International Journal of Scientific Research & Engineering Trends
Volume 10, Issue 6, Nov-Dec-2024, ISSN (Online): 2395-566X

Raman Spectroscopy: Diagnostic Tool for Cancer Cell Identification

Rakshit pandey, Deepak Rawat, Professor Himmat singh
Department of Zoology & life Science
S.S. Jain Subodh P.G. (Autonomous) College, Jaipur, Technos Instrument Jaipur

Abstract- Non-destructive spectroscopic techniques represent the top-choice for any kind of process monitoring . Among all of the available techniques, Raman spectroscopy is one of the most solid and versatile tools to analyze several materials, both in lab and on-field conditions . Raman analysis has grown, reaching several industrial sectors such the food and textiles sectors .Raman spectroscopy displays several advantageous features over other techniques like infrared spectroscopy. For example, the quality of the signal collected is barely affected by the presence of water, allowing for use in plenty of applications where infrared analyses are not reliable . A representative case study is the in-situ monitoring of a fermentative process where Raman techniques outperformed any other spectroscopic approach .Molecular-level tissue characterization is highly potent for cancer diagnosis. As a tissue starts becoming cancerous, specific biomolecules are overexpressed or aberrantly expressed, which can be used as cancer molecular markers. If we can detect these molecular markers spectroscopically, it would lead to a new molecular-level cancer diagnosis with high objectivity.

Index Terms- Raman spectroscopic , Raman shift , Cancer , Etx.

I. INTRODUCTION

Non-destructive spectroscopic techniques represent the top-choice for any kind of process monitoring . Among all of the available techniques, Raman spectroscopy is one of the most solid and versatile tools to analyze several materials, both in lab and on-field conditions . Raman spectroscopy was first independently developed in the first half of the 20th century by the Nobel laureate Chandrasekhara Venkata Raman and Grigorij Samuilovič Landsberg , but it was established after the implementation of laser light equipped spectrometers in the second half of the century .

The establishment of Raman spectroscopy opened the path to a more detailed knowledge about materials, with a particular emphasis on carbonaceous materials such as graphite .Throughout the years, Raman analysis has grown, reaching several industrial sectors such the food and textiles sectors .Raman spectroscopy displays several advantageous features over other techniques like infrared spectroscopy. For example, the quality of the signal collected is barely affected by the presence of water, allowing for use in plenty of applications where infrared analyses are not reliable . A representative case study is the in-situ monitoring of a fermentative process where Raman techniques outperformed any other spectroscopic approach . Nonetheless, Raman analysis suffers from some difficulties such as the challenge of developing quantitative robust and trustworthy methods of data analysis . Furthermore, the presence of highly active Raman species such as carbon particles could mask the presence of other species . Several studies have been devoted to overcoming these drawback

Cancer ranks among the leading causes of death worldwide, second only to heart disease. Among them, head and neck cancer (HNC) stands as the seventh most common cancer globally, with approximately 900,000 new cases and over 480,000 deaths reported in 2022 . Furthermore, both its incidence and mortality rates are steadily rising, with a projected 30% increase by 2030, and HPV-associated oral cancers continue to rise at a, for 90% and human papillomavirus infection . Currently, although numerous new therapeutic strategies exist, the primary treatment for head and neck cancer generally involves multi-disciplinary team (MDT) therapy, which encompasses surgery, radiotherapy (RT), and chemotherapy Despite advancements in treatment modalities, the global 5-year survival rate for HNC averages at 50%. Generally, early-stage HNSCC can be effectively managed through surgical intervention or radiotherapy, with 5-year survival rates ranging from 70 to 90%10 rate of 2% per year 14. Squamous cell carcinoma accounts of cases of head and neck cancer, profoundly impacting patients' quality of life. Risk factors include smoking, alcohol consumption, betel chewing

Radiation-related caries is well-documented as one of the most common complications, affecting approximately 29-37%

of post-radiotherapy head and neck cancer patients, with its incidence tending to increase with the dose of radiotherapy RRC manifests as a serious rapid, and progressive destruction of the hard tissue of the tooth following radiation therapy In comparison to conventional caries, it exhibits characteristics of rapid progression, wide accumulation range, and concentration in the tooth cervical areas and the dental cusp. Furthermore, the development of radiation-related caries poses challenges in clinical treatment due to patients' diminished physical condition post-radiotherapy, reduced oral saliva, and the high cost of treatment. Moreover, research on RRC is hindered by the difficulty of obtaining dental specimens and the lack of an in vitro model. Therefore, the objective of this study is to assess the effects of different radiation approaches on enamel structure and caries susceptibility, aiming to establish a reference model of RRC in vitro. This may serve as a foundation for further research on the prevention and management of RR.

