Raman spectroscopic detection of silicone leakage in human breast and lymph node tissues

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Abstract – *Raman spectroscopy was utilized to study surgical excision specimens of human breast and lymph node tissues from patients with leaking silicone bag-gel breast implants. This may offer a new method of detection to evaluate tissues.*

INTRODUCTION

Silicone (polydimethylsiloxane) elastomer has commonly been used for reconstruction or augmentation of the female breast. Rupture of a silicone bag-gel prosthesis or slow bleeding of silicone gel through its outer bag may cause inflammation and scarring of breast tissue adjacent to the implant. Silicone gel may accumulate within lymph nodes and other organs. In a small minority of cases, this may be associated with systemic sclerosis [1], a disease in which abnormal immune reaction produces inflammation and fibrosis scarring of the skin, gastrointestinal tract, joints, kidneys, lungs, and other organs. Citing these potential health risks, the restrictions upon the use of these silicone gel prostheses have been placed in many countries.

Current practices for the identification of the cause of lymph node enlargement in post-mastectomy patients or the determination of whether silicone leakage has occurred in patients developing auto-immune disease subsequent to receiving breast implants require the removal of tissue by needle biopsy [2] or surgical excision [3]. The presence of extracellular and intracellular deposits of refractile material in this tissue can be detected by light microscopic examination. In patients known to have a silicone gel breast prosthesis, the presence of such refractile material can be interpreted as consistent with silicone infiltration. Definitive identification of elemental silicon can be accomplished by X-ray diffraction crystallography analysis [2,3], but this procedure is both time-consuming and expensive. It has been explored to use the laser-Raman microprobe to identify microscopic inclusions of silicone polymer in standard paraffin section of lymph node [4], to trace the contaminant silicone in solvents [5], to detect the presence of silicone infiltration within lymph node biopsy specimens [6], and to characterize the human breast tissues [7]. In the present work, we demonstrate a non-destructive and convenient method for the detection of microscopic silicone leakage from the silicone bag-gel breast implants through the use of conventional Raman spectroscopy without using the microprobe. Both formalin fixed specimens and tissues embedded in paraffin blocks were studied.

EXPERIMENT

Raman measurements were performed on normal breast and lymph node tissues obtained from surgical specimens submitted for routine histopathological analysis. Specimens of both breast and lymph node tissues with silicone infiltration were obtained from female patients (who signed informed consent permitting investigational use) with ruptured silicone bag-gel implants undergoing surgical revision.

Portions of lymphoid and breast tissue surgically excised for diagnostic evaluation were fixed for 12 - 72 hours in 10% formalin buffered with 50mM phosphate to pH 6-7, dehydrated in a graded series of alcohol and xylene mixtures, and embedded in paraffin wax.

RESULTS

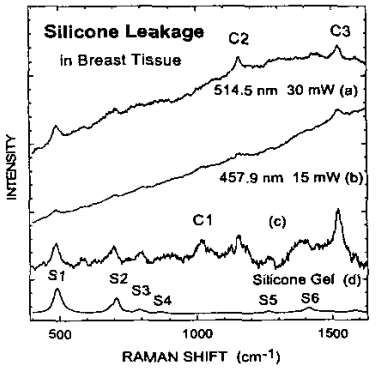

Figure 1. Raman spectra for a fresh breast specimen with silicone infiltration, excited at (a) 514.5 nm with 30 mW; and (b) 457.9 nm with 15 mW at the sample. Both were measured at ambient temperature. Spectrum (c) is the result of removing a smooth background from the spectrum in (b), and magnified. (d) is the spectrum from the pure silicon gel.

Figure 1 (a) and (b) show Raman spectra from a specimen of breast tissue at two different excitation wavelengths, 514.5 and 457.9 nm, respectively, from an Ar^+ laser, while Fig. 1 (c) shows the result of subtracting a smooth curve from the spectrum in Fig. 1 (b) to remove the fluorescence background. A reference spectrum from a sole silicone gel is exhibited in Fig. 1

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(d). The series of peaks at 490, 710, 790, 864, 1264, and 1412 cm^{-1} (labeled as S1-S6) are characteristic Raman lines from silicone molecule [5,7]. Breast tissue has a (relatively broad) fluorescence peak at about 530 nm [7] which contributes a sloping background. We have identified [7] that β-carotene exhibits the characteristic Cl, C2 and C3 Raman lines under the 514.5 nm excitation. These beta carotene like C-series of lines can be seen in spectra Fig.1 (a-b) and the strongest silicone lines of Sl and S2 are also observed. From Fig. 1 (c) after removing the fluorescence background, the β-carotene characteristic Cl, C2 and C3 Raman lines can be identified more clearly. Even the weaker S3-S6 lines of silicone can be resolved in addition to the strongest silicone lines of Sl and S2. Silicone leakage was clearly detected for this specimen and confirmed by polarization microscopy. Comparative examinations of normal specimens obtained from patients without silicone implants or without silicone infiltration show the absence of these spectral features associated with silicone (S1-S6). Only the carotenoid and lipid features are observed in these control specimens [7].

Figure 2 shows Raman spectra using near-infrared excitation at 782 nm with a Ti:Sapphire laser. Fig. 2 (a) shows the Raman spectrum obtained from a formalin fixed lymph node with silicone infiltration. Under the higher resolution than that in Fig. 1; a shoulder, S2', at 686 cm^{-1}, in the low frequency side of the peak S2 can be resolved. All the lines (S1-S6) characteristic of silicone can be seen also in the node from Fig. 2 (b). The reduced background is due to lower intensity of the low energy tail of the fluorescence band with NIR excitation. Thus, the weaker, higher frequency (and thus longer wavelength) peaks (S3-S6) are less interfered by the fluorescence background. In contrast, these peaks are either on top of the peak of the fluorescence (with 514.5 nm excitation; Fig. 1(a)) or on the high energy side (and thus closer to the peak) of the fluorescence band (with 457.9 nm excitation; Fig. 1(b)). Fig. 2(b) represents our effort to detect silicone infiltration from an archival block with lymph node tissue embedded in paraffin. Peaks due to silicone, Sl and S2, are seen in Fig. 2(b). Sharp peaks beyond 800 cm^{-1}, labeled by P, are due to the paraffin base [6].

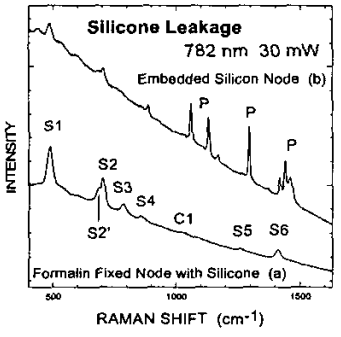

Figure 2. Raman spectra of (a) a formalin fixed node with silicone; and (b) a silicone node embedded in paraffin base, using near infra-red excitation at 782 nm with 30 mW at the sample from a Ti:Sapphire laser, both measured at ambient temperature.

CONCLUSION

Raman spectroscopy has been successfully applied to study surgical excision specimens of human breast and lymph node tissues from patients with leaking silicone bag-gel breast implants. The unique Raman spectral features of silicone were easily distinguished from the spectral features of both normal breast and lymph node tissues and can thus be used as molecular signature of silicone. The detection of silicone present in microscopic quantities within these tissues was demonstrated. This technique may be of value in the management of patients with silicone prostheses as it provides a test which is accurate, rapid, and non-destructive. By virtue of being adaptable to optical fiber techniques, the possibility of using this laser-based spectroscopic technique to evaluate tissues *in situ* may offer new methods of detection and treatment.

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