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Original Article

Clinical relevance of Digital Dentistry during COVID-19 outbreak: a scoped review

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Aim: To perform a scoped literature review on advantages of digital workflows in dentistry that could be widely adopted to address safety issues raised during the coronavirus (COVID-19) pandemic. **Methods:** Recent studies on any advantages of digital dentistry – as compared to conventional methods – that could help addressing the new safety demands for dental treatments that emerged due to the current pandemic were included. PUBMED, Embase, and Web of Knowledge databases were searched for eligible articles published in the last five years. The guidelines of PRISMA statement were followed during data extraction and evaluation. **Results:** The present search strategy yielded 181 publications. After application of exclusion criteria, a total of 34 studies were finally considered eligible to be discussed. Among the most important advantages of digital dentistry that contribute to safety during the current pandemic are: reduced number of clinical appointments required, shorter chairside time, less invasive surgeries and safer procedures. **Conclusion:** Within the limitations of this study, the findings observed herein suggest that the use of digital workflows in dentistry could lead to increased safety and reduced transmission of COVID-19 during the current pandemic.

Key Words: Technology, dental. Dentistry. Workflow. COVID-19.

Introduction

Recently, the World Health Organization (WHO) declared COVID-19 a current pandemic related to a disease caused by the new coronavirus (Sars-Cov-2/COVID-19). WHO suggested several actions to be taken by health-related institutions. As a result, healthcare facilities considered to be essential had to adapt to this new reality by taking measures of biosafety and social isolation to actively break the COVID-19 chain of transmission.

It is known that COVID-19 can be transmitted directly from person to person by means of respiratory droplets and contact routes/fomites[1]. In this context, virus carrying saliva droplets may lead to COVID-19 infection by means of inhalation, ingestion, and direct mucous contact[2-4]. The first contamination of dental professionals during the first COVID-19 outbreak revealed that its transmission can also occur from asymptomatic patients[5]. In addition, a previous study suggested that saliva should be considered a major transmitting agent of COVID-19 in asymptomatic cases[6].

While droplets of saliva discharged by people sneezing or coughing generally varies in size from 1 to 5 mm, particles in aerosol are considerably smaller, varying from 0.3 mm to 100 μm in diameter. This emphasizes the high contamination risk that clinicians are submitted during dental procedures[7], which in turn require appropriate disinfection of devices and facilities offering dental treatments[8-10].

To facilitate disinfection of dental clinics, it is recommended that disposable guards are placed on surfaces and devices to avoid direct contamination. Such disposable guards can be easily removed after each clinical procedure, which in turn should be followed by proper chemical disinfection[11]. Furthermore, dental professionals should be adequately informed on possible COVID-19 transmission routines[12-13].

There is agreement among studies that all dental elective treatment should be avoided during the current pandemic and quarantine periods[4-14], whereas only emergency dental procedures should still be performed[15]. For this purpose, a screening process would be advisable prior to the patient appointment in dental clinics to avoid excessive exposure of the dental team and patients themselves[16].

As an essential area of healthcare, dentistry should adapt to the above mentioned changes during and after the current pandemic. In this context, relatively recent studies on digital dentistry have presented methods and technological improvements that offer advantages in the different fields of study in dentistry to treat patients during the current pandemic. Nevertheless, little is known on how digital workflow tools and methods could be useful to address the safety concerns related to the current COVID-19 pandemic.

Thus, the aim of this study is to perform a literature review to identify advantages of digital workflows in dentistry that could be widely adopted to address safety issues raised during the COVID-19 pandemic.

Material and Methods

A literature review was carried-out to describe the advantages of digital dentistry – as compared to conventional methods – that could help addressing the new safety

demands during dental treatments due to the current pandemic. Such advantages were addressed by area of knowledge. Included areas were: oral and maxillofacial radiology, esthetic dentistry, dental emergency, prosthodontics, orthodontics, periodontics, endodontics, oral and maxillofacial surgery and implant dentistry. PUBMED and EMBASE databases were searched for articles published in the last five years (i.e. from April of 2015 to April of 2020), with restriction to English language publications according to keywords following the search strategy: (digital dentistry OR digital workflow) AND (conventional OR analog) AND (advantages OR comparison) AND (oral radiology OR endodontics OR periodontology OR dental implants OR prosthodontics OR aesthetic OR restorative dentistry OR dental emergency or oral surgery). Reference lists of any potential articles and OpenGrey12 database were screened for relevant unpublished studies or papers not identified by electronic searching.

