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Experimental and theoretical investigation of Young's modulus of liver cancer tissue using rectangular, V-shaped and dagger cantilevers of an atomic force microscope

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Abstract

The liver is one of the most important organs of the body, which is responsible for the metabolism of proteins and detoxification of the body. Examining tissue and studying its mechanical properties can be a platform for early diagnosis of cancer and then identification of treatment methods. Atomic force microscope is a very powerful tool in imaging and identifying the mechanical properties of nanoparticles and in more advanced stages for the manipulation of these particles. In this research, the Young's modulus of liver cancer tissue was investigated using atomic force microscope and using three types of cantilevers with rectangular, V-shaped and dagger geometries. Then, using the Hertz contact model, the range of Young's modulus was simulated for all three types of atomic force microscope cantilevers. The results of experimental work and theoretical simulations were compared. Finally, in order to validate, the results obtained in this study were compared with other studies. The obtained results showed that the use of V-shaped cantilever achieves a more accurate range of Young's modulus. Also, Young's modulus for liver cancer tissue was obtained in the range of 800 to 1500 pascals.

Keywords: Atomic force microscope, Liver cancer tissue, Rectangular cantilevers, V-shaped cantilevers, Dagger cantilevers

1. Introduction

Uninhibited and abnormal proliferation of body cells in different parts causes cancer. Primary liver cancer begins in liver cells and is divided according to the type of cancer cell. The origin of this type of cancer can be different cells and tissues of the liver. Primary liver cancer is the sixth most common type of cancer worldwide and the fifth leading cause of cancer death in men, while it is the eighth leading cause of cancer death in women. Throughout history, various studies have been conducted to extract Young's modulus of healthy and cancerous liver tissue. These researches have been different in the method of studying and extracting tissue, environmental conditions and choosing the type of sample.

In this research, the displacement of cancerous liver tissue has been discussed. The innovation of this research is the use of liver cancerous tissue in order to obtain the Young's modulus of cancerous tissue, using displacement based on atomic force microscope and performing theoretical simulations. The difference between this research and previous researches is the use of 3 types of cantilevers with rectangular, V-shaped and dagger geometries in order to extract Young's modulus of liver cancer tissue. First, Young's modulus was obtained using an atomic force microscope, then the results obtained for each cantilever geometry were compared with the simulation results.

2. Modeling

In this research, in order to investigate and estimate Young's modulus of liver cancer cells, atomic force microscope cantilevers with rectangular, dagger and V-shaped geometries were used. In order to check the accuracy of the research, the experimental samples have been compared with the values obtained from the simulation in MATLAB software. For this reason, the cancerous tissue of the liver has been studied by means of an atomic force microscope after being separated from the body. Finally, topographical images and experimental diagrams indicating the results have been obtained. Then, by comparing the theoretical and experimental results, the appropriate cantilever geometry and the approximate value of Young's modulus of liver cancer tissue have been determined.

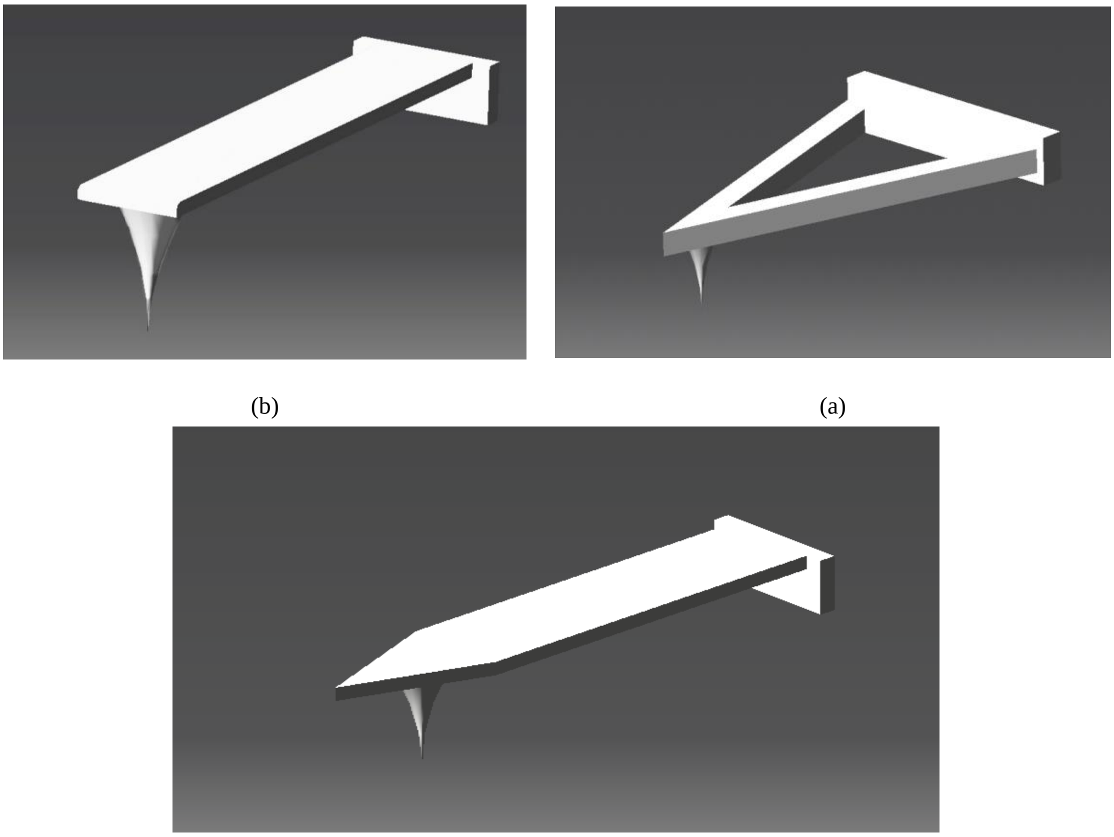
2-1. Experimental works and introduction of tissue