II. RAMAN VARIANTS IN ORAL CANCER STUDIES

RS, in its simplest form, implies the phenomenon of Spontaneous Raman scattering Spontaneous Raman scattering has seen increasing popularity in biomedical research, but Raman effect is inherently weak and is essentially competing with stronger signals from Rayleigh scattering and tissue autofluorescence. Experimentally, the use of higher-powered lasers and longer signal acquisition times can improve the Raman signal and photobleaching can quench the autofluorescence. However, the potential damage that can be induced following application of these experimental approaches poses significant challenges both t biological and clinical applications. Consequently, numerous Raman-based techniques have been developed to enhance the weak Raman signal and overcome issues with fluorescence interference, whilst minimizing photodegradation. Furthermore, the development techniques such as Spatially offset RS and Transmission RS make it possible to probe biomolecules in deep tissue layers for potential non-invasive in vivo measurements. The based principles and examples of where these variants have been applied in BC detection and diagnosis.

Current challenges and future outlook for clinical implementation

Capabilities of RS hold promise for future applications in BC detection and diagnosis. However, there are several barriers that remain with regards to its widespread clinical translation.

Good general information is currently available for obtaining spectra from biological samples , but, there is a real lack of uniformity regarding protocols amongst studies. This includes: the way the samples are prepared; the substrate on which they are mounted; the spectrometer instrument settings and the computational pre-processing methods applied. The use of different protocols for analyzing the same samples can result in significantly different spectra. As spectral differences between cancerous and non-cancerous samples can be very subtle, experimental variability may be responsible for disparity amongst studies with regards to spectral biomarkers for the same disease or even lead to the discovery of false biomarkers. Therefore, it is of paramount importance to optimize and standardize the experimental setup, as well as validate its robustness, for future analysis of biological sample.

III. RESULT AND DISCUSSION

Molecular-level tissue characterization is highly potent for cancer diagnosis. As a tissue starts becoming cancerous, specific biomolecules are overexpressed or aberrantly expressed, which can be used as cancer molecular markers. If we can detect these molecular markers spectroscopically, it would lead to a new molecular-level cancer diagnosis with high objectivity.

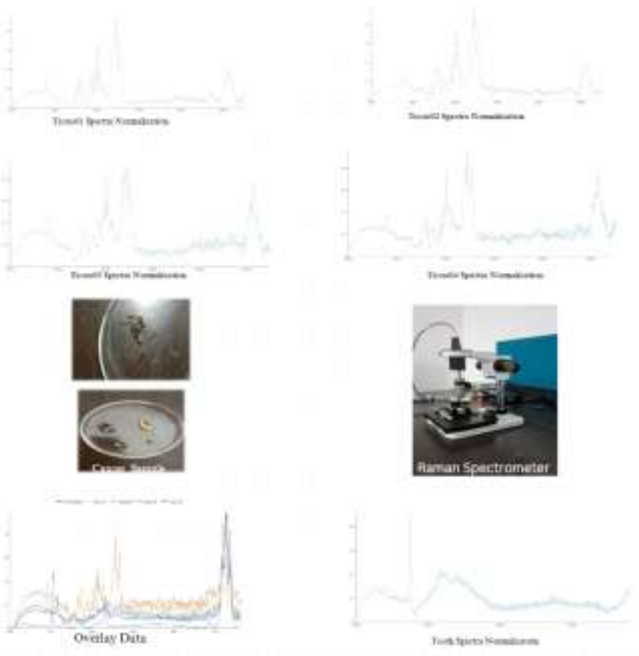

Figure 1: Result & provided sample

Keratin-family proteins (M.W. 40000 ~ 67000) are major components of fibrous structural proteins in epithelial cells. They play important roles in the formation of cytoskeleton network and help maintain the structural integrity of cellular morphology. Several studies have shown that keratin is aberrantly expressed in many different types of human epithelial cancers including skin cancer, lung cancer, breast cancer, cervix cancer, esophagus cancer, salivary gland cancer and oral cancer . In the present study, we focus on oral cancer.

Oral squamous cell carcinoma (OSCC) is one of the most common cancers (95% in oral malignancy) in oral cavity. Keratin is a well-established molecular marker of OSCC; oral malignancy can be diagnosed by detecting the variations in keratin expression between OSCC and normal oral tissues. At present, keratin in oral tissues is detected and analyzed by means of immunohistochemistry (IHC). However, IHC is expensive, time-consuming and needs specialist attention. An economic and straightforward alternative for keratin detection in oral tissues is longed for,The provided sample was non cancerous.

IV. CONCLUSION

Applying the Raman effect Since the frequencies of light absorbed when a molecule is illuminated are unique to the molecule and type of bonds, detecting these frequencies of light will allow us to figure out which molecules are present in the sample.

This is the aim of Raman spectroscopy.

So how can we detect which frequencies of light were absorbed by molecules in the sample? Well, when those molecules absorb some of the light (inelastic scattering), the frequency of the light changes. So to detect the Raman effect, we can simply determine the frequency shift between the original beam of light and the Raman scattered light. The frequency shift is called the Raman shift.

By using a monochromatic laser for the experiment we can easily determine the frequency of the original light beam, since lasers emit light that is all the same wavelength and frequency. The typical choice is a green laser (532 nm). To make it clear: When the sample is illuminated with the laser, some of the laser light will be absorbed by the sample to excite molecular vibrations, causing Raman scattering. The Raman scattered light is then collected at a detector so we can determine its frequency. That will give us all the information we need to determine the Raman shift.

REFERENCES

1. Sun, T.-T., Shih, C. & Green, H. Keratin cytoskeletons in epithelial cells of internal organs. Proc. Natl. Acad. Sci. USA 76, 2813-2817 (1979).
2. Sivaramakrishnan, S., DeGiulio, J. V., Lorand, L., Goldman, R. D. & Ridge, K. M. Micromechanical properties of keratin intermediate filament networks. Proc. Natl. Acad. Sci.USA 105, 889-894 (2008).
3. Schlegel, R., Banks-Schlegel, S., McLeod, J. A. & Pinkus, G. S. Immunoperoxidase Localizationof Keratin in Human Neoplasms. Am. J. Pathol. 101, 41-49 (1980).
4. Ramaekers, F. C. S. et al. Use of antibodies to intermediate filaments in the characterization of human tumors. Cold Spring Harb. Symp. Quant. Biol. 46, 331-339 (1982).
5. Guze, K., Short, M., Zeng, H., Lerman, M. & Sonis, S. Comparison of molecular images as defined by Raman spectra between normal mucosa and squamous cell carcinoma in the oral cavity. J. Raman Spectrosc. 42, 1232-1239 (2011).
6. Krafft, C. et al. Advances in optical biopsy - correlation of malignancy and cell density of primary brain tumors using Raman microspectroscopic imaging. Analyst 137, 5533-5537 (2012).
7. Bergner, N. et al. Unsupervised unmixing of Raman microspectroscopic images for morphochemical analysis of non-dried brain tumor specimens. Anal. Bioanal. Chem. 403, 719- 725 (2012).
8. Venkatakrishna, K. et al. Optical pathology of oral tissue: A Raman spectroscopy diagnostic method. Curr. Sci. 80, 665-669 (2001).
9. Krishna, C. M. et al. Micro-Raman spectroscopy for optical pathology of oral squamous cell carcinoma. Appl. Spectrosc. 58, 1128-1135 (2004).
10. Malini, R. et al. Discrimination of normal, inflammatory, premalignant and malignant oral tissue: a Raman spectroscopy study. Biopolymers 81, 179-193 (2006).
11. Guze, K. et al. Parameters defining the potential applicability of Raman spectroscopy as a diagnostic tool for oral disease. J. Biomed. Opt. 14, 014016-1-014016-9 (2009).
12. Singh, S. P., Deshmukh, A., Chaturvedi, P. & Krishna, C. M. In vivo Raman spectroscopic identification of premalignant lesions in oral buccal mucosa. J. Biomed. Opt. 17, 105002-1- 105002-9 (2012).
13. Rekha, P. et al. Raman spectroscopic characterization of blood plasma of oral cancer. IEEE ICP 135-137 (2013).
14. Guze, K. et al. Pilot study: Raman spectroscopy in differentiating premalignant and malignant oral lesions from normal mucosa and benign lesions in humans. Head & Neck 37, 511-517 (2015).
15. Siegel, R. L., Miller, K. D. & Jemal, A. Cancer statistics, 2020. CA Cancer J. Clin. 70(1), 7-30 (2020).
16. De Martel, C., Georges, D., Bray, F., Ferlay, J. & Clifford, G. M. Global burden of cancer attributable to infections in 2018: A worldwide incidence analysis. Lancet Glob. Health 8(2), e180-e190 (2020).
17. Chow, L. Q. M. Head and neck cancer. N. Engl. J. Med. 382(1), 60-72 (2020).
18. Warnakulasuriya, S. Global epidemiology of oral and oropharyngeal cancer. Oral Oncol. 45(4-5), 309-316 (2009).
19. Eberly, H. W., Sciscent, B. Y., Lorenz, F. J., Rettig, E. M. & Goyal, N. Current and emerging diagnostic, prognostic, and predictive biomarkers in head and neck cancer. Biomedicines. (2024).