The inclusion criteria considered original articles, systematic reviews, technique reports and clinical reports for the analyses. Conference abstracts and book chapters were excluded from the study. To be considered eligible for inclusion, studies should have reported at least one advantage of any digital workflow in dentistry that could be useful to improve safety against the COVID-19 pandemic. The guidelines of PRISMA statement were followed during data assessment and evaluation[17].

Data Extraction

Two independent reviewers with expertise in digital dentistry screened the titles, abstracts and full texts of articles identified. When considered required, attempts to contact study authors were performed. Data extracted from the studies included: year of publication; location of the study, sample and group characteristics; methodologic characteristics; outcome measures and conclusions.

Results

A total of 181 potentially eligible papers were screened. Of these, 122 were excluded after title, keywords and/or abstract assessment, yielding 59 papers that potentially met the inclusion criteria. Then, a total of 25 studies were also excluded, since their full texts did not present any direct evidence of advantages of digital dentistry, as compared to conventional methods. As a result, a total of 34 studies were finally identified as eligible for inclusion in this literature review. Characteristics of advantages raised by the studies included are summarized in Table 1.

Of the studies analyzed, 21% were published in 2020, 39% in the 2019, 18% in 2018, and 22% between 2015 and 2017. Furthermore, 36% of the studies were performed in the American continent (8% from North America), 31% in Asia, and 33% in European countries. Regarding the study design, 89% of the studies were observational, descriptive and analytical (of these, 48% were case reports), whereas 11% were experimental studies. Characteristics of clinical relevance concluded by the studies are also summarized in Table 1.

Table 1. Summary of advantages of digital dentistry with relevance for the current pandemic raised by the studies assessed

Field of Study	Studies Assessed	Relevance for the COVID-19 pandemic
Oral and Maxillofacial Radiology	References 18-26	Scans are faster and safer. Digital 3D data storage decreases number of appointments.
Aesthetic Dentistry	References 27-29	Facially driven digital wax-up decreases number of clinical appointments.
Orthodontics	Reference 30	Orthodontic aligners require less clinical appointments.
Prosthodontics	References 31-38	CAD-CAM procedures lead to less chairside time and reduced number of appointments.
Implant Dentistry	References 23, 39-42	Prosthetically-driven guided surgery decreases surgical time and number of appointments.
Oral and Maxillofacial Surgery	References 43-46	CAD-CAM surgical guides lead to faster and less invasive procedures.
Endodontics	References 47-50	Endodontic guides lead to faster procedures while decreasing the risk of iatrogenesis.
Periodontology	Reference 51	Surgical guides for crown lengthening decrease chairside time and number of appointments.

Oral and Maxillofacial Radiology

One of the most important aspects raised by the literature that could be important in the current pandemic is the establishment of faster, safer and optimal imaging diagnostic protocols[18]. For this purpose, imaging diagnostic centers should have adequate equipment hardware to perform faster scans, as well as to store and send images digitally to the responsible clinician, avoiding generation of printed exams. However, one of the main concerns raised by the literature, is the fact that most dental clinicians seem to be using printouts or static image files sent by email, instead of receiving original Digital Communication in Medicine (DICOM) files and performing digital analyses on software programs[19].

With the advent of cone beam computed tomography (CBCT) technology, significant improvements in hardware and software components have reduced radiation doses for patients. These enhancements include changes in sensor technology, smaller fields of view, and pulsed radiation technique following the ALARA (as low as reasonably achievable) radiation guidelines. Furthermore, several optimized exposure protocols (e.g. child mode, adult mode, high-resolution mode, high definition mode) have constantly been developed by manufacturers[20]. For this reason, modern and faster dental CBCT devices with smaller field of views have replaced medical CT scans of the craniofacial region, thus decreasing the total radiation dose for the patient[21].

