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# A new dawn: The impact of digital technologies in oral and maxillofacial pathology

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**Abstract**

The rapid evolution of digital technology in all walks of the life is an important indicator that a different future is waiting for us. Technology has become a mainstay of daily life and is being increasingly used in education, research as well clinical activities with new innovations aiding healthcare and increase our knowledge, productivity and efficiency. There is no doubt that the healthcare sector, including dental sciences will be influenced by these rapid changes with many standard procedures likely to change. This is supported by the fact that some medical and dental specialties such as radiology have already made the digital leap. Digital pathology is an emerging area which has started to transform education and workflow in pathology. In this review, we will discuss how these novel and 'disruptive' technologies are likely to change education, training and diagnostic work flow in oral and maxillofacial pathology.

**Keywords:** artificial intelligence, digital pathology, education, image analysis, machine learning, oral and maxillofacial pathology

## 1. Introduction

Digital pathology (DP) has started to transform training, education and the conventional ways of working in pathology. There has been an explosion of research and development in this area over the last few years and it appears quite likely that DP will become a part and parcel of the oral and maxillofacial pathology workflow beginning from the biopsy accession to signing the report in near future. In addition to digital reporting, this workflow includes laboratory information management systems (LIMS), digital dictation and voice recognition tools as well as digital image analysis (Griffin and Treanor, 2017; Williams et al., 2018). A significant body of evidence has shown that transition to DP has numerous advantages over conventional light microscopy including improvements in safety, quality and efficiency in pathology laboratories. This is prudent at a time when there are significant workforce shortages in pathology laboratories across the world and expert consultations are becoming the norm.

The use of digital technology in pathology began in the 1960s with the first use of telepathology via real-time "television microscopy" (Weinstein, 1986). The term telepathology was first used in the 1980s allowing remote diagnosis using digitized/analogue video or a still image (Weinstein et al., 2012). This technology has been used successfully for primary diagnosis, intraoperative consultations (frozen section), rapid cytology, second-opinion practice consultation, archival review, quality assurance, multidisciplinary meetings (MDTM) and patient consultations (Pantanowitz et al., 2014). However, it has numerous limitations including suboptimal resolution, lack of standardization of file formats, loss of image quality due to compression as well as associated costs which continue to remain high. The advent of DP has rendered 'conventional' telepathology almost obsolete. High resolution slide scanners have now been around for almost 20 years with continuous technological improvements allowing capture of images from glass slides at a high magnification resulting in a whole slide image (WSI). Numerous scanners have now been approved and validated for diagnostic work by regulatory bodies and several studies have shown DP to be non-inferior to conventional light microscopy (Snead et al., 2016). Advent of low-cost scanners as well as high throughput scanners along with an increase in computational power has further accelerated digital deployment in the field of pathology. These advances in DP have the potential to revolutionize oral and maxillofacial pathology (OMFP) practice by transforming education, clinical training, case sharing and diagnostic workflow.

## 2. Workflow

DP has the potential to help improve clinical workflows in many ways. Digital techniques can be used in a number of processes from specimen reception/booking to archiving the pathology report. The process starts with barcode application to the specimen forms and containers reducing misidentification errors (Zarbo and D'Angelo, 2007) and

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providing electronic identification of the biopsy specimen. The macroscopic/gross features of the specimen can also be recorded digitally by the pathologist and uploaded in a secure manner allowing immediate remote transcription. This is further complemented by use of digital photographs. Even the standard procedures of tissue embedding and glass slide preparation have changed with the advent of automated microtomes and autostainers. Once the glass slides have been obtained, they can be scanned in batches, linked with the LIMS and immediately assigned to pathologists for reporting. Acquisition of a high-resolution digital image removes the need for physical transport of slides, 'immortalises the staining', reduces the need for storing glass slides and prevents the risk of glass slides getting broken or lost. The workflow becomes much more efficient and lean by reducing waste and streamlining processes providing a good audit trail and reducing errors. After digitization, the WSI can be assigned to pathologists who can report the cases from their workstations or remotely (Randell et al., 2014). Even at that stage, digital dictation as well as voice recognition tools have been widely adapted to aid reporting. DP access and implementation also means that interesting cases can be easily saved for teaching sets and MDTMs. At the end of the workflow, the reports can also be signed out electronically and stored digitally reducing the need for printing and posting and avoiding loss of confidential patient information. Hence a fully digital system from start to finish can offer safety, quality, flexibility and efficiency in any pathology setup.

### 2.1. Digital slides

The digitization process involves a robotic microscope that can obtain WSI by scanning sections of the slide at different magnifications and focus distances to facilitate a sufficient depth of field comparable to a microscope (Zarella et al., 2019). Once an image has been captured, it is digitally stitched to produce a composite virtual image mimicking the whole slide, which can be viewed on a digital screen by a pathologist (Indu et al., 2016) (Fig.1). The WSI can have a magnification of up to x40 and multiple slides can be viewed at the same time by multiple people. They can integrate with the LIMS and also make simplify slide sharing and collaboration. The scanning times are continually improving and the size of the produced images are also reducing due to improvement in image compression methods. Furthermore, WSI acquisition also facilitates more quantifiable and accurate information from tissue sections. A number of free WSI viewing software are available on the internet, almost all of which have features allowing measurement of lesions, distance from margin, annotations and export as still images or snapshots. Having said that, there is an initial cost associated with a scanner setup, service contracts for software upgrades as well as certain computing and networking requirements for smooth running of the system however the improvement in efficiency and turnaround times still make a compelling case for DP implementation.

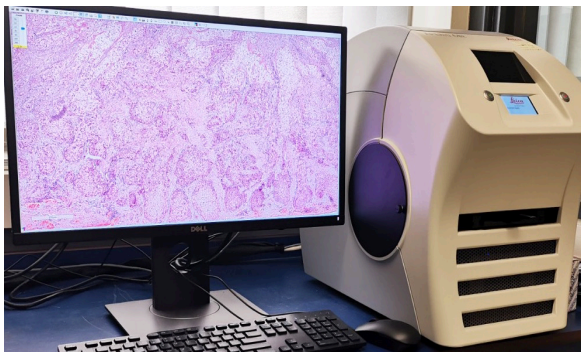

**Fig. 1.** A representative image showing a digital slide scanner and associated workstation

As previously mentioned, WSI produced using digital scanners have now been evaluated in a number of studies, all of which show that DP is equivalent to glass slides for diagnostic purposes (Mukhopadhyay et al., 2018). A recent systematic review has also shown a considerable amount of concordance between diagnosis made by pathologists on glass and digital slides (Williams et al., 2017; Araújo et al., 2019). Despite its widespread use and validation in general histopathology, use in OMFP remains limited with only one small validation study to date (Araújo et al., 2018). How far DP has come is shown by the fact that most of the regulatory pathology bodies now have recommendations and guidelines for its use and application including the Royal College of Pathology UK (Cross et al., 2018) and the College of American Pathologists (Hipp et al., 2017).

The disadvantages of digital pathology include expensive equipment, the need for secure platforms allowing exchange of images/documents and laboratory infrastructure and information systems that are not yet ready to support digitalization for each pathology laboratories.

### 2.2. Image analysis

The application of digital image analysis in pathology is rapidly evolving. Propriety image analysis software systems have been available for a while for evaluation of immunohistochemical (IHC) markers and have been shown to improve the consistency and accuracy of scoring but have largely been used in research to date (Helin et al., 2016). WSI are large images containing a wealth of information ideal for application of image analysis tools which can reduce the subjectivity to provide more meaningful and accurate dimensions and quantitative scores to aid patient management. This can include variables such as tumour size, depth of invasion, distance from margins or scoring of personalised/ therapeutic IHC markers such as HER2 and PD-L1. Numerous open-source software (such as QuPath, Cytomine and Orbit) have also emerged recently as really valuable tools for researchers and clinicians allowing quantification of a wide range of features in pathology images and WSI (Marée et al., 2016; Bankhead et al., 2017; Stritt et al., 2020) (Fig. 2).

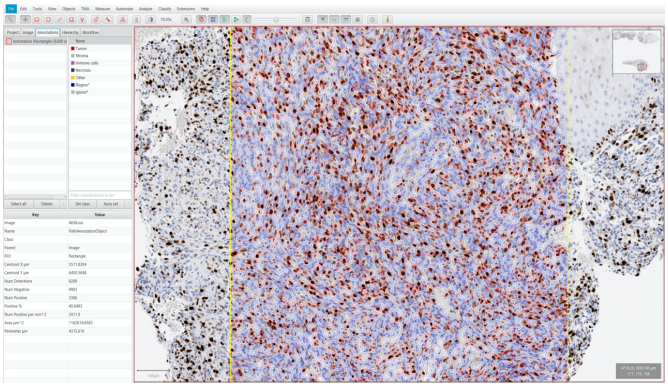

**Fig. 2.** Ki67 scoring in an OMFP specimen using QuPath. Red cell=positive, blue cells= negative. Percentage positivity = 40%

### 2.3. Artificial intelligence and deep learning

Development in whole slide scanner technology and computational power and reduction in scanner costs have led to a large number of glass slides being scanned and archived digitally. These multi-gigapixel digital images are ideal for application of artificial intelligence (AI) not only to aid the pathologist in terms of interpretation and workload reduction but also to maximize the amount of information gleaned and facilitate discovery of novel 'digital biomarkers' and morphologic patterns to predict the prognosis. AI and Deep Learning (DL) have been widely used to predict disease behavior in breast (Ehteshami et al., 2018), lung (Coudray et al., 2018), thyroid (Guan et al., 2019), colorectal (Weis et al., 2018) and prostate (Arvaniti et al., 2018) cancers. In numerous studies, AI has shown similar (and in some case better) performance compared to experienced pathologists removing subjectivity and variability by producing standardization and quantitative outputs (Kourou et al., 2015; Vu et al., 2019).

Application of AI and DL to OMFP has been somewhat limited compared to other specialties. Recently, an automated AI-based tumour infiltrating lymphocyte score used for oral squamous cell carcinoma (OSCC) patient stratification has been reported (Shaban et al., 2019). Attempts have also been made in a handful of studies to explore the potential of AI in oral potentially malignant disorders (including dysplasia) and oropharyngeal squamous cell carcinoma. Figure 3 demonstrates an example of automated identification of OSCC, stroma and immune cells in a WSI resulting in a quantitative measurement which can be compared with other clinicopathological variables. The advent of open-source image analysis tools and reported results of the studies to date show that AI has the potential to be a diagnostic/prognostic aid in OMFP but also highlight the need for further larger and multi-centric studies to harness the true potential of AI.

Despite the recent surge in AI related publications and research funding, translation of AI algorithms for clinical and prospective use in pathology remains a problem and is fraught with numerous obstacles and challenges such as validation, interpretability, pathologist engagement, acceptance of patients and clinicians and regulatory approval (Jiang et al., 2020).

However, considering the vast amount of research that has emerged in this area within the last few years, it is likely that these problems will be overcome eventually and AI based tools will become a part of pathology practice as a useful adjunct.

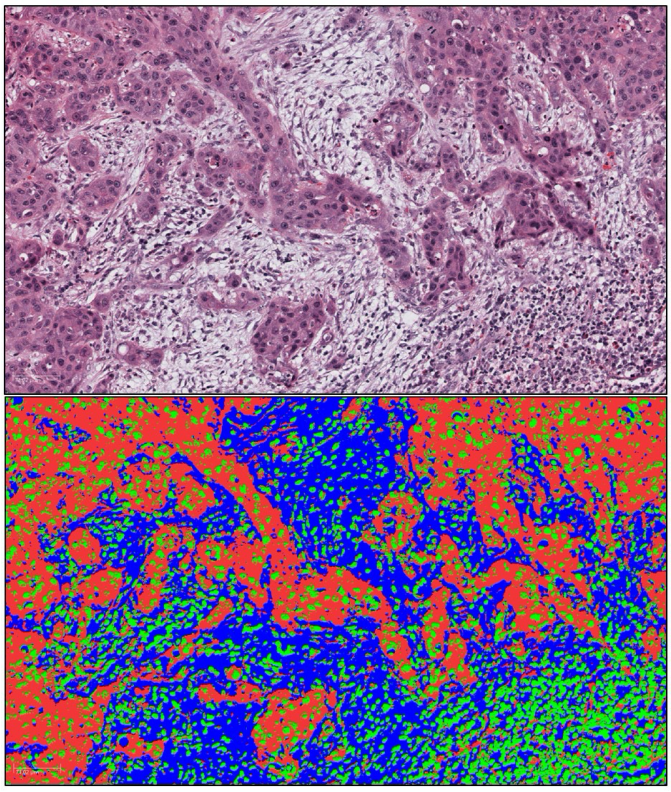

**Fig. 3.** H&E and overlay images showing automated detection of tumour/OSCC (Red), stroma (blue) and immune cells (green). Image generated using Orbit Image Analysis Software

### 2.4. Digital pathology in education

In an age with such advanced technology, changes in education systems are inevitable and essential. This has been highlighted prominently during the COVID-19 pandemic where digital learning and education tools have proven invaluable allowing people to work flexibly and remotely. This is supplemented by the fact that access to information in the current times is much easier than it has ever been. Even access to large digital achieves of pathology slides and data sets is becoming increasingly common (e.g. The Cancer Genome Atlas/TCGA) and proving to be a huge educational resource for students and trainees. Publicly available DP platforms have made sharing of WSI really easy and such initiatives have been strongly complemented by the widespread use of social media by pathologists. It is now possible to access WSI in digital media for many pathology publications shown by the fact that the WHO Classification series has established a digital platform to start providing WSI of the images used in the books. In addition, many pathology associations upload interesting cases with clinical information, radiological images and WSI to engage students, residents/trainees and pathologists. Among these associations, the British Association for Oral and Maxillofacial Pathology (BSOMP) has been a trail blazer for OMFP, publicly sharing a highly interesting OMFP case of the

month on its website and social media accounts since April 2018 covering a range of odontogenic, mucosal, salivary and dental pathologies (https://www.bsomp.org.uk/cotm).

A number of web based digital pathology platforms have also emerged to provide educational tools to students, trainees and specialists (e.g. Pathpresenter, Kiko XP and Open Zoom etc.). Pathpresenter.net is one of the leading example of a digital pathology education system (https://pathpresenter.net/#/). It is a platform created by pathologists for sharing of digital educational content and research data. It also has a very useful OMFP section with examples of some classical pathologies. Such platforms can also be used for presentations, lectures and quizzes for students/trainees removing the need to use microscopes and facilitating learning. This is complemented by the fact that the current and next generation of students and pathologists are technology savvy preferring to use digital tools and 'smart devices' to view WSI (Fig.4). One criticism of using virtual microscopy is that it prevents students from learning microscope-handling skills. This might be true, but this is a separate goal from the analysis and interpretation of tissue sections where the advantages of virtual microscopy clearly outweigh the disadvantages.

## 3. Conclusion and the future

Development of digital technologies has already made a great impact on our lives. These days, especially when the Covid-19 pandemic has ground the world to a halt and with social distancing being the most effective way of protection, examples of this digital technology revolution can be seen everywhere with virtual meetings, on-line education, remote working from home, virtual patient consultations as well as use of DP and remote reporting indicating that a new dawn is already here. It is almost certain that even more education institutions and pathology laboratories will make the transition to DP in the near future as this digital future appears to offer an equally effective and alternative learning, teaching and working opportunity for all of us.

**Fig. 4.** The students using their phones to see WSI simultaneously with the screen in a pathology practical lesson

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