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Invited review

Optical diagnostic techniques for use in lesions of the head and neck: review of the latest developments

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Abstract

Optical biopsy systems are a potential adjunct to the histopathological assessment of tissue specimens; they are not invasive and can give an immediate result. We review the most common optical biopsy techniques used to detect lesions of the head and neck: elastic scattering spectroscopy, microendoscopy, narrow band imaging, fluorescence, and optical coherence tomography, and discuss their clinical use.

Keywords: skin cancer; oral cancer; optical biopsy; elastic scattering spectroscopy; narrow-band imaging; fluorescence; microendoscopy; optical coherence tomography

Introduction

Currently, histopathological analysis is the gold standard for tissue diagnosis, and optical diagnostic methods are a useful adjunct. They can provide similar information to a biopsy examination and also have other advantages (Table 1). Each has its own mechanism of action and different modes of data analysis, and they all provide a real-time, non-invasive, and in situ optical signature using light of varying wavelengths to examine suspicious lesions.[1–3] They can differentiate between normal and pathological lesions, and also aid in the diagnosis of those that present with similar clinical characteristics (Table 2). To be clinically useful, clinicians need to know the specific characteristics of each system (Table 3) and the advantages and disadvantages of each one (Table 4).

Elastic scattering spectroscopy (ESS)

This system generates a wavelength spectrum that reflects the basic properties within tissues such as the nucleus and subcellular organelles, and other components such as proteins and lipids. It has been used in studies on premalignant and malignant ex vivo oral tissue.[3,4] In one, sensitivity of 72.7% and specificity of 75% were obtained after assessment of clinically suspicious oral lesions in 25 patients, and the spectra could be combined as a result of analysing different anatomical sites.[4] Assessment of nodal metastases had a sensitivity of 98% and specificity of 68%, but false positives were found in 40%.[5] When used to measure the extent of invasion in the mandible, sensitivity was 85% and specificity 80%.[6] There are 2 main limitations: a lack of data on oral lesions and a lack

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Table 1
Advantages of an of optical detection system.

Real time
Enables optimal biopsy examination without removal of excess tissue
Guide to effective diagnosis
Guide to consent
Guide to effective sampling
Guide to treatment during and after operation
Potential to guide other methods of treatment such as photodynamic therapy (PDT)

of correlation between the sites investigated using optical and surgical methods.[5,6] Formalin can also have a considerable impact on results as it affects the spectra obtained.[6]

ESS has potential for the assessment of skin, and has been used to discriminate between normal, benign, and malignant lesions including basal cell carcinoma (BCC) in 73 patients.[7] The results were low, possibly because of the large number of false negatives caused by the small sample size. False positives were the result of inflammatory changes that may mimic the disease.[7] ESS can also be used to assess margins in Mohs micrographic surgery. Upile et al showed that results were better than frozen section and its use reduced the amount of normal tissue excised.[8]

Microendoscopy

This technique allows for the histopathological assessment of tissue in vivo. It can be used to monitor the mucosal surface and allows adequate identification of abnormalities in the tissue, so theoretically can reduce the amount of tissue taken.[9] The microendoscope is attached to a camera, and different sized scopes can be used for specific areas of interest. The maximum magnification is x 150. When compared with frozen and paraffin sections, microendoscopy detected dysplastic mucosa with a sensitivity of 95% and specificity of 90%.[9] A recent study showed that after training, it can potentially achieve sensitivity of 98% and specificity of 92%.[10] Muldoon et al found that it allowed for real-time analysis of tissues, it enabled informed decisions to be made on resection margins, and reduced thermal and orientation artefacts.[11] However, the system has limitations as it can penetrate to a maximum depth of only 50 μm, and keratinisation can cause background artefacts.[9,11]

Table 3
Characteristics of an ideal optical detection system.

Done in real time
Usable with both hand-held and endoscopic devices
High sensitivity
High specificity
Independent of operator
Validated against gold standard
Can be used in the outpatient clinic
Can be used in theatre
Easy to use
Documentation available (photos)
Cheap and cost-effective

Table 2
Summary of common optical biopsy techniques [7].

Optical diagnostic technique	Mechanism of action	Clinical application
Elastic scattering spectroscopy (ESS)	Disorganised epithelial architecture and orientation Changes in morphology, texture, and surface of epithelium Cell crowding and increased distance from the subepithelial layer Enlargement and hyperchromicity of cell nuclei Increase in metabolic concentration of organelles Presence of abnormal protein packages or particles	Detection of dysplasia, carcinoma-in-situ or cancer Guides biopsy examinations Measurement of surgical margins Measurement of oxygen saturation in tissues Measurement of uptake of photosensitiser for photodynamic therapy Measurement of concentration of drugs or chemotherapy in tissues
Fluorescence	Shift in NADH, NADPH to oxidised states as a result of increased cell metabolism Increased level of fluorophores Cell crowding and assessment of increased distance from subepithelial collagen layer Changes in epithelial morphology, surface texture, and thickness	Detection of dysplasia and cancer Assessment of the perfusion of free flaps
Microendoscopy	Altered cytoplasmic ratio with flavine dye Disordered keratinisation Irregular cell lines and cell architecture Neoangiogenesis with irregular formation of vessels	Direct visualisation of epithelial morphology Measurement of surgical margins Allows for real-time assessment of vasculature Allows for visualisation of subdermal layers without damage to structures
Narrow band imaging (NBI)	Neoangiogenesis with irregular, elongated, or dilated vessels	Detection of dysplasia and cancer
Optical coherence tomography (OCT)	Irregular epidermal thickening Dark irregular bands detected as hyperkeratosis Dermal lobular structures detected	Detection of oral and skin lesions Measurement of surgical margins Guidance for treatments such as photodynamic therapy