20. Fasano, M. et al. Head and neck cancer: The role of anti-EGFR agents in the era of immunotherapy. Ther. Adv. Med. Oncol. 13, 1758835920949418. (2021).
21. Almstahl, A., Finizia, C., Carlen, A., Fagerberg-Mohlin, B. & Alstad, T. Explorative study on mucosal and major salivary secretion rates, caries and plaque microflora in head and neck cancer patients. Int. J. Dent. Hyg. 16(4), 450-458 (2018).
22. Sroussi, H. Y. et al. Common oral complications of head and neck cancer radiation therapy: Mucositis, infections, saliva change, fibrosis, sensory dysfunctions, dental caries, periodontal disease, and osteoradionecrosis. Cancer Med. 6(12), 2918-2931 (2017).
23. Palmier, N. R. et al. Radiation-related caries: Current diagnostic, prognostic, and management paradigms. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. 130(1), 52-62 (2020).
24. Siegel, R. L., Giaquinto, A. N. & Jemal, A. Cancer statistics, 2024. CA Cancer J. Clin. 74(1), 12- 49 (2024).
25. Gormley, M., Creaney, G., Schache, A., Ingarfield, K. & Conway, D. I. Reviewing the epidemiology of head and neck cancer: Definitions, trends and risk factors. Br. Dent. J. 233(9), 780-786 (2022).
26. Sung, H. et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J. Clin. 71(3), 209-249.
27. Kielbassa, A. M., Hinkelbein, W., Hellwig, E. & Meyer-Luckel, H. Radiation-related damage to dentition. Lancet Oncol. 7(4), 326-335 (2006).
28. Moore, C. et al. Dental caries following radiotherapy for head and neck cancer: A systematic review. Oral Oncol. 100, 104484.(2020).
29. Chopra, A. et al. Indices for the assessment of radiation-related caries. J. Conserv. Dent. 25(5), 481-486 (2022).
30. Butler HJ, Ashton L, Bird B, Cinque G, Curtis K, Dorney J, et al. Using Raman spectroscopy to characterize biological materials. Nat Protoc. 2016;11:664-87.
31. Cordero E. In-vivo Raman spectroscopy: from basics to applications. J Biomed Opt. 2018;23:1.Katie Hanna, Emma Krzoska, Abeer M. Shaaban, David Muirhead, Rasha Abu-Eid & Valerie Speirs.
32. Katie Hanna, Emma Krzoska, Abeer M. Shaaban, David Muirhead, Rasha Abu-Eid & Valerie Speirs.
33. Po-Hsiung Chen, Rintaro Shimada, Sohshi Yabumoto, Hajime Okajima, Masahiro Ando, Chiou-Tzu Chang, Li-Tzu Lee, Yong-Kie Wong, Arthur Chiou & Hiro-Hamaguchi.
34. Rui-huan Gan, Li-qing Lan, Dan-ni Sun, Fan Tang, Gang Niu, Da-li Zheng, Bin Wang & You-guang Lu.