Digital revolution: A new era in dentistry

Dr. Naseemoon Shaik
Department of Pedodontics and Preventive dentistry, MNR Dental College and hospital, Sangareddy
Email: dr.naseemoonshaik@gmail.com

Dr. Pudi Sriharsha
Department of Prosthodontics and Crown & Bridge, MNR Dental College and Hospital, Sangareddy
Corresponding author email: sriharshabds@gmail.com

Dr. Pranav Sundararajan
Intern, MNR Dental College and Hospital, Sangareddy
Email: pranavsundar999@gmail.com

Dr. Supriya Yadlapati
Intern, MNR Dental College and Hospital, Sangareddy
Email: yadlapati6839@gmail.com

Dr. P. Rajeetha
Department of Conservative Dentistry and Endodontics, MNR Dental College and Hospital, Sangareddy
Email: rajithapabba@gmail.com

Abstract---The Covid 19 pandemic has had a huge impact on human society as a whole. The field of dentistry is not an exception to this. Adaptation to the new situations in the pandemic, due to the vulnerability of dental staff and students, is highly necessary. To do this newer protocols have been generated that are to be used along with the strict adherence of older safety methods. With the advancements of technology, Teledentistry, online learning and other digital alternatives are being introduced to enhance, preserve and continue the various fields of dental practice and education. With the onset of the pandemic, the amount of research being done in various fields of digital dentistry has increased from 2019 to 2020 compared to that of previous years. This review provides an insight about the digitalization of dentistry, the most common technologies in use, a few technologies that have a promising future and the tremendous rise in the research of digital dentistry.

Introduction

In December 2019, COVID 19 was first identified in Wuhan province china, and spread causing the world-wide.[1] The word pandemic is Greek in origin (pan meaning all and demos meaning people). According to WHO, a pandemic is defined as an epidemic that occurs world-wide, or over a wide area, crossing international borders, usually affecting a large number of people. [2] SARS-CoV-2 was confirmed as a 'Public Health Emergency of International Concern (PHEIC)', warranting a co-ordinated international response to fight this unprecedented public health crisis in January 2020. [3,4] The WHO declared COVID 19 a pandemic on 11th March 2020.[5] The Pandemics that occurred in the past include the White Plague of London, Black death of the 15th century, 1918 Spanish flu, 1957-1958, 1968, 2009 swine flu.[6,7]

Computing Technology is ever growing and almost omnipresent in today's world. It creeps into almost any field due to its versatility and enhances both efficiency and comfort due to its ease of use. Dentistry is by no means an exception to this trend. Over the past 6 decades, technology has given dentistry many tools that not only allow for better treatment procedures but also allow for more comfortable treatment modalities for both the dentist and the patient.[8] Other than clinical practice, dental technology has allowed for more accurate and efficient research to be conducted which has helped the field immensely.[9] Digitalisation of dental data and both clinical and research techniques have paved the way for smarter stronger and more accurate methods of treating dental disease.[10] The onset of COVID 19 and its subsequent effects have led to a boom in the use of digital technologies for various reasons ranging from consultations to dental education.[11] The trend of digitalisation in dentistry has hastened to adapt to the new Pandemic situation and many of these changes may influence dentistry as a whole in the future.[12,13]

Clinical Manifestations

COVID 19 is a Predominantly respiratory disease. Patients have general complaints of fever, myalgia, sore throat, runny nose, cough, headache, loss of smell and taste, etc. In patients without previous recent ENT history, loss of smell and taste is suggestive of COVID 19.[14] Other signs and symptoms can include cutaneous manifestations such as; maculopapular rashes, urticaria, vesicular and chibilain like lesions, petechial and purpuric lesions. [15] lesions include: anorexia, dysgeusia, nausea, diarrhoea, hematemesis, dysphagia, melena abdominal pain, faecal occult blood, reflux disease etc. [16] In more severe cases patients have also been reported to show Pneumonia, ARDS, Acute Liver Injury, Acute cardiac injury, etc.

COVID and Dentistry

The SARSCoV-2 Virus has been causing havoc in the entire world especially Health Care Workers (HCW's). The receptors to which the virus binds i.e., the Angiotensin Converting Enzyme (ACE)-II receptors are expressed in large numbers in the mucosa of the oral cavity and these receptors are especially increased during Pregnancy.[17] This puts dentists in a dangerous spot as they become more prone to catching the disease through droplet and aerosols. [18]

Major routes of transmission in the dental is via Droplets (Airborne particles > 5 microns) and aerosols (Airborne particles < 5 microns). The spread via droplets occurs in close proximities like on the dental chair or while close interactions. [19]
The spread via aerosol is possible at a larger distance. The transmission can also be via fomites i.e. via particles from inanimate objects. [20]

Patient screening is done by temperature and blood oxygen monitoring. Proper coverage of nose and mouth of patients in the waiting room. Pre-procedural mouthwash with 0.12% Chlorhexidine solution to reduce viral load and reduce transmission.0.5% Povidone Iodine has also been proven to reduce viral load. [3]
Use of ppe kits, face shields, eyewear and masks that have N-95 certification and FFP-3 respirators should be used. [21] Use of Rubber dam wherever possible to provide better isolation and reduce mucosal contact. [22]

Environmental sterilisation between appointments to ensure proper aseptic and sterile conditions to prevent transmission. The nature of disease in many cases can be subjective and hence a proper protocol is necessary to properly classify various treatments and to properly manage said treatments in a systematic manner. Treatment procedures can be broadly classified as non-urgent, urgent and emergency. [23, 24]

Non-urgent: general check-ups
Urgent: Pain due to pulpal inflammation, 3rd molar pain, pericoronitis, gingival bleeding, abscess, tooth trauma, etc.
Emergency: Uncontrolled bleeding, Cellulitis and other spreading face infections, Trauma involving facial bones/ teeth that can potentially block the airway. [25]
A protocol was devised by the joint work of the Indian Endodontic Society (IES), International Federation of Endodontic Society (IFES) and Indian Dental Association (IDA). In this they gave a 3 step protocol to assess patients' condition and health status in the pandemic. These steps: [26]

- Step 1: Dental Emergency assessment: The patient is subject to an emergency severity assessment and put into one of 3 categories, which include, Emergency, Urgent and Scheduled care.
- Step 2: COVID 19 Screening: The patient is asked to fill out a questionnaire and vitals maybe taken to categorise people into High risk or Low risk groups.
- Step 3: Emergency Dental Management: It involves giving utmost importance to non-aerosol generating procedures like extractions. Aerosol production must be completely avoided or limited to as little as possible to reduce transmission in the dental office.[27,28]

What is the second wave and why it matters?