In addition to CBCT, some non-invasive methods of diagnosis have become increasingly implemented in the clinical routine. Intraoral scanners are fast and prevent manipulation of impression trays with saliva. Evaluation of carious lesions using near-infrared light transillumination (NILT) is also feasible and has been shown to be as accurate as interproximal radiographs[22]. Some intraoral scanners have implemented this technology, such as the iTero 5D (Align Technologies, San Jose, California, USA).

With the appropriate computer-aided design and computer-aided manufacturing (CAD-CAM) techniques, fully digital workflow methodologies can be performed from stored digital imaging files of the exams, leading to a reduced number of clinical appointments to finalize oral rehabilitation treatments[23]. For this purpose, several types of files such as photographs, videos, intra- and extraoral scans and CBCT can be imported and combined in the same software to orientate treatment planning and execution by means of CAD-CAM technologies[24,25]. While CBCT should not be performed routinely without proper clinical indications, intra- and extraoral scans could be routinely stored, in order for the professional to have a backup of a patient's dental arch. This would allow the professional to analyze such dental arch without requiring a clinical appointment solely for this reason[26].

Aesthetic and Restorative Dentistry

In aesthetic dentistry, the use of facially driven digital wax-up tools such as the Digital Smile Design (DSD), combined with the traditional mock-up technique allows for predictability of treatments, leading to higher success rates[27]. Digital imaging allows patients to visualize the expected final result, as compared to their current oral health condition[27,28]. In this context, conventional mockups still used in some digital workflows can be replaced by photos, videos, and 3D models. DSD programs incorporate digital technology to the smile design process and can be used as tools for diagnosis, treatment plan visualization, and communication with the patient and technician that can increase treatment outcome predictability[29]. Therefore, treatment plan and details can be discussed with no need of a physical appointment.

Orthodontics

In the case of orthodontic patients, one of the most important preventive measures to prevent the spread and control the infection by COVID-19 is to perform an adequate screening of patients who should not attend the dental clinic[16]. In this context, digital workflow with orthodontic aligners requires less clinical appointments at the chairside, as compared with other orthodontic therapies. According to recent evidences, the use of orthodontic aligners is considered an aesthetic technique recommended to solve simple to moderate alignment cases[30].

On the other hand, an orthodontic aligner can be broken or lost by the patient. In this case, patients are oriented to continue to use a previous aligner in the sequence, depending on how long the patient had already used the broken / lost aligner. This decision would avoid the need of the patient to immediately schedule a physical appointment, which can be therefore postponed to a more adequate occasion, when the clinician is able to perform new digital impressions. Moreover, any treatment planning changes could still be performed digitally, which also avoids unnecessary physical appointments with the patient[16].

Prosthodontics

In conventional prosthetic dentistry, a number of clinical steps are usually necessary for try-in and adjustments of prostheses coming from the laboratory. However, digital workflow techniques can optimize prosthetic planning and fabrication, which is espe-

cially beneficial for patients and professionals during the current pandemic due to several reasons. Firstly, CAD/CAM procedures have the potential to produce reliable prostheses with a reduced number of appointments, with shorter chairside times, as well as higher precision and accuracy, as compared with conventional methods[31,32]. Furthermore, optimal occlusal and proximal contacts can be forecasted and designed in software, especially when making monolithic complete anatomy prostheses, without the need of further ceramic layering. Therefore, an anatomic analysis using full digital workflow is encouraged to obtain optimized results for digital crowns, fixed bridges, and full arch implant rehabilitations, leading to improved adaptation and reduced number of laboratory adjustments required[33].

Selection of materials for CAD-CAM restorations depends on the extension of the prosthetic span and the expected duration of the prosthesis (e.g. PMMA can be used for provisionalization, vitroceramics are indicated for crowns, liquid resin is indicated for provisionalization or prototypes, translucent zirconia can be used from crowns to full-arch prostheses)[34]. Similarly, CAD-CAM technology can be also applied to fabricate removable dental devices, such as complete dentures, removable partial dentures and splints with a reduced number of clinical steps, shorter chairside time and better adaptation results, as compared with the conventional workflow[35,36].

Despite such evidences, dentists must be aware that the use of high speed handpieces generate spray and airborne saliva particles[9]. Therefore, procedures involving such handpieces should be avoided during the current pandemic. Nevertheless, in cases that tooth preparation is mandatory, finishing line of preparations may be left at gingival level to avoid bleeding, and to facilitate digital impressions without the presence of blood[37,38].

Implant Dentistry

Digital technology was introduced in implant rehabilitations, leading to new different workflows to enable easier and faster ways to resolve cases. Digital implant-prosthetic planning and image-guided surgery techniques decrease the number of clinical appointments, since there is no need for clinically trying-in a conventional diagnostic wax-up in the mouth. Therefore, it is possible to perform an image-guided implant surgery after performing imaging examinations, virtual planning and surgical guide 3D-printing. Use of surgical guide developed from full digital workflow increasing predictability of implant positioning[23,39].

Digital workflow can also be used in cases of immediate implants. The advantages of immediately placed implants include reduced treatment time, fewer surgical procedures, better aesthetics and preservation of the alveolar bone in height and thickness[40]. Similarly, image-guided immediate implant surgery is performed less invasively, with less bleeding, often being a flapless surgery, and thus diminishing the dental cabinet potential contamination. Finally, since digital prosthetic planning is carried-out before surgical planning to allow for a prosthetically-driven implant placement, infrastructures and temporary prostheses can be manufactured even before implant placement surgery. Such advantages also apply for cases of bone grafting surgeries related to implant dentistry. In this context, two studies have reported the usefulness of CAD-CAM digital workflow to virtually plan the shape of block bone grafts[41], and to fabri-

cate surgical guides to remove fixation screws of block grafts allowing for subsequent flapless implant placement that leads to reduced surgical time and enhanced post-surgical healing[42].

Oral and Maxillofacial Surgery

During the current pandemic, oral and maxillofacial surgical procedures should allow for faster procedures with reduced amount of aerosol produced in the environment[15]. In this context, digital simulation of third-molar extraction surgeries based on CBCT scans has proved valuable for surgical guidance[43]. This leads procedures to be faster and less invasive and therefore safer for the patient, while requiring a lower amount of aerosol from clinical procedures during surgeries.

Models and surgical guides digitally designed from CBCT scans in CAD software and manufactured with 3D printing facilitate various procedures related to oral surgery, such as cases of periapical surgeries[44], surgeries for excision of large oral lesions[45], and surgeries to treat maxillofacial fractures[46]. Among the advantages of image-guided surgery described by the aforementioned studies are fast procedures and shorter chairside time required to perform surgeries.

Endodontics

Treatment planning using digital workflow and the use of endodontic guides simplified root channel treatment in obliterated teeth while decreasing the risk of iatrogenesis at the same time[47,48]. In addition, scientific evidences in endodontics suggest that treatment of compromised cases can be safely performed with digital workflow by less specifically experienced or skilled clinicians[47]. Among the advantages described in the literature discussed herein are: reduced treatment time for the clinician while offering higher predictability and success rates.

Surgical endodontic treatment can also benefit from digital dentistry methods. With freehand osteotomy and resection, clinicians make sequential adjustments to correct for errors in perforation site, angulation, and depth, possibly resulting in overextended osteotomy and nonideal resection, prolonging the surgical time[49]. On the other hand, guided surgery allows for a more efficient osteotomy and resection ideal of the surgical site and reduced surgical time potentially augmenting the healing process[49]. Surgical endodontic treatment aided by a 3D printed surgical guide provides an accurate osteotomy and root-end resection procedures[50].

Periodontology

In the field of periodontology, the most common treatment performed with digital workflow is the crown lengthening procedure, in which virtual planning allows for creation of CAD-CAM surgical guides to orientate gingivectomy and osteoplasty procedures in the aesthetic region. In this context, periodontal surgical outcomes can be predicted after the assembly of the digital project in a CAD-CAM software to carry out the aesthetic planning[51]. Such digital planning may include a face-guided wax pattern, a CBCT scan and intraoral scans of both dental arches[51]. The aforementioned digital workflow has been found to decrease the number of necessary clinical appointments when compared with the conventional methodology, while also improving treatment predictability.

Discussion

Digital Dentistry is based on the use of CAD-CAM methodologies. As described by the articles discussed herein, the initial project phase is characterized by transfer of patient's data to the digital world by using CAD methodologies to enable virtual treatment planning. When the latter is ready, one or more dental treatment devices can be fabricated with a CAM technique (e.g. 3D printing or milling). In this context, acquisition of intraoral scans is the first step of a digital workflow, and lead to greater comfort and less direct contact of the operator with the infected oral tissues, blood and saliva, as compared with conventional impressions. Nevertheless, all removable parts from intraoral scanners, such as tips, must undergo steam heat sterilization after each use. Similarly, fixed parts of the hardware such as screens and computers must be disinfected with chemical solutions with a single-use disposable wipe[52,53].

Despite its high cost, intraoral scanners can be used to accurately collect the data required to fabricate fixed or removable prosthetic devices[54]. Such data may include: implant tridimensional locations, details on gingival contours; prosthetic implant emergence profiles; previous prosthesis gingival volume; previous tooth shapes and tridimensional positions, vertical dimension, the opposing arch anatomy and dynamic occlusal contacts[33]. After data acquisition, digital workflows can be performed usually requiring less clinical appointments and shorter chairside time during treatment, reducing inaccuracies, and decreasing the number of steps and chances of occurrence of human errors[54].

Among the general advantages of digital over conventional workflows for the COVID-19 pandemic discussed herein are: decreased number of steps, higher productivity and possibility to perform several of the treatment steps directly in software, with no need of human contact[22,23]. As a result, planners and CAD professionals do not necessarily need to perform some of these tasks at laboratories or clinical facilities. Instead, in situations where quarantine is indicated, tasks could be performed remotely from the professionals' homes, following the recommendations to lessen the impact of the current pandemic.

For dental technicians working in laboratories, there are also several safety advantages provided by digital dentistry, such as avoiding conventional impressions that may carry biologic materials that are risk factors for the transmission of any type of microbial agents, including the coronavirus[12,15]. Another intrinsic advantage of digital workflow is the decreased working time from dental technicians during fabrication of devices with CAM, in which a milling machine and/or digital 3D printer can produce several pieces for hours simultaneously. As a result, digital laboratory workflows can be performed faster and with a reduced number of workers inside the laboratory environment, as compared to conventional workflows that require the physical presence of more dental technicians on benches to zmanually produce prosthetic devices and components[55].

The above-mentioned observations indicate that the advent of digital dentistry by dental laboratories could encourage dentists to work with and send preferably digital impressions in order to reduce human contact to biologic material and to benefit from the usefulness of digital workflows. On the other hand, in situations where the use of regular impressions is unavoidable, dentists could decontaminate the material prior

to sending it to laboratories by using 0.1% sodium hypochlorite or 70% ethanol or 0.5% hydrogen peroxide, which are disinfectants already available in dental clinics[56]. It is advisable to re-decontaminate all material when arriving, while changing laboratory sector, and when leaving the dental laboratory.

In addition to the new measures in dentistry discussed herein, dental clinicians could also benefit from CAD-CAM methodologies to participate in projects developing novel tools to improve biosafety during the current pandemic. In this context, the use of rubber dam and additional suction devices could prevent contamination from airborne particles during dental procedures[4]. Moreover, CAD-CAM knowledge could also be applied for the fabrication of customized equipment such as 3D-printed face masks and face shields[57].

Among the limitations of this scoped literature review is the limited number of experimental studies on digital dentistry. This occurs due to the fact that literature on digital workflows are very recent, including several case reports and description of techniques. Such techniques, in turn, have been developed along with the current fast technological improvements, and still need to be assessed in larger clinical and experimental studies. Another limitation is that, as expected, the relationship between clinically relevant advantages of digital workflows and the current pandemic is not necessarily explicit in articles on digital dentistry. Therefore, future public health studies would still be recommended to address the actual impact of digital workflows on the reduction COVID-19 transmission in dental clinics.

Within the limitations of this study, the findings observed herein suggest that the use of digital dentistry tools can lead to increased safety and reduced transmission of COVID-19 during the current pandemic.

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