In order to investigate and diagnose tissue health, the process of conducting experimental tests and the results thereof have been discussed. Experimental work has been done in two stages of cell preparation and study with the help of atomic force microscope. The steps of the experimental work are as follows.

- Preparation of liver cancer cell for tissue study and examination
- Cell culture in order to control cell growth and prevent tissue decomposition using stabilizers
- Preparing the slide and adjusting the height of the sample in relation to the device
- Imaging using an atomic force microscope, identifying the exact location of the cell and extracting images with different dimensions and aspects
- Analyzing images to determine cell geometry
- Extraction of topographical images

2-2. Study the hardness of different types of cantilevers

One of the most important things in using atomic force microscopes is the use of suitable cantilevers. These cantilevers are categorized into three rectangular, dagger and V-shaped forms. In the rest of the section, the pillars and their true equations are discussed. The hardness of each cantilever can be calculated in two-dimensional and three-dimensional space. This hardness is calculated in two-dimensional space by dividing the force by the displacement of the hardness. Figure 1 shows three different types of cantilever.



(b) (a)

(c)

Figure 1. **Types of cantilever geometries**
(a) rectangular cantilever (b) dagger cantilever (c) V-shaped cantilever

3. Analysis of experimental results

In this part, the results of imaging with atomic force microscope are discussed and experimental diagrams and theoretical simulations are analyzed.

3-1. The results of the experimental test

In this research, Hertz's contact mechanics theory has been used in order to provide graphs related to force-penetration depth and the results of experimental tests. The diagrams of force-penetration depth resulting from the displacement of liver cancer cells when using all 3 rectangular, V-shaped and dagger cantilever, where the force is in nano-newtons and the needle penetration depth is in nanometers, are shown in Figure 2. During the loadings, the tests were performed five times and the average results were plotted. The purpose of applying the use of all three geometries was to choose the right cantilever in order not to destroy the tissue and also to access the accurate Young's modulus.