The second wave of COVID 19 refers to the increased number of cases mainly due to the double mutant strain in India along with the mutant strains that were discovered in UK, Brazil, SA and Japan. (According to the CDC website)
These (Variant of Concern) strains [29]: -

- B.1.1.7: United Kingdom
- P.1: Japan and Brazil
- B.1.351: South Africa
- B.1.427 and B.1.429: United States.

On February 10th 2021, the second wave of the pandemic started with a report of 11,000 cases and increased to a total of 22,000 cases nation-wide in a single day within just 50 days of its initiation. The second wave is proving to be worse than the first wave due to its increasing spread especially in the younger population, its ability to avoid detection (20% false negative cases of RT-PCR have been reported) and its ability to produce symptoms other than the classical ones which include Only headache, only loose motions, only body ache, only weakness, Uneasy feeling, Vomiting, Hearing problems, Conjunctivitis or in combinations.[30] These symptoms are not only quite vague but also quite confusing which can increase the risk dentists possess especially while treating high risk patients.[31]

Technologies to help dentistry to adapt the pandemic

Dentistry as a field has developed quite dependant on a wide variety of technological advancements over the years with the developments of dental chairs, better restorative materials, better intervention protocols, CAD/CAM, CBCT scans etc. Life as a dentist is much simpler now as compared to that even just 5 decades ago. New and improved technological advancements, show a good promise in improving many aspects of existing dentistry and opening new paths to improve and develop the field as a whole. During the time of the pandemic, these technological breakthroughs both small and big can allow for safer, less strenuous, and healthier dental practice. [32-34] The major focus of dental technology especially targeting to the COVID pandemic aims to have as little patient visits as possible, shorter appointments, efficient treatments and protocols by avoiding unnecessary exposure to the patient and the dentist.[35]

The scope of dentistry that must be looked at spreads farther than only clinical practice and can include: [36]

- Dental Education
- Public Awareness
- Dental product manufacture and distribution
- Dental Research

These aspects can be improved using various technologies, for example Online learning and Virtual reality can be used to improve Dental education, Online marketplaces can allow for easier purchase and sale of dental goods thus improving the material industry. [37]

Electronic Dental Records

Dental Records (EDR's) are records of patient data that has been collected in a systematic way based usually on a pre-set query system to collect important meaningful details of the patient. This allows for clinicians to get the chore of data collection done quickly and allows for building better rapport and detailed discussions with the patients about their care. [38] Done with a good understanding of the process, it can be helpful to a dentist and allow for better judgements without other distracting information that may hamper decision making. [39, 40]

Other than serving as legal evidence in case of dispute this data is very useful for research. EDR's make collecting epidemiologically significant data much easier and helps in improving accuracy of results as shown in a study conducted by Kristina et al, 2019. [41]

Y. Hamrang-Yousefi et al Suggested the use of dental radiographs as a part of electronic medical records to improve accuracy especially in trauma cases and prevent unnecessary re exposure of the patient. [42]
Shortcomings: [43]

- Many dentists prefer paper records over electronic ones. [44]
- It is a common feeling of dental and medical professionals that electronic records bring a robotic and monotonous feel to the practice and reduce the joy of providing patient care.[45]
- The learning curve for the use of technology is not welcome by many.

Teledentistry

Tele dentistry is a field in which the patient and the dentist interact via a telecommunication device instead of a direct in person meeting. Teledentistry is used in various dental fields involving preventive dental care, orthodontics, endodontics, oral surgery, and periodontal diseases. It helps in the early detection of dental caries, patient education, oral medicine, and diagnosis.[46] This field has been slowly gaining popularity as a means of dental visits due to: -

- Lowered costs
- Comfort of both the patients and dentist
- Reduced clinic visits for insignificant problems.[47]

Teledentistry is advantageous in settings where patients are infected with COVID-19 or suspected to be infected. [48] For those not infected with COVID-19, but at higher risk of being affected, it provides a safe alternative by avoiding congested hospitals or dental office waiting rooms. [49] According to Mane et al 2020, Dentists with knowledge in teledentistry can be appointed at the primary health centres and community health centres to discuss about the diagnosis and treatment plan of the difficult cases with the specialists.[50] Dental colleges in underserved areas could be main places to serve the population through teledentistry consultation as they include all the specialists under the same roof.[51] A team of specialists could communicate with the dentists/hygienists/patients at the remote clinics.[52]

OP Kharbanda et al 2019, suggested that Teledentistry as a means to improve availability of oral health services in areas with inadequate accessibility of general and specialised dental care is emerging as a practical solution in emergency aid, initial consultations and expert opinion.[53]

Shortcomings of teledentistry:

- Requires a telecommunication device or a connection to the internet and is affected by the lack of these factors.
- There is a lack of awareness on the topic which is one of the reasons for its limited usage especially in a country like India where telehealth is a relatively new field. [42]
- There may be a lack of cooperation from the patient which may hinder the dentist from making accurate diagnoses.

