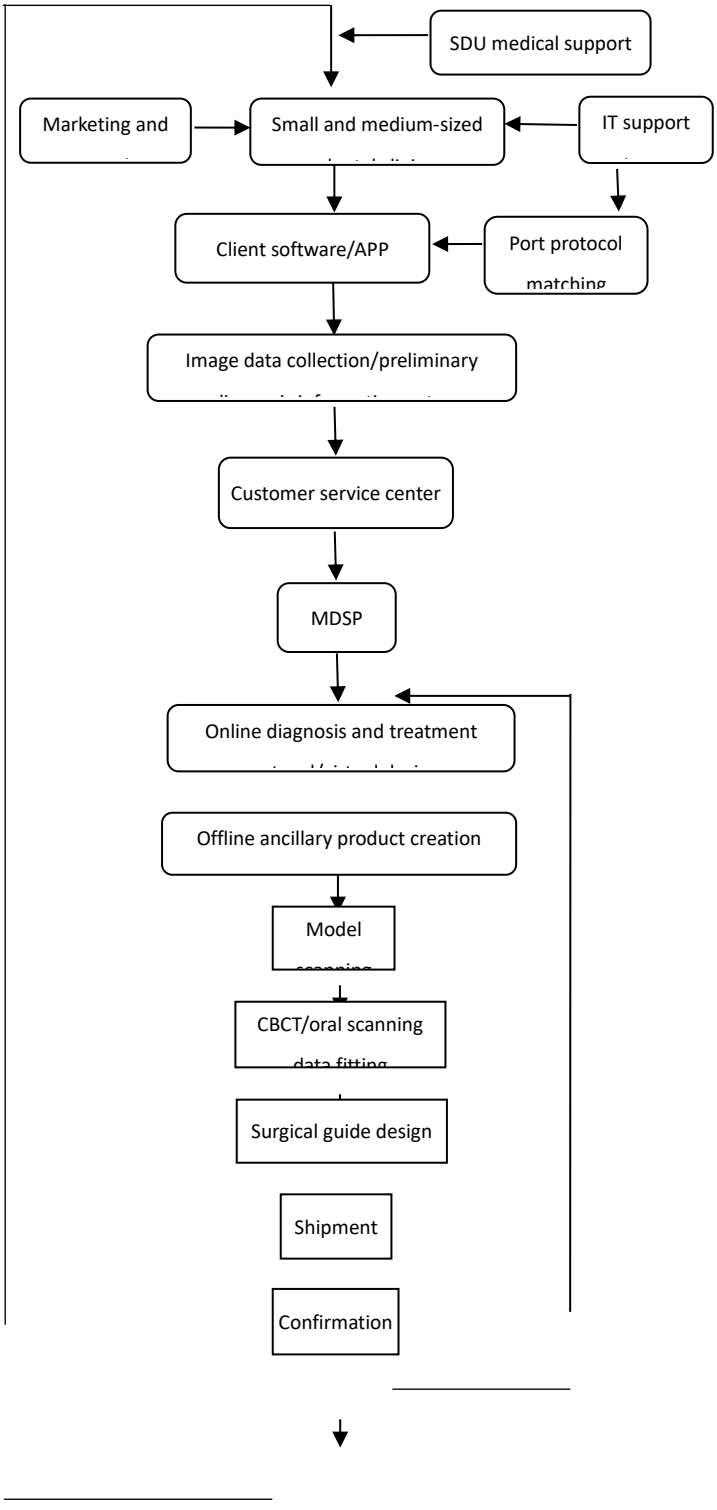

Figure 1. DDDSC service flow for difficult and complex implant cases.

DMSS Construction Powered by DDDSC

DMSS includes public information service and diagnosis and treatment service.