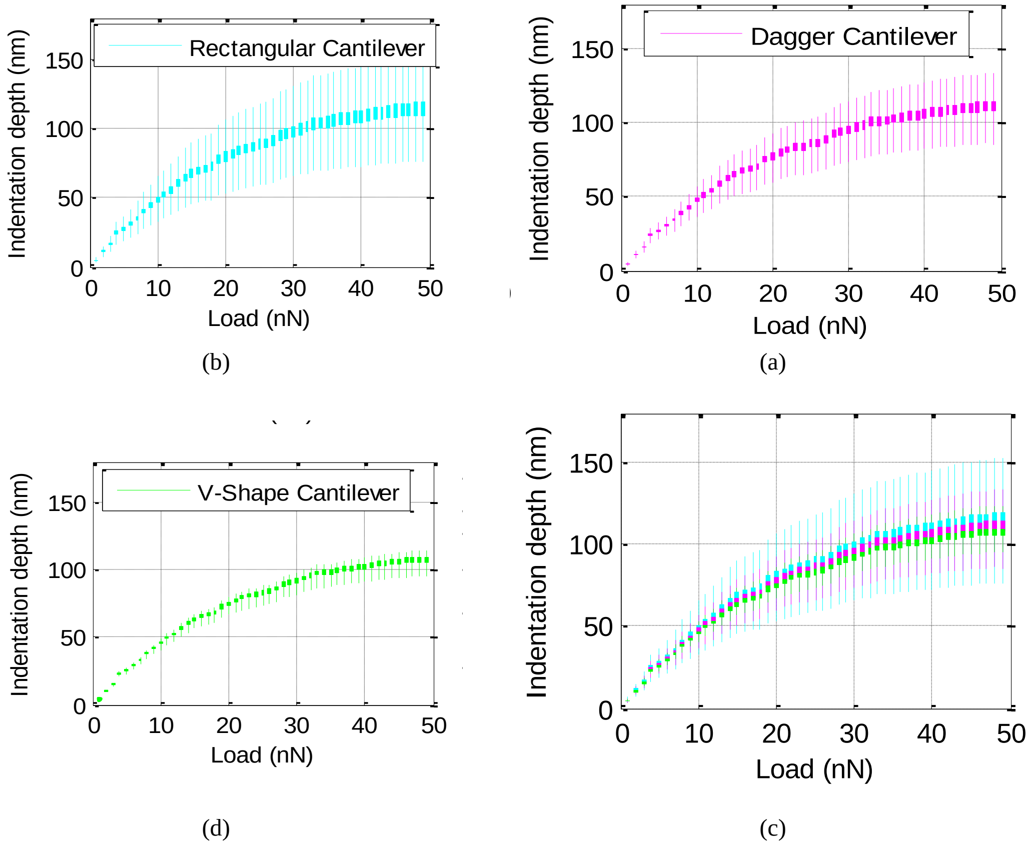


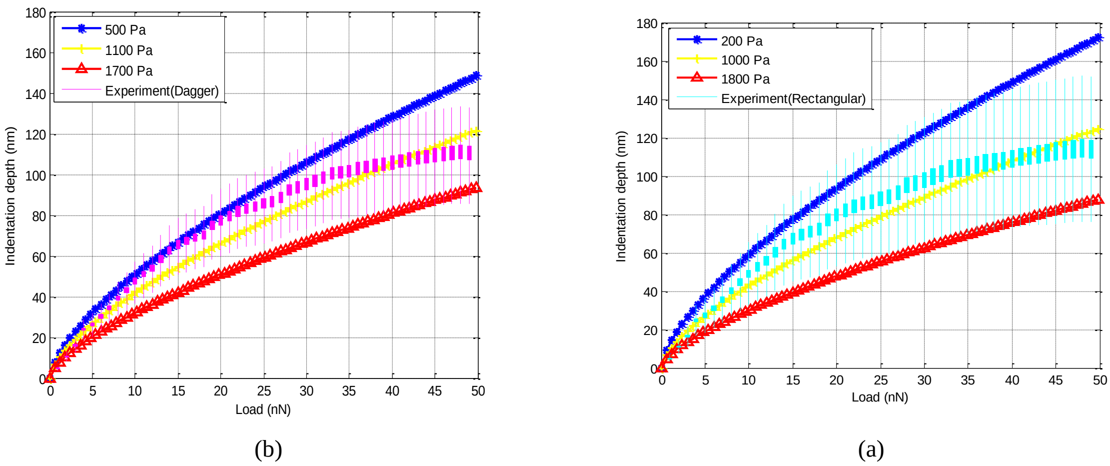
Figure 2. **Experimental diagram of force-penetration depth of cantilevers**

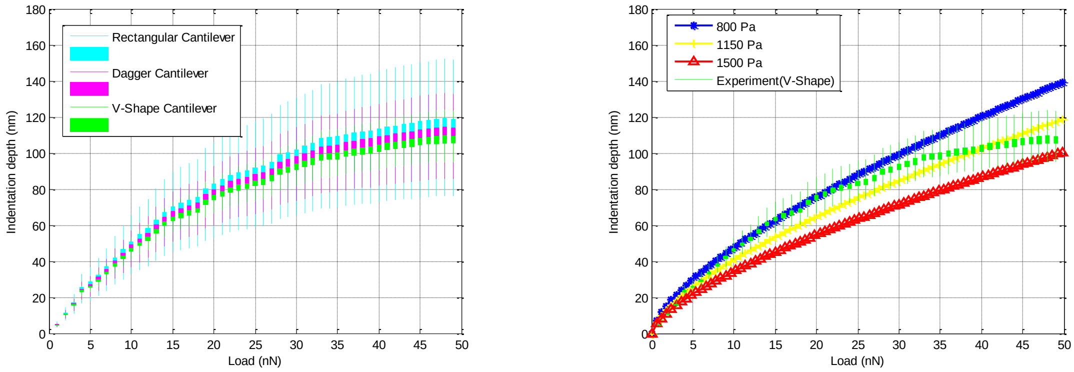
(a) rectangular cantilever (b) dagger cantilever (c) V-shaped cantilever (d) all three cantilevers

4. Extraction and investigation of Young's modulus experimentally

In this section, in order to extract the Young's modulus of cancer cells using the Hertz contact model, the simulation of the displacement process in liver cancer tissue using rectangular, V-shaped and dagger cantilevers has been used. In Figure 3-a, the range of 200 to 1800 pascal is considered for Young's modulus of liver cancer tissue. In Figure 3-b, the range of Young's modulus is 500 to 1700 pascals. In Figure 3-c, the range of Young's modulus is considered equal to 800 to 1500 pascals.

It can be seen in Figure 3-c, by changing the value of Young's modulus range and using the V-shaped cantilevers, the experimental diagram is placed in a lower range of Young's modulus, between the diagrams obtained from the simulation. Because the V-shaped cantilever is less rigid than the rectangular and dagger-shaped cantilevers, it imposes less force on the tissