

# Potential Applications of Vibrational Spectroscopy in Plastic Surgery and Burns Treatment

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## **Abstract**

Background: Vibrational spectroscopy represents a non-invasive optical technique capable of providing real-time biochemical characterization of tissues based on molecular vibrations. These label-free modalities offer significant potential for advancing diagnostic and therapeutic approaches in plastic surgery and burn treatment.

Burn Depth Assessment: Accurate burn depth determination remains critical for treatment planning and surgical decision-making. Raman spectroscopy achieves approximately 92% accuracy in classifying burn severities on ex vivo porcine skin, with proteins, lipids, amide III, and amino acids serving as key discriminatory biomarkers.[1] When combined with optical coherence tomography, diagnostic accuracy reaches 85% in distinguishing superficial partial-thickness, deep partial-thickness, and full-thickness burns.[2] Terahertz time-domain spectroscopic imaging demonstrates receiver operating characteristic curve areas of 0.88-0.93 for different burn depths, with 94.7% accuracy in predicting wound healing outcomes.[3][4] However, clinical validation remains limited, with systematic review of human studies showing pooled sensitivity of 86% and specificity of 84%, but with significant methodological heterogeneity.[5]

Wound Healing Monitoring: Spectroscopy enables non-invasive tracking of wound healing progression through detection of biochemical changes across inflammatory, proliferative, and remodeling phases. The technique identifies metabolic activity patterns, with higher concentrations of carbohydrates, proteins, lipids, and nucleic acids evident in early post-burn days compared to healthy skin, and reduced amounts during later healing phases.[6] Raman microspectroscopy coupled with multivariate analysis accurately identifies different phases of wound healing and can detect slowly healing wounds as outliers, providing quantitative measures of inflammation and granulation.[7]

Skin Cancer Detection and Surgical Margin Assessment: In dermatologic and reconstructive surgery, Raman spectroscopy demonstrates high diagnostic accuracy for skin cancer detection. Meta-analysis reveals pooled sensitivity

and specificity of 0.99 and 0.96 for ex vivo basal cell carcinoma detection, and 1.00 and 0.98 for melanoma detection.[8] Real-time in vivo Raman spectroscopy achieves receiver operating characteristic values of 0.879 for distinguishing skin cancers from benign lesions and 0.823 for melanomas from non-melanoma pigmented lesions.[9] For intraoperative margin assessment, Raman spectroscopy identifies tumor margins with 90% sensitivity and 92% specificity based on nuclear content, keratin, collagen, and lipid biomarkers.[10] These capabilities may reduce unnecessary biopsies and enable real-time surgical guidance.

Tissue Engineering Applications: Vibrational spectroscopy provides non-destructive compositional assessment of engineered tissue constructs for reconstructive surgery. Near-infrared spectroscopy combined with multivariate analysis successfully predicts proteoglycan (R=0.82) and collagen (R=0.84) content in engineered cartilage, correlating with mechanical properties and enabling optimal harvest timing.[11]ATR-FTIR spectroscopy of culture media monitors glucose consumption and lactate secretion, with strong correlation to proteoglycan content (R=0.80), providing a novel approach to assess construct development without tissue destruction.[13]

Conclusion: Vibrational spectroscopy offers multiple promising applications in plastic surgery and burns treatment, including objective burn depth classification, wound healing monitoring, skin cancer detection with surgical margin assessment, and tissue-engineered construct evaluation. While preclinical data demonstrate high diagnostic accuracy, rigorous multicenter clinical validation with standardized protocols and ground truth standards is required before widespread clinical implementation.

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