Augmented Reality (AR) and Virtual Reality (VR)

Virtual Reality is a computer generated simulation where the user can experience a 3 dimensional experience in a simulated world that is separate from the real world. Augmented Reality is a computer generated shape or form that can be viewed in an electronic device with the real world as the background. [54] VR and AR have been shown to be useful in many fields of dentistry however their use in teaching and oral and maxillofacial surgery is of high interest. Some studies in the field include Huang et al 2018, concluded that VR and AR can be used by all fields of dentistry and can be used by the students and Post graduates to train their skills themselves and not depend on schools and administration especially in a preclinical setting. [55]

Dixon et al 2021, observed that when students were placed within a VR setting and performed cavity preparations a 78% agreement rate was observed between the judgement of the VR and clinical staff. They concluded that VR was both a reliable and convenient tool for dentistry. [56] Morales-Vadillo et al 2019, used Second Life platform to provide semi adjustable articulators to students and understand the anatomical landmarks and movements of the temporomandibular joint. They observed that the SL environment helps students to understand anatomical interactions that are difficult to observe in real life, is attractive to students, and contains tools with high didactic potential. [57] Ayoub et al 2019, observed that virtual planning improved the accuracy of inserting dental implants using either a statistic guidance or dynamic navigation. Prediction planning and intraoperative navigation was observed to be the major use of VR in orthognathic surgeries. [58]

Kwon et al 2018, suggested that although the use of AR in dentistry has mainly been focused on the applications of AR in cranio-maxillofacial surgery, such as surgical preplanning and navigation systems, AR technology can also be expanded to other areas of dentistry, such as restorative dentistry, orthodontics and endodontics; this expansion has been expedited by technological advances. [59] Disadvantages of AR and VR:

- There can be a huge learning curve that may be tedious.

- It can have side effects like anxiety and may also precipitate seizures.
- It is still an expensive technology to make use of in all fields.

Online Learning

Online learning is a form of education where lessons and discussions are held over the internet using various platforms such as, zoom, skype, google meet etc. This form of education has been adopted in the pandemic as it allows for classes to be conducted without the requirement of physical presence of the students. [60-62] All the content is put out virtually and classes conducted in a virtual space. Although this has allowed for theoretical teaching to be largely unaltered, practical subjects are quite difficult to be taught in this setting. [63]

In a study conducted in Germany, by Schlenz MA et al, it was observed that the overall attitude of students towards online learning was positive but the optimum amount of suggested online classes varied (students suggesting 53.2% with a standard deviation of 24.9 and lecturers suggesting 38.6% 21.5). Overall, 36.8% of students preferred "Face to face" learning over pure online learning. [64, 65] Abbasi MS et al 2020, found in their study that, satisfaction levels of E- learning were better among developed countries compared to developing countries. The majority of students agreed that E-learning was satisfactory for gaining knowledge, however it was not as effective in acquiring clinical and technical skills. [66, 67] Disadvantages of online learning:

- Inability to acquire technical and clinical skills
- Prone to disturbances due to network issues
- The technological aspects tend to deter certain people due to the requirement of learning to use new technologies.[68]

Other Technologies

Online marketplaces and Digital Marketing

Online marketplaces are websites or apps that allow selling of various goods and services across the internet. This allows for sales to happen without the need of a physical shop. For the buyers, it provides a safer alternative in the pandemic as compared to traditional marketing. [69] Digital marketing is act of creating a presence on the world wide web. It can include making websites, social media accounts, mobile apps and using other platforms to further one's business and profits. Dental practitioners make web profiles to increase their reach and dental laboratories and suppliers can sell via online markets digitally.[70] In the pandemic, Digital marketing has also been seen as a method to promote teledentistry and online learning to reduce human to human contact as much as possible.[71]

Artificial Neural Networks

Artificial Neural Networks (ANN) are artificial neural mechanisms that are connected to each other via mathematical concepts which allow them to make logical decisions based on an existing database of sample materials. This concept is mainly useful in dentistry as it forms the basis of image recognition software.

Imaging studies form a core part of dental practice and the use of a logical device can aid in making clinical decisions and store data more accurately and robustly as compared to traditional storage methods. [72]

Thanathornwong B et al 2020 concluded that the faster Regional Convolutional Neural Network trained on a limited amount of labelled imaging data performed satisfactorily well in detecting periodontally compromised teeth. The application of a faster and smarter version of R-CNN to assist in the detection of periodontally compromised teeth can reduce diagnostic effort by reducing or even completely negating assessment time and allowing automated screening documentation. [73]

Block Chain Technology

Block Chain Technology (BCT) is an open-source code that allows for construction of large, decentralised databases with orderly arrangement of data in the form of blocks. It is best envisioned as a set of "blocks" or "Lego bricks" that form a tower over a period of time. [74] This allows for a set of interactions between users (transactions) all of which are parts of the tower. Information about each transaction is stored in a block and the whole set is part of a public ledger. Each block is identified by its own hash and the hash before it. It uses a 2-key system which includes a public key and a private key. Private keys are the properties of users and can be used to view and verify transactions; however, public keys cannot provide the data alone. Every time a transaction is made a new block is added to the chain and is connected to the previous chain. [75] Wutthikarn et al, 2018 made a prototype block chain for a dental service application that aimed at setting participant authoritarian system that could eliminate additional operative costs for all the participants involved by creating a trust among the participants. [76]

Kho et al, 2018, Mentioned the empowering characteristics of BCT to prevent the counterfeited medicine, clinical trials to guarantee transparency, healthcare information exchanges or personal health record systems to ensure data integrity and interoperability, etc. [77]

Discussion

The pandemic has left us in a sudden and extreme situation that is not the easiest to recover from. In this period of difficulty mankind tends to turn to technology to facilitate both work and recreation. Many fields have started to "go digital" and the field of dentistry is no exception.[78,79] With the advancements in communication technologies allowing for real time wireless long distance reach, the practice of dentistry has started to move towards a screen to screen patient-dentist interaction.[80]

The research in digitalisation has also increased substantially in the time period from 2019-2020 (Table 1 and Figure 1). The number of published articles related to digitalisation of dentistry have doubled in the previous 2 years as compared to the standard increase. This suggests that the shift to a more digital future has been hastened due to the COVID 19 Pandemic.[81] This is also seen by the fact that many businesses are now dependant on online media for their survival. With the

increase in online learning and teledentistry the requirement for in person education and consultations have decreased drastically. This has allowed for more systemic appointment schedules and a decreased workload for dental faculty.[82] With the use of online marketplaces and digital marketing, trade of dental products has become less risky and comfortable especially for practicians and clinicians.[83] With the advent of supplementary like ANN's, VR, AR, BCT, etc. the field of Dental Practice, Research and Education have seen a massive boost in ease of diagnosis, better understanding of concepts, and easy access to previously poorly accessible data.[84]

With the increasing number of cases in the so called 'second wave', the requirement of research has increased exponentially and the likelihood of exposure in the dental practice has also increased. As previously described the symptoms of the second wave are more obscure and can easily be overlooked that can lead to deadly consequences.[85]

Conclusion

The COVID 19 pandemic has left a huge impact on the society as a whole and an even bigger impact in the healthcare industry.[86] Dentistry as a whole suffered many losses ranging from monetary loses due to lesser profits, educational due to closure of schools and colleges to loss of one's general wellbeing due to being in constant threat of exposure to the SARS-CoV2 Virus.[87] This has led to alternative solutions being proposed to battle the pandemic while continuing to provide dental care and services. These can range from newer protocols to implementation of new technologies into the system. With the use of various technologies such as teledentistry, Electronic dental records, digital marketing etc. dental practice has been slowly gaining track and recovering from its losses.

The use of Online learning platforms has helped continue dental education without the need of being physically present. Although these solutions are not perfect and cannot replace traditional practices anytime soon, they play an important role in filling the gap that has been produced by the pandemic. With an increase in the research in digital dentistry (over twice as much as previous years), the technology of the future is now at grasp more than it ever has been.With these advancements dental practice and education is sure to improve in both quality and reach and ultimately provide dental care to as many people as possible.

References

1. World Health Organisation. Novel Coronavirus (2019-nCoV) SITUATION REPORT – 1 https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200121-sitrep-1-2019-ncov.pdf . Published: 21 Jan 2021. Accessed: 17 May 2021
2. The classical definition of a pandemic is not elusive. [Last updated: July 2011, Cited: May 12,2021]. Available at: https://www.who.int/bulletin/volumes/89/7/11-088815/en/
3. Chopra A, Sivaraman K, Radhakrishnan R, Balakrishnan D, Narayana A. Can povidone iodine gargle/mouthrinse inactivate SARS-CoV-2 and decrease

the risk of nosocomial and community transmission during the COVID-19 pandemic? An evidence-based update. Jpn Dent Sci Rev. 2021;57:39-45. doi:10.1016/j.jdsr.2021.03.001

4. Pinals DA, Hepburn B, Parks J, Stephenson AH. The Behavioral Health System and Its Response to COVID-19: A Snapshot Perspective. Psychiatr Serv. 2020 Oct 1;71(10):1070-1074. doi: 10.1176/appi.ps.202000264. Epub 2020 Aug 12. PMID: 32781926.

5. Cucinotta D, Vanelli M. WHO Declares COVID-19 a Pandemic. Acta Biomed. 2020;91(1):157-160. Published 2020 Mar 19. doi:10.23750/abm.v91i1.9397.

6. Adam Felman. What to know about pandemics. Medical News Today. https://www.medicalnewstoday.com/articles/148945. Published:30 March, 2020. Accessed: 17 May, 2021.

7. Mishra SR, Lygidakis C, Neupane D, Gyawali B, Uwizihiwe JP, Virani SS, Kallestrup P, Miranda JJ. Combating non-communicable diseases: potentials and challenges for community health workers in a digital age, a narrative review of the literature. Health Policy Plan. 2019 Feb 1;34(1):55-66. doi: 10.1093/heapol/czy099. PMID: 30668690.

8. Leeson D. The digital factory in both the modern dental lab and clinic. Dent Mater. 2020 Jan;36(1):43-52. doi: 10.1016/j.dental.2019.10.010. Epub 2019 Nov 12. PMID: 31727448.

9. Fernandes L, FitzPatrick ME, Roycroft M. The role of the future physician: building on shifting sands. Clin Med (Lond). 2020 Apr 17;20(3):285–9. doi: 10.7861/clinmed.2020-0030. Epub ahead of print. PMID: 32303498; PMCID: PMC7354041.

10. Bogucki OE, Mattson AB, Leasure WB, Berg SL, Mulholland HL, Sawchuk CN. Adaptations of an Integrated Behavioral Health Program During COVID-19. Cogn Behav Pract. 2021 Mar 22. doi: 10.1016/j.cbpra.2021.01.006. Epub ahead of print. PMID: 33776398; PMCID: PMC7983459.

11. Deiters W, Burmann A, Meister S. Digitalisierungsstrategien für das Krankenhaus der Zukunft [Strategies for digitalizing the hospital of the future]. Urologe A. 2018 Sep;57(9):1031-1039. German. doi: 10.1007/s00120-018-0731-2. PMID: 30088025.

12. Ghani F. Covid-19 Outbreak - Immediate and long-term impacts on the dental profession. Pak J Med Sci. 2020 May;36(COVID19-S4):S126-S129. doi: 10.12669/pjms.36.COVID19-S4.2698. PMID: 32582331; PMCID: PMC7306954.

13. Lusardi R, Tomelleri S. The Juggernaut of Modernity Collapses. The Crisis of Social Planification in the Post COVID-19 era. Front Sociol. 2020 Dec 23;5:611885. doi: 10.3389/fsoc.2020.611885. PMID: 33869527; PMCID: PMC8022827.

14. Din S, Kent A, Pollok RC, Meade S, Kennedy NA, Arnott I, Beattie RM, Chua F, Cooney R, Dart RJ, Galloway J, Gaya DR, Ghosh S, Griffiths M, Hancock L, Hansen R, Hart A, Lamb CA, Lees CW, Limdi JK, Lindsay JO, Patel K, Powell N, Murray CD, Probert C, Raine T, Selinger C, Sebastian S, Smith PJ, Tozer P, Ustianowski A, Younge L, Samaan MA, Irving PM. Adaptations to the British Society of Gastroenterology guidelines on the management of acute severe UC in the context of the COVID-19 pandemic: a RAND appropriateness panel. Gut. 2020 Oct;69(10):1769-1777. doi: 10.1136/gutjnl-2020-321927. Epub 2020 Jun 8. PMID: 32513653; PMCID: PMC7299646.

15. Singh H, Kaur H, Singh K, Sen CK. Cutaneous Manifestations of COVID-19: A Systematic Review. Adv Wound Care (New Rochelle). 2021;10(2):51-80. doi:10.1089/wound.2020.1309.

16. Elshazli RM, Kline A, Elgaml A, et al. Gastroenterology manifestations and COVID-19 outcomes: A meta-analysis of 25,252 cohorts among the first and second waves. J Med Virol. 2021;93(5):2740-2768. doi:10.1002/jmv.26836.

17. Zelop CM, Bonney EA. COVID-19 in pregnancy: possible mechanisms not to be discounted. J Matern Fetal Neonatal Med. 2020 Aug 18:1-4. doi: 10.1080/14767058.2020.1807508. Epub ahead of print. PMID: 32811230.

18. Jain M, Patel D. Overcoming the Challenges of COVID-19 Pandemic in Orthodontic Practice. Front Dent. 2020 Jun;17(12):1-4. doi: 10.18502/fid.v17i12.4129. Epub 2020 Jun 25. PMID: 33615288; PMCID: PMC7883656.

19. Benzian H, Niederman R. A Dental Response to the COVID-19 Pandemic-Safer Aerosol-Free Emergent (SAFER) Dentistry. Front Med (Lausanne). 2020 Aug 12;7:520. doi: 10.3389/fmed.2020.00520. PMID: 32903453; PMCID: PMC7434942.

20. Banerjee D, Meena KS. COVID-19 as an "Infodemic" in Public Health: Critical Role of the Social Media. Front Public Health. 2021 Mar 18;9:610623. doi: 10.3389/fpubh.2021.610623. PMID: 33816415; PMCID: PMC8012664.

21. Jamal M, Shah M, Almarzooqi SH, Aber H, Khawaja S, El Abed R, Alkhatib Z, Samaranayake LP. Overview of transnational recommendations for COVID-19 transmission control in dental care settings. Oral Dis. 2021 Apr;27 Suppl 3:655-664. doi: 10.1111/odi.13431. Epub 2020 Jun 3. PMID: 32428372; PMCID: PMC7280672.

22. Ge ZY, Yang LM, Xia JJ, Fu XH, Zhang YZ. Possible aerosol transmission of COVID-19 and special precautions in dentistry. J Zhejiang Univ Sci B. 2020;21(5):361-368. doi:10.1631/jzus.B2010010.

23. Bhanushali P, Katge F, Deshpande S, Chimata VK, Shetty S, Pradhan D. COVID-19: Changing Trends and Its Impact on Future of Dentistry. Int J Dent. 2020;2020:8817424. Published 2020 May 29. doi:10.1155/2020/8817424.

24. Arora S, Abullais Saquib S, Attar N, Pimpale S, Saifullah Zafar K, Saluja P, M Abdulla A, Shamsuddin S. Evaluation of Knowledge and Preparedness Among Indian Dentists During the Current COVID-19 Pandemic: A Cross-Sectional Study. J Multidiscip Healthc. 2020 Aug 24;13:841-854. doi: 10.2147/JMDH.S268891. PMID: 32922024; PMCID: PMC7455766.

25. Khanal N , Singh AK . Knowledge, Attitude and Practice Regarding COVID-19 and its Impact on Dentistry: A Cross-sectional Survey among Nepalese Dentists. Kathmandu Univ Med J (KUMJ). 2020 COVID-19 SPECIAL ISSUE;18(70):3-9. PMID: 33605231.

26. IES, IEFS, IDA. Dental Practice during COVID 19 Pandemic. https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.ies.org.in%2Fpdf_server.php%3Ffile%3Ddental-practice-covid-19&psig=AOvVaw06MSIu4Kw-r3Azm6FxDgFs&ust=1621360991633000&source=images&cd=vfe&ved=0CAQQtaYDahcKEwiQyaTC6tLwAhUAAAAAHQAAAAAQJw . Accessed: May 18,2021

27. Chomakhashvili N, Chomakhashvili Z, Zosidze N, Franchuki K. ; ERGONOMIC PRINCIPLES IN MEDICINE AND DENTISTRY (REVIEW). Georgian Med News. 2020 Jul-Aug;(304-305):158-163. PMID: 32965268.

28. Hegde MN, Qaiser S, Hegde ND. Clinical protocols in dental practice: Post-COVID-19. *J Conserv Dent.* 2019;22(5):408-410. doi:10.4103/JCD.JCD_287_20.

29. SARS-CoV-2 Variant Classifications and Definitions. Availible at: https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/variant-surveillance/variant-info.html [last updated May 12,2020: Cited May12, 2020]

30. Understanding & Dealing with Second Corona Wave. https://nitdgp.ac.in/uploads/bd851d81d81c931d4dab9bfe2270f894.pdf

31. Barabari P, Moharamzadeh K. Novel Coronavirus (COVID-19) and Dentistry-A Comprehensive Review of Literature. Dent J (Basel). 2020 May 21;8(2):53. doi: 10.3390/dj8020053. PMID: 32455612; PMCID: PMC7345990.

32. Ho CW, Caals K, Zhang H. Heralding the Digitalization of Life in Post-Pandemic East Asian Societies. J Bioeth Inq. 2020 Dec;17(4):657-661. doi: 10.1007/s11673-020-10050-7. Epub 2020 Nov 9. PMID: 33169256; PMCID: PMC7651810.

33. Alauddin MS, Baharuddin AS, Mohd Ghazali MI. The Modern and Digital Transformation of Oral Health Care: A Mini Review. Healthcare (Basel). 2021 Jan 25;9(2):118. doi: 10.3390/healthcare9020118. PMID: 33503807; PMCID: PMC7912705.

34. Gallagher JE, Johnson I, Verbeek JH, Clarkson JE, Innes N. Relevance and paucity of evidence: a dental perspective on personal protective equipment during the COVID-19 pandemic. Br Dent J. 2020 Jul;229(2):121-124. doi: 10.1038/s41415-020-1843-9. PMID: 32710059; PMCID: PMC7380159.

35. Gross D, Gross K, Wilhelmy S. Digitalization in dentistry: ethical challenges and implications. Quintessence Int. 2019;50(10):830-838. doi: 10.3290/j.qi.a43151. PMID: 31538146.

36. Rekawek P, Rice P, Panchal N. The impact of COVID-19: Considerations for future dental conferences. J Dent Educ. 2020 Nov;84(11):1188-1191. doi: 10.1002/jdd.12330. Epub 2020 Jul 27. PMID: 32715466.

37. Nambisan S, Nambisan P. How Should Organizations Promote Equitable Distribution of Benefits from Technological Innovation in Health Care? AMA J Ethics. 2017 Nov 1;19(11):1106-1115. doi: 10.1001/journalofethics.2017.19.11.stas1-1711. PMID: 29168682.

38. Seneviratne CJ, Lau MWJ, Goh BT. The Role of Dentists in COVID-19 Is Beyond Dentistry: Voluntary Medical Engagements and Future Preparedness. Front Med (Lausanne). 2020 Oct 6;7:566. doi: 10.3389/fmed.2020.00566. PMID: 33117825; PMCID: PMC7574679.

39. Kanda W, Kivimaa P. What opportunities could the COVID-19 outbreak offer for sustainability transitions research on electricity and mobility? Energy Res Soc Sci. 2020 Oct;68:101666. doi: 10.1016/j.erss.2020.101666. Epub 2020 Jun 29. PMID: 32839695; PMCID: PMC7322472.

40. Vandenberghe B. The digital patient - Imaging science in dentistry. J Dent. 2018 Jul;74 Suppl 1:S21-S26. doi: 10.1016/j.jdent.2018.04.019. PMID: 29929585.

41. Wanyonyi KL, Radford DR, Gallagher JE. Electronic primary dental care records in research: A case study of validation and quality assurance

strategies. Int J Med Inform. 2019;127:88-94. doi:10.1016/j.ijmedinf.2019.04.007.

42. Hamrang-Yousefi Y, Pannu M, Siddiqi J. Dental radiographs in electronic medical records. Br Dent J. 2019;226(7):472. doi:10.1038/s41415-019-0215-9.

43. D'Cruz L, Rattan R. Electronic clinical dental records: unintended consequences. Br Dent J. 2018;224(8):582-583. doi:10.1038/sj.bdj.2018.311.

44. Thu SWYM, Kijsanayotin B, Kaewkungwal J, Soonthornworasiri N, Pan-Ngum W. Satisfaction with Paper-Based Dental Records and Perception of Electronic Dental Records among Dental Professionals in Myanmar. Healthc Inform Res. 2017;23(4):304-313. doi:10.4258/hir.2017.23.4.304.

45. Trenerry B, Chng S, Wang Y, Suhaila ZS, Lim SS, Lu HY, Oh PH. Preparing Workplaces for Digital Transformation: An Integrative Review and Framework of Multi-Level Factors. Front Psychol. 2021 Mar 23;12:620766. doi: 10.3389/fpsyg.2021.620766. PMID: 33833714; PMCID: PMC8021873.

46. Levy S, Mason S, Russon J, Diamond G. Attachment-based family therapy in the age of telehealth and COVID-19. J Marital Fam Ther. 2021 Apr;47(2):440-454. doi: 10.1111/jmft.12509. Epub 2021 Mar 22. PMID: 33749898; PMCID: PMC8251076.

47. Boringi M, Waghray S, Lavanya R, Babu DB, Badam RK, Harsha N, Garlapati K, Chavva S. Knowledge and Awareness of Teledentistry among Dental Professionals - A Cross Sectional Study. J Clin Diagn Res. 2015 Aug;9(8):ZC41-4. doi: 10.7860/JCDR/2015/13303.6320. Epub 2015 Aug 1. PMID: 26436045; PMCID: PMC4576639.

48. Plaza-Ruíz SP, Barbosa-Liz DM, Agudelo-Suárez AA. Impact of COVID-19 on the Knowledge and Attitudes of Dentists toward Teledentistry. JDR Clin Trans Res. 2021 Jul;6(3):268-278. doi: 10.1177/2380084421998632. Epub 2021 Feb 25. PMID: 33632011.

49. Juneja A, Singh N, Sultan A, Aggarwal I, Palkit T, Ohri T. Integration of teledentistry in oral health care during COVID-19 pandemic. St s Int Dent J. 2020;4(2):77.

50. Krendyukov A, Nasy D. Evolving Communication with Healthcare Professionals in the Pharmaceutical Space: Current Trends and Future Perspectives. Pharmaceut Med. 2020 Aug;34(4):247-256. doi: 10.1007/s40290-020-00341-0. PMID: 32557342.

51. Sim J, Shaw T, Li ST, Courtney E, Yuen J, Chiang J, Nazir M, Tan R, Ngeow J. Understanding patients' views and willingness toward the use of telehealth in a cancer genetics service in Asia. J Genet Couns. 2021 May 1. doi: 10.1002/jgc4.1432. Epub ahead of print. PMID: 33934420.

52. Mane AN, Shivakumar KM, Kadashetti V. Feasibility assessment for using telehealth technology among dentists and general population in Satara district, Maharashtra. Indian Journal of Dental Sciences. 2020;1;12(4):258.

53. Kharbanda OP, Priya H, Balachandran R, Khurana C. Current scenario of teledentistry in public healthcare in India. J Int Soc Telemed eHealth. 2019;7. doi:10.29086/jisfteh.7.e10.

54. Machoy ME, Szyszka-Sommerfeld L, Vegh A, Gedrange T, Woźniak K. The ways of using machine learning in dentistry. Adv Clin Exp Med. 2020 Mar;29(3):375-384. doi: 10.17219/acem/115083. PMID: 32207586.

55. Huang TK, Yang CH, Hsieh YH, Wang JC, Hung CC. Augmented reality (AR) and virtual reality (VR) applied in dentistry. Kaohsiung J Med Sci. 2018;34(4):243-248. doi:10.1016/j.kjms.2018.01.009

56. Dixon J, Towers A, Martin N, Field J. Re-defining the virtual reality dental simulator: Demonstrating concurrent validity of clinically relevant assessment and feedback. Eur J Dent Educ. 2021;25(1):108-116. doi:10.1111/eje.12581.

57. Morales-Vadillo R, Guevara-Canales JO, Flores-Luján VC, Robello-Malatto JM, Bazán-Asencios RH, Cava-Vergiú CE. Use of virtual reality as a learning environment in dentistry. Gen Dent. 2019;67(4):21-27.

58. Ayoub A, Pulijala Y. The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery. BMC Oral Health. 2019;19(1):238. Published 2019 Nov 8. doi:10.1186/s12903-019-0937-8.

59. Kwon HB, Park YS, Han JS. Augmented reality in dentistry: a current perspective. Acta Odontol Scand. 2018;76(7):497-503. doi:10.1080/00016357.2018.1441437.

60. Garg D, Kapoor D. Perception of Dental Students of COMS-TH regarding Future of Dentistry in Nepal amid COVID-19 Pandemic. JNMA J Nepal Med Assoc. 2020 Sep 27;58(229):677-680. doi: 10.31729/jnma.5115. PMID: 33068090; PMCID: PMC7580324.

61. Zitzmann NU, Matthisson L, Ohla H, Joda T. Digital Undergraduate Education in Dentistry: A Systematic Review. Int J Environ Res Public Health. 2020 May 7;17(9):3269. doi: 10.3390/ijerph17093269. PMID: 32392877; PMCID: PMC7246576.

62. Shah S, Diwan S, Kohan L, Rosenblum D, Gharibo C, Soin A, Sulindro A, Nguyen Q, Provenzano DA. The Technological Impact of COVID-19 on the Future of Education and Health Care Delivery. Pain Physician. 2020 Aug;23(4S):S367-S380. PMID: 32942794.

63. García-Morales VJ, Garrido-Moreno A, Martín-Rojas R. The Transformation of Higher Education After the COVID Disruption: Emerging Challenges in an Online Learning Scenario. Front Psychol. 2021 Feb 11;12:616059. doi: 10.3389/fpsyg.2021.616059. PMID: 33643144; PMCID: PMC7904694.

64. Schlenz MA, Schmidt A, Wöstmann B, Krämer N, Schulz-Weidner N. Students' and lecturers' perspective on the implementation of online learning in dental education due to SARS-CoV-2 (COVID-19): a cross-sectional study. BMC Med Educ. 2020;20(1):354. Published 2020 Oct 9. doi:10.1186/s12909-020-02266-3.

65. Kumar Mallineni S, Chandra Bhumireddy J, Nuvvula S. Dentistry for children during and post COVID-19 pandemic outbreak. Child Youth Serv Rev. 2021 Jan;120:105734. doi: 10.1016/j.childyouth.2020.105734. Epub 2020 Nov 19. PMID: 33235401; PMCID: PMC7676364.

66. Abbasi MS, Ahmed N, Sajjad B, et al. E-Learning perception and satisfaction among health sciences students amid the COVID-19 pandemic. Work. 2020;67(3):549-556. doi:10.3233/WOR-203308.

67. Yaqinuddin A, Kashir J, AlKattan W, AlKattan K. Applying integrated video assisted learning approaches for medical clerkship - potential adaptations in the post-COVID-19 era. J Med Educ Curric Dev. 2020 Oct 26;7:2382120520963043. doi: 10.1177/2382120520963043. PMID: 33195800; PMCID: PMC7594250.

68. Wu DT, Wu KY, Nguyen TT, Tran SD. The impact of COVID-19 on dental education in North America-Where do we go next? Eur J Dent Educ. 2020 Nov;24(4):825-827. doi: 10.1111/eje.12561. Epub 2020 Jul 12. PMID: 32654328; PMCID: PMC7404882.

69. Shen ZJ, Song L. [Trend of collaboration and sharing in digitalized restorative dentistry]. Zhonghua Kou Qiang Yi Xue Za Zhi. 2020 Dec 9;55(12):932-937. Chinese. doi: 10.3760/cma.j.cn112144-20200524-00291. PMID: 33280356.

70. Webb H, Parson M, Hodgson LE, Daswani K. Virtual visiting and other technological adaptations for critical care. Future Healthc J. 2020 Oct;7(3):e93-e95. doi: 10.7861/fhj.2020-0088. PMID: 33094267; PMCID: PMC7571754.

71. Sim SS, Yip MY, Wang Z, Tan ACS, Tan GSW, Cheung CMG, Chakravarthy U, Wong TY, Teo KYC, Ting DS. Digital Technology for AMD Management in the Post-COVID-19 New Normal. Asia Pac J Ophthalmol (Phila). 2021 Jan-Feb 01;10(1):39-48. doi: 10.1097/APO.0000000000000363. PMID: 33512827.

72. Su YC. [The elementary discussion on digital implant dentistry]. Zhonghua Kou Qiang Yi Xue Za Zhi. 2016 Apr 9;51(4):194-200. Chinese. doi: 10.3760/cma.j.issn.1002-0098.2016.04.002. PMID: 27117209.

73. Thanathornwong B, Suebnukarn S. Automatic detection of periodontal compromised teeth in digital panoramic radiographs using faster regional convolutional neural networks. Imaging Sci Dent. 2020;50(2):169-174. doi:10.5624/isd.2020.50.2.169.

74. Liu H. [The rise and development of general dentistry in China]. Zhonghua Kou Qiang Yi Xue Za Zhi. 2016 Feb;51(2):65-8. Chinese. doi: 10.3760/cma.j.issn.1002-0098.2016.02.001. PMID: 26926188.

75. Low STH, Sakhardande PG, Lai YF, Long ADS, Kaur-Gill S. Attitudes and Perceptions Toward Healthcare Technology Adoption Among Older Adults in Singapore: A Qualitative Study. Front Public Health. 2021 Feb 15;9:588590. doi: 10.3389/fpubh.2021.588590. PMID: 33659232; PMCID: PMC7917068.

76. Wutthikarn R, Hui YG. Prototype of Blockchain in Dental care service application based on Hyperledger Composer in Hyperledger Fabric framework. In: 2018 22nd International Computer Science and Engineering Conference (ICSEC). IEEE; 2018.

77. Kho W. Blockchain revolution in healthcare: the era of patient-centered dental information system. International Journal of Oral Biology. 2018;43(1).

78. Kunkel GH, Roberts GK. Hospital Dentistry: The Swiss-Army Knife of Dental Medicine. J Dent Educ. 2021 Feb;85(2):112-115. doi: 10.1002/jdd.12476. Epub 2020 Nov 22. PMID: 33225443.

79. Lucas B, Brammen D, Schirrmeister W, Aleyt J, Kulla M, Röhrig R, Walcher F. Anforderungen an eine nachhaltige Standardisierung und Digitalisierung in der klinischen Notfall- und Akutmedizin [Requirements for a sustainable standardization and digitalization in clinical emergency and acute medicine]. Unfallchirurg. 2019 Mar;122(3):243-246. German. doi: 10.1007/s00113-019-0603-2. PMID: 30666344.

80. Pentapati KC, Siddiq H. Clinical applications of intraoral camera to increase patient compliance - current perspectives. Clin Cosmet Investig Dent. 2019 Aug 23;11:267-278. doi: 10.2147/CCIDE.S192847. PMID: 31692486; PMCID: PMC6712211.

81. Nayyar N, Ojcius DM, Dugoni AA. The Role of Medicine and Technology in Shaping the Future of Oral Health. J Calif Dent Assoc. 2020 Mar;48(3):127-130. PMID: 32189957; PMCID: PMC7080193.

82. Orsini G, Pagella P, Putignano A, Mitsiadis TA. Novel Biological and Technological Platforms for Dental Clinical Use. Front Physiol. 2018 Aug 8;9:1102. doi: 10.3389/fphys.2018.01102. PMID: 30135661; PMCID: PMC6092501.

83. Currie GM. A Lens on the Post-COVID-19 "New Normal" for Imaging Departments. J Med Imaging Radiat Sci. 2020 Sep;51(3):361-363. doi: 10.1016/j.jmir.2020.06.004. Epub 2020 Jun 9. PMID: 32624352; PMCID: PMC7836427.

84. Barnes SJ. Information management research and practice in the post-COVID-19 world. Int J Inf Manage. 2020 Dec;55:102175. doi: 10.1016/j.ijinfomgt.2020.102175. Epub 2020 Jun 19. PMID: 32836635; PMCID: PMC7304950.

85. Knorr D, Khoo CH. COVID-19 and Food: Challenges and Research Needs. Front Nutr. 2020 Dec 3;7:598913. doi: 10.3389/fnut.2020.598913. PMID: 33344494; PMCID: PMC7744420.

86. Airaksinen M, Toivo T, Jokinen L, Savela E, Parkkamäki S, Sandler C, Kalliomäki H, Dimitrow M. Policy and vision for community pharmacies in Finland: A roadmap towards enhanced integration and reduced costs. Pharm Pract (Granada). 2021 Jan-Mar;19(1):2288. doi: 10.18549/PharmPract.2021.1.2288. Epub 2021 Feb 4. PMID: 33628348; PMCID: PMC7886313.

87. Alsanea N. The future of health care delivery and the experience of a tertiary care center in Saudi Arabia. Ann Saudi Med. 2012 Mar-Apr;32(2):117-20. doi: 10.5144/0256-4947.2012.117. PMID: 22366822; PMCID: PMC6086652.

Figure legends

Figure 1: Graphical representation of the values of Table 1. The points at 2019 and 2020 denote (X) and (Y) respectively. The line joining these 2 points denotes the increase in the number of publications from 2019-2020. The entire line graph gives an idea of the general trend of the research on the particular fields. Graph (A) describes the trend in the number of articles published about Artificial intelligence in dentistry. Graph (B) describes the trend in the number of articles published about Teledentistry. Graph (C)describes the trend in the number of articles published about. Graph (D) describes the trend in the number of articles published about Technology in Dentistry. Graph (E) describes the trend in the number of articles published about Digital Dentistry.

Table

Serial no.	Keywords searched in PubMed database	No. of articles in the year 2019(X)	No. of articles in the year 2020(Y)	% increase from 2019 to 2020	Average % increase of Previous years
1	Artificial intelligence in dentistry	139	222	22%	11%
2	Teledentistry	11	63	70%	18%

3	Virtual reality in dentistry	46	65	17%	6%
4	Technology in dentistry	3424	4040	8%	4.425%
5	Digital dentistry	1682	1374	10%	7%

Table 1: The number of articles associated with various keywords searched in the PubMed database. (X) Denotes the number of articles published about a given keyword in 2019. (Y) denotes the number of articles published in the year 2020. The percent increase is the % of articles increased from 2019 to 2020 calculated as (X-Y) x100/(X+Y). This value is compared with the average increase depicted in column 4.

Fig 1 :