The public information service is mainly about providing patients with personalized visual schematic design and dental knowledge, dentists with predictable and practical personalized plan design, and dental clinics with business information and other services. The purpose is to promote the dissemination of information so that relevant personnel can access the service offerings conveniently, and patients, physicians, and medical institutions can view what they care about separately. DDDSC allows patients to learn about the diagnosis and treatment flow and get prepared for the prognosis. They can also better understand and confirm the service results and satisfaction, which can help avoid unnecessary disputes. Dental diagnosis and treatment service relies on DDDSC to predict and design the results. Dental Medical Quality Management (DMQM) in the process can improve dentists' efficiency and make the service more convenient for patients.[7]

While providing diagnosis and treatment services for small and medium-sized dental clinics, DDDSC also exports to them the medical management evaluation system, which means standard treatment process, considerate and well-rounded service items, and strict service quality control. In the case of difficult and complex implant surgery, for example, the services provided may seem to only include a surgical guide for precise implantation and advice on surgical procedures and risk avoidance, yet there are lots of preparations for the two. The need for online joint consultations will press clinics to collect medical data, execute clinical examinations, and upload images and data in a standardized model. At the same time, clinicians must also provide their preliminary diagnoses and treatment schemes. The pre-consultation data collection, uploading, and subjective judgment cultivate the habit to follow a standard diagnosis and treatment process for the medical institutions, and the habit will be likely to be continued in handling simple cases or other diseases in the future. Secondly, DDDSC facilitates the concept of considerate and well-rounded services, which include early consultation, perioperative psychological and physiological care, postoperative follow-up, and humanistic care for previous patients. All of these services will be supported and guided by SDU staff off-site. Thirdly, a

combination of preoperative, intraoperative, and postoperative supervision demands higher medical quality: preoperative consultation and virtual design are completed on MDSP before the operation is completed under the guidance of an SDU-made guide that has been validated with a physical model; real-time imaging surgical system will uploads the entire surgical process, with risk control by MDSP; there are postoperative complication control and risk avoidance plan, along with technical support from SDU. Last, unlike the traditional operation and management of a streetside clinic, the need for standard treatment and diagnosis flow, considerate service, and stringent quality control forces the management of small and medium-sized dental clinics to maintain a smooth relationship among employees responsible for medical service, data O&M personnel, guidance and marketing, finance and logistics support. All the favorable factors within the institution must be combined to ensure a smooth operation. This is also a typical example of how new technologies stimulate management model reform.

The DMSS of small and medium-sized dental clinics built on DDDSC boasts digital storage, which means retrospective and traceable data.[8] The traceability can contribute to a Plan-Do-Check-Act (PDCA) problem-solving flow that covers diagnosis, treatment, and related details within the institution, which would boost a service quality spiral at the clinics. In addition, the phased traceable data can also provide an objective basis for health care administrations to evaluate whether small and medium-sized dental clinics meet the operational standards, thus ending the history of no rating. As DDDSCs in different regions share the data, a big data center can be established to not only serve dental clinics but also provide data support for health administrations.

DDDSC Market Analysis

1. The number of newly-opened small and medium-sized dental clinics is growing quickly and the overall level of private dentists in these institutions is low. Today small dental clinics (with an area of less than 300 square meters) prevail in China, accounting for 90% of the entire dental care market. Statistics show that there

were some 65,000 small and medium-sized dental clinics in China in 2016, and the 2019 number rose to 100,000. According to incomplete figures, Fuzhou had 1,600 small and medium-sized dental clinics in 2019. Despite the epidemic in 2020, there was a rush to open new dental clinics. In 2020, the number of newly-opened dental clinics was about 150, and the annual growth rate would be 3.5%. Nevertheless, it is still necessary to raise the threshold for private dentists through further training and standard practice.

2. The population is aging and patients with missing teeth are large in number. In 2015, China's population aged 60 and above reached 222 million, accounting for 16.15% of the total. The numbers increased to 248 million and 17.17% in 2020, and people aged over 80 years amounted to 30.67 million. By 2025, Chinese over 60 years old will exceed 300 million, making China a "super-aged" country. The number of Chinese oral patients has now exceeded 600 million, an incidence of nearly 50%, but the consultation rate is less than 5%, meaning the vast majority of patients have not been properly treated. Moreover, a striking 86.1% of Chinese aged between 65 and 74 have lost teeth, according to the 4th National Oral Health Survey. There is a great deal of demand for tooth replacements.

3. Quality oral health care is urgently needed. Growing information technologies have minimized the information inequality between doctors and patients, and it becomes evident that patients need high-quality oral health care.

4. The oral health care market is seeing explosive growth. In 2008, China's dental market was just valued at CNY 20 billion, and by 2017, it was close to CNY 100 billion, with a ten-year compound growth rate of 18%. The market compound growth rate in the next decade will hit 30% or higher, and the market will grow by CNY 300 billion.

DDDSC's Innovation

DDDSC can use the minimal investment to help small and medium-sized dental clinics overcome the challenges of standard operation and market competitiveness, i.e. the optimization of the dental service. At the same time, third-party guidance is

provided. By ensuring patient safety and satisfying doctors, DDDSC can improve clinic efficiency and profitability and benefit society.

Estimation of DDDSC Construction Cost and Expected Earnings

As the regional DDDSC is built on SDU, the wealth level to invest in DDDSC is high, but the silver lining is that the quality of DDDSC can be indirectly improved. In addition to building SDU, MDSP is also needed to recruit a large number of "cloud" dentists with rich clinical experience in subspecialties to form a solid technical team. DDDSC also needs a powerful customer service center and IT support team, all of which require sufficient funds. Despite the high initial investment, DDDSC can promise ample return in the long run as the domestic dental market is seeing cut-throat competition. On top of that, the data services provided by DDDSC can also find their way into national health administrations.

Under the regional DDDSC architecture, building an SDU is estimated to cost CNY 6 million; setting up MDSP and assembling a "cloud" expert team need CNY 5 million; the customer service center and IT support team cost CNY 3 million; and other miscellaneous expenses amount to CNY 1 million.

The estimated pricing of the medical service provided by the regional DDDSC is CNY 500 each time, and the total revenue is positively related to the number of services required by the small and medium-sized dental clinics.

Conclusion

Along with the rapid transition from digital oral technology 3.0 to 4.0, the service scenario of doctors and patients becomes completely different in China. DDDSC will become the epitome of the change. DDDSC makes dental clinical work safer, more efficient, and more predictable. DDDSC can reduce the diagnosis and treatment risks, enhance patient safety, expand the clinical skills of the clinic staff, and improve the management effectiveness of medical facilities. All of these will lead to a dramatic revolution in the services of small and medium-sized dental clinics, and will also indirectly improve the overall market competitiveness of private dental clinics.

References

1 Li, Wei, et al. "Construction of new-generation digital hospital in smart city." Chinese Medical Equipment Journal, vol. 36, no. 11, 2015, pp. 52-56. Print.

2 Sun, Yuting, and Liye Zhou. "Opportunity and challenge of mobile health care under the background of 'Internet +'." Soft Science of Health, vol. 31, no. 1, 2017, pp. 27-30. Print.

3 Wang, Zushun. "Stomatology from digital to intelligent future—looking forward to the oral 4.0 era." The Guide of Science & Education, no. 10, 2019, pp. 53-54. Print.

4 Li, Hua, et al. "Construction and exploration of digital dental management model." People's Military Surgeon, vol. 62, no. 12, 2019, pp. 1221-1224. Print.

5 Wang, Xiao, Aidi Zhang, and Jin Yan. "Application prospects of big data in health care." Chinese General Practice, vol. 18, no. 1, 2015, pp. 113-115. Print.

6 Li, Wei, et al. "Present situation and solutions for hospital information platform in China." Chinese Medical Equipment Journal, vol. 39, no. 2, 2018, pp. 96-102. Print.

7 Li, Wei, et al. "Regional healthcare big data platform solutions planning and preliminary design." Chinese Medical Equipment Journal, vol. 39, no. 7, 2018, pp. 34-40. Print.

8 Gong, Jun, et al. "Research and practice of medical big data platform." Chongqing Medicine, vol. 48, no. 14, 2019, pp. 2504-2507. Print.