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Pedagogy and innovative care tenets in COVID-19 pandemic: An enhancive way through Dentistry 4.0

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ABSTRACT

The global oral healthcare sector has now woken to implement Dentistry 4.0. The implementation of this revolution is feasible with extensive digital and advanced technologies applications and the adoption of new sets of processes in dentistry & its support areas. COVID-19 has bought new challenges to dental professionals and patients towards their customised requirements, regular dental health checkups, fast-paced and safe procedures. People are not visiting the dentist even for mild cases as they fear COVID-19 infection. We see that this set of technologies will help improve health education and treatment process and materials and minimise the infection. During the COVID-19 pandemic, there is a need to understand the possible impact of Dentistry 4.0 for education and innovative care. This paper discusses the significant benefits of Dentistry 4.0 technologies for the smart education platform and dentistry treatment. Finally, this article identifies twenty significant enhancements in dental education and effective care platforms during the COVID-19 pandemic by employing Dentistry 4.0 technologies. Thus, proper implementation of these technologies will improve the process efficiency in healthcare during the COVID-19 pandemic. Dentistry 4.0 technologies drive innovations to improve the quality of internet-connected healthcare devices. It creates automation and exchanges data to make a smart health care system. Therefore, helps better healthcare services, planning, monitoring, teaching, learning, treatment, and innovation capability. These technologies moved to smart transportation systems in the hospital during the COVID-19 Pandemic. Modern manufacturing technologies create digital transformation in manufacturing, optimises the operational processes and enhances productivity.

1. Introduction

In the current scenario, there is an essential requirement for a diverse advancement in the healthcare. Technologies of Dentistry 4.0 play an essential role in education, training, planning, treatment, part development, and surgery. The major technologies of Dentistry 4.0 are Artificial Intelligence (AI), Internet of Dental Things (IoT), Additive Manufacturing (AM), Cloud Computing, 5G technologies, dental digital scanners, Virtual reality, Robotics, Big data, and others. These technologies create an online teaching and learning platform in institutes of higher education during the COVID-19 Pandemic. It helps to enhance learning for creative and innovative techniques of the treatment process. Industries catering to the healthcare sector are now adopting advanced technical concepts for improving the treatment process. Further, they are employing applications like data mining, data analytics, and pattern recognition. IoT connects all dentistry parts through the internet application and provides opportunities for smart devices and sensors. It monitors all ongoing hospital management systems during the COVID-19 pandemic [1–3].

The skills of doctors and surgeons can be improved with the help of Dentistry 4.0 technologies. It provides disruptive transformation in the dentistry field. They can further undertake various research, development, and commercialisation activities. Dentistry 4.0 technologies are

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used to improve the safety and comfort of the patient with better connectivity. These are used to record and track various dental devices' data, which helps to increase security. These Dentistry 4.0 technologies have great potential to fulfil the challenge of customisation, speed, and complexity during critical dental equipment manufacturing. It provides an ideal opportunity for development and growth in healthcare, thus providing much more development in dentistry among all other dental revolutions [4–6].

Robotics is an advanced emerging technology used to create automation in the dentistry field during the COVID-19 Pandemic. All essential tasks, incredibly repetitive or hazardous tasks, can quickly be undertaken in the hospital, not easily. Dentistry 4.0 technologies create digital transformation in healthcare and facilitate better management of the entire value chain. Virtual technologies create a virtual world that is helpful for better communication, teamwork, and decision-making process. These are used to analyse the behaviour of complex dental procedures [7,8]. Dentistry 4.0 technologies are helpful for the dentist to sort out various challenges in the current scenario. This makes better protection of the patient during the COVID-19 pandemic.

Additive manufacturing technologies are used to manufacture patient-specific implants, teeth, dental, braces, and other required devices. This is helpful to repair the fracture of teeth and undertake other complicated dental treatments. Dentistry 4.0 technologies provide better tools and surgical devices to enhance the quality of patient outcomes [9,10]. This paper discusses the Dentistry 4.0 technologies useful for healthcare education and effective care during the COVID-19 Pandemic in the current scenario. Discusses the Smart education platform of Dentistry 4.0 technologies diagrammatically and Improving patient treatment using Dentistry 4.0 technologies. The significant enhancement of dental education and dental care platform during COVID-19 Pandemic using Dentistry 4.0 technologies is discussed briefly. Thus, Dentistry 4.0 technologies play a significant role to create advancements in the field of healthcare.

2. Dentistry 4.0 for healthcare in the period COVID-19 pandemic

The quality of healthcare can be improved by using Dentistry 4.0 Technologies, which includes dentistry devices, vaccines/medicines, and dentistry procedures or operations at a lower cost. Artificial Intelligence, Virtual Reality, Voice Search, and Blockchain are some emerging propitious dental care technologies, which can play a critical role in the health care industry. These help patients to take their medicine within a prescribed time frame and create an automatic reminder mechanism. These are also helpful for identifying patients at higher risk and enabling the dental staff for operative measures on a priority basis [11–13]. As a priority for high-risk patients, personalised care can play a huge role. Based on the patient's previous treatment history, the forthcoming dental procedures are designed and recommended for customised personal health care. Thus, Dentistry 4.0 technologies play an important for the dental industry.

3. Dentistry 4.0 strategies for the erudition of craniofacial cure

For craniofacial treatment, the main challenge is to treat complicated skull and face bone and other hard tissues. So, dentistry 4.0 technologies are available to fulfil this challenge and help perform facet joints' proper functioning to address various craniofacial related learning problems. These technologies develop various devices which can be used to address various clinical requirement during COVID-19 Pandemic. Dentistry 4.0 technologies like additive manufacturing offer customisation, which is an essential requirement in healthcare. Surgical implants are developed for the repair of connective tissues and can facilitate quick clinical trials and investigations. These technologies are used for patient-specific 3D craniofacial implants in lesser time and cost [14,15].

All craniofacial related implants and prosthetics are used for proper face joint replacement and alignment of the surgery. Technologies like Artificial intelligence is used to create human-like intelligence, which helps to predict disease and defects. Dentistry 4.0 shows promising applications for personalised patient management and promotes practice to perform the actual dental surgery. These are used for clinical trials to facilitate the dentistry field in the future [16,17].

4. Perquisites of Dentistry 4.0 notion in education

Dental industries will change and update with growing technological advancements to hold their positions in the education system. Dentistry 4.0 technologies also an excellent example of it as all the processes from patient's registration data monitoring and test reports. The patient's previous history of self-care data is managed online, which can helpful for the teaching-learning process. Dentistry 4.0 technologies' most prominent advantage is that an individual's data stored on it is not available on some server owned by some application; instead, it remains with the individual. These are so capable and simple at the same time that they can innovate the whole digital system of marketing with continuous data collection, displaying of digital advertisements, along with the safety and holding of digital assets. Health care can indirectly benefit from virtual reality as no other technology is available that relate virtuality so precisely [18–20].

During these COVID-19 days, people or patients can have counselling sessions from their own homes with complete privacy as smartphones and tablets replace traditional monitoring and recording devices. Innovations are making household gazettes like smartphones or tablets more accessible and user friendly from the point of view of both the health care industry and patients. This way, the technical advancements are giving options to the people or patients according to their choice. Remote areas benefit dental education and care with telemedicine with the same facilities as metropolitan cities. Hospital infrastructures are well equipped for fast communication during any emergency using dentistry 4.0 technologies during the COVID-19 pandemic [21,22].

5. Smart pedagogy platforms through Dentistry 4.0 technologies in COVID-19 pandemic

The philosophies like Dentistry 4.0 are being reported as a perfect candidate that serves all the features and strategies in uplifting the healthcare domain and the societal living standard during the COVID-19 pandemic [23,24]. Fig. 1 explains the numerous revealed facts, notions, and concepts from the Dentistry Revolution background, i.e., Dentistry

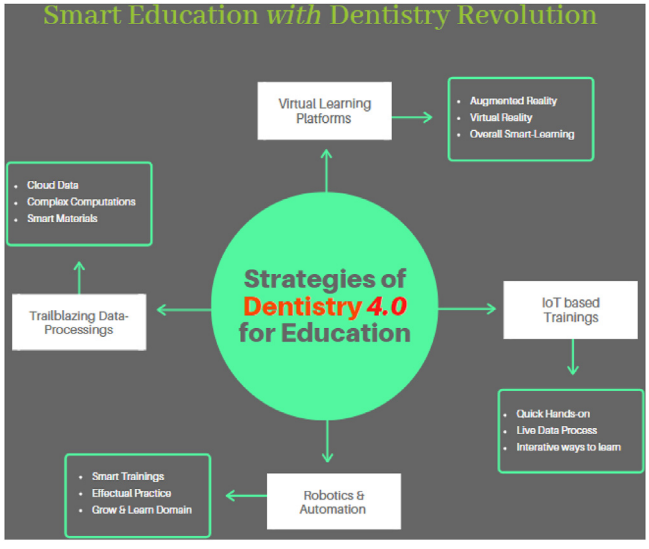

Fig. 1. Dentistry 4.0 deliverables for making Smart Education during COVID-19 Pandemic.

4.0, to support the education level at several platforms. It also explores the contemporary data processing methodologies, education-based applications of the internet of things, smart learning through umpteen virtual bases, etc. Automation, robots, and smart computations further enable and open the doors for this medical revolution informing education more practically.

Shifting of Electronic Health Records will be beneficial for everything and help tackle smooth functioning in the dentistry field. Technologies provide an extensive network that can communicate, but several networks will be non-communicable due to the lack of interconnectivity. Electronic Health Records are often intertwined with Big Data, a kind of buzzword of the digital era. A huge amount of data is collected and processed for the analytic purpose [25,26]. This reduced the cost of healthcare and improved the life quality of teeth with proper treatment. Dentistry 4.0 technologies enhanced quality, efficiency and provided advanced dental research.

6. Enhancing learning of patient care process via smart Dentistry 4.0 technologies in COVID-19 period

The patients' support and care are two utmost issues to be undertaken while implementing any relevant concept in this domain during the COVID-19 Pandemic. In this way, Dentistry 4.0, along with its all the smart and updated tooling, offer a bunch of fruitful outcomes in terms of smart care, better treatments for the patients, serving at remote levels, learning with working, applications of smart processing's and compatible materials, etc. for making the patients happier at the end door [27,28]. Data management makes this philosophy more interactive, safer, and confidential during the COVID-19 Pandemic through cloud-based services. Fig. 2 reflects the discussed Dentistry 4.0 and its support in making the learning of patients treatment more effective and healthier.

7. The significant potential of Dentistry 4.0 technologies during COVID-19 pandemic

Technology, like deep learning, provides new solutions to fulfil various challenges. This helps to predict the dental treatment outcomes of the COVID-19 patient. Big data is used to collect a massive amount of data and information for personalised patient's personalised treatment. The data can be analysed from a variety of sources. The innovative drug can quickly develop to improve the quality of healthcare. Robots change the way of healthcare treatment. This has excellent potential to helps the surgeon while performing surgery. It is used to perform physical therapy and another essential treatment process [29,30].

3D printing is revolutionising in healthcare to fulfil the dental supply chain requirement during the COVID-19 Pandemic. This disruptive innovation changes the manufacturing of dental implants, prostheses, and other tools and devices. Researchers are trying this technology to produce human skin layer, organs and tissue. With the help of intelligent physical components, healthcare becomes smart to achieve better performance. Embedded software can communicate and connect through the internet service. Devices can be easily tracked and trace by using a remote control system through connective technologies and sensors. These are enabled to search and collects data from various locations. This helps to exchange and connect the information to perform the various essential task in healthcare. High-quality dental implants are easily manufactured as per desired shape and size with the required materials. Dentistry 4.0 technologies reduce the treatment time, waste and increase automation to prevent errors [31–33].

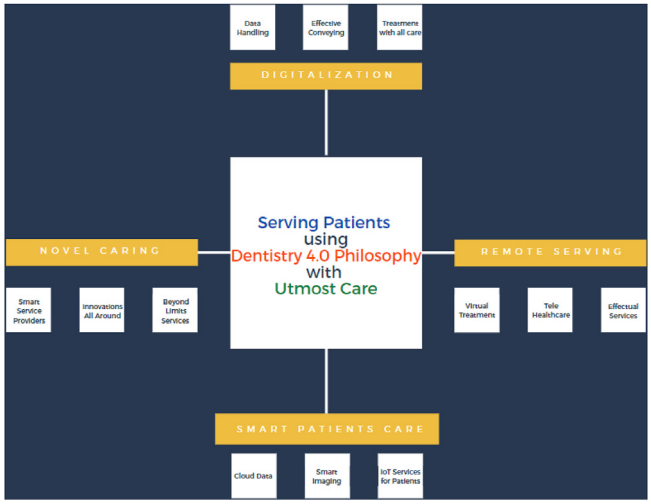

Fig. 2. Dentistry 4.0 support in better treating the patients during COVID-19.

8. Strengthening the dental education and treatment ways during COVID-19 Pandemic using Dentistry 4.0 strategies

In the digital world, the dental industry is continuously transforming by employing new innovative technologies. Various innovations have taken place in dentistry using various smart dentistry devices like electronic chips and electronic health records. It helps to increase the overall satisfaction of doctors and patients during the COVID-19 Pandemic. Dentistry 4.0 technologies make fundamental changes to educate and trained doctors in this ongoing COVID-19 Pandemic. Technologies help to perform a complex and invasive dental surgical process. This can track the health record and medical history of the patient [34,35]. It assists the entire real-time picture of the dental patient's health. Medical billing, clinical trials, and supplying essential medical items are done efficiently. Table 1 discusses dental education and care platform enhancement during the COVID-19 Pandemic using Dentistry 4.0 technologies.

Dentistry 4.0 provides a digital revolution to connect all essential medical devices for better maintenance in hospitals and even beyond. The dentistry field can now gain better quality implants, artificial tools, and devices [113–115]. These technologies have great potential to manufacture various dental tools and devices. The significant benefits of Dentistry 4.0 technologies like sensors are used to manage the ongoing dental processes and even manufacturing all essential treatment-related instruments. These create innovation during the treatment of the patient and convey appropriate information [116–118]. It is used for the manufacturing of customised surgical guides, implants, and other plastic formed models.

9. Dentistry 4.0 technologies complimenting the post-COVID-19 education platform

The ongoing COVID-19 Pandemic has forced researchers, technologists, scientists, educationalists, dental practitioners, industrialists, etc., around the globe to think upon the conceivable and feasible solutions in order to make suitable improvements in the existing structure of all services once this COVID-19 time gets over. In this way, various technological enhancements are coming up to make the current education platform more innovative and superior. This new education platform will be equipped with smart education devices such as tools, quick learning setups, easier hands-on, etc. The techniques like virtual and augmented reality further make this education level more innovative and more advanced too.

10. Discussion

Patient-centric treatment or personalised medicines are proving their roles/importance over the traditional ways of healthcare. Dentistry 4.0 technologies, during the COVID-19 Pandemic, can provide accurately and promised benefits with patient-centric treatment based on individual patient's medical histories. Electronic Health Records are also playing an essential role in dental research to enhance their knowledge base for

Table 1
Enhancement of dental education and dental care platforms during COVID-19 Pandemic using Dentistry 4.0 technologies.

S No	Enhancement	Description	References
1	Appropriate suggestions for dentistry students	•Machines can be intelligently demonstrated for dentistry students •These help to improve the quality of the life of the dental patients by the appropriate suggestions and reminders using intelligent technologies	[36–38]
2	Dental trails for students	•Researchers use digital technologies to perform various trials regarding dental care in lesser time and cost during the COVID-19 Pandemic •These are helpful for the development of new drugs for better care	[39–43]
3	High-performance dentistry tools and devices	•New emerging technologies like AM are used to manufacture high-performance devices in COVID-19 days quickly. •Helps design and development of customised devices	[44–46]
4	Learning of teeth related pain/disease	•These technologies play an essential role to improve the quality of life of patients and helps for learning of teeth related pain/disease. •The patient feels comfortable during the surgery, and there is accuracy during teeth cutting.	[47–50]
5	Understanding patient behaviours	•AI has a great capacity to understand the behaviour of dental patients •This provides adequate support and detects diseases at an earlier stage	[51–54]
6	Learning patient teeth anatomy	•Using 3D printed dentistry parts, dental practitioners can better understand the patient anatomy. •Practical to manufacture precautionary items as required for COVID-19	[55–57]
7	An appropriate decision regarding hard tissue	•With the help of these technologies, appropriate decision regarding hard tissue is provided •Dentistry 4.0 is readily available to fulfil the need of doctors and patients.	[58–60]
8	Dental fracture management	•Technologies like AI and IoT, with the help of innovative procedures, are used for better management of the fracture	[61–63]
9	Dental research	•Facilitates better research, development and commercialisation in the oral healthcare •Teeth diseases are easily identified and create better innovation in teeth graft	[64–67]
10	Real-time locations for the better learning process	•Using IoT, hospitals would be able to manage several new devices and hospital assets for a better understanding •This is used to provides real-time location services of various important and specific devices during the COVID-19 Pandemic. •Dentistry 4.0 have powerful technology used to provide more opportunities in the healthcare system	[68–72]
11			[73–77]

Table 1 (*continued*)

S No	Enhancement	Description	References
	Dental Information management	•With the help of actionable intelligence, information is in the hospitals can be easily managed. •Appropriately manage the dental patient during entering and exits with the help of a digital information system.	
12	Analysis of teeth pain	•Teeth pain is the common cause of pain, which can be easily analysed by using these technologies. •This provides better surgical procedures during the teeth surgery	[78–82]
13	Smart sensor-enabled dental implants	•Embedded sensors are used to provide smart dentistry implants, which provide real-time information. •These smart dentistry implants provide a better fit after implanted in the patient body.	[83–86]
14	Best dental practice	•Teledentistry is a cost-effective way to remotely communicates with the patient. •It is a better way to improve communication by discussing in the online platform •These technologies seem the best tool for virtual meetings and practices	[87–89]
15	Teaching and education	•Holography is a better tool for the teaching, learning and training process •This helps to improve the planning of the entire treatment process •Technology like virtual reality can provide better information to the doctors and patient •Doctors can now visualise patient dentistry data in 3D form	[90–94]
16	Patient record keeping for future learning	•Digital technologies used in Dentistry 4.0 is used to save patient record with their detailed profile •This helps to improve the outcome during treatment in future	[95–97]
17	Craniofacial fracture detection	•AI is used to detect the fracture in the mouth and other hard tissues •It is better used to assess risk and prediction of patient outcomes	[98–101]
18	Robotics enabled surgery	•Robotic technology is introduced in dentistry to perform surgery •This technology improves performance during total knee and hip replacement •It is superior to other conventional technique which reduces blood loss and time while performing an operation	[102–106]
19	Development of real-time capabilities	•Technologies help to develop real-time capabilities to improve the efficiency of the healthcare system •This provides actionable intelligence which can quickly help to tackle ongoing hospital services	[107–109]
20	Transparent information system for the learning process	•These have capabilities of transparent information through the creation and keeping of digital records. •This transparency helps to make appropriate decisions for the students for better learning	[110–112]

developing treatment procedures during some general health problems. The significant enhancement of dental education and dental care platform during COVID-19 Pandemic by using Dentistry 4.0 technologies are: appropriate suggestions, dental trails, high-performance dentistry tools & devices, teeth pain relief, understanding patient behaviours and teeth patient anatomy, appropriate decision regarding hard tissue, dental fracture management, dental research, real-time locations, dental Information management, analysis of teeth pain, smart sensor-enabled medical implants, best dental practice, teaching and education, patient record keeping, bone fracture detection, Robotics enabled surgery, development of real-time capabilities and transparent information system. This way, the healthcare information system can be developed to provide insight during the COVID-19 outbreak and enable the preventive measures well in time.

11. Future scope

In the future, dental education will become better through video conferencing, video streaming, and online discussion platform. There is a better way to communicate and discuss ideas for best practice and consultation. This improves the working environment during the manufacturing of various customised dentistry parts, and it provides a sustainable working platform and rapid response to deliver timely information. This converts the vision into reality and creates a better opportunity for the research and development process. In the future, Dentistry 4.0 technologies can provide endless possibilities in healthcare. Using digital technologies, doctors can save past medical information digitally. Digital imaging systems quickly analyse the patient images and reduces the cost of the treatment process. Some ethical challenges like privacy, accessibility, security and data protection can be quickly sorted out in future. It makes medical concepts through online modes with real-time information. Dentistry 4.0 technologies will adopt efficient results with the help of advanced manufacturing and services. This will innovative the way of dentistry teaching with the best student's experience.

12. Conclusion

Dentistry 4.0 changed our day-to-day healthcare service with the help of intelligent technologies. It reduces human efforts and provides more opportunities to improve the dental education system. These technologies' major benefits are predicting the outcomes and handling all ongoing activities during the COVID-19 Pandemic. Dentistry 4.0 also uses intelligent manufacturing technologies which help to design and manufacture customised dentistry parts. It can be used to improve the safety and quality of surgery. In the future, these technologies would be helpful to perform independent tasks. These can be used to forecast healthcare growth and new developments for improvement. They create a flexible platform for the development of a new product. Dentistry 4.0 technologies are also helpful in analysing the fracture and craniofacial function and analysing the proper functioning. During the COVID-19 pandemic, these technologies understand and analyse various healthcare issues. Dentistry 4.0 enables mass customisation and will introduce new innovative healthcare services.

Declaration of competing interest

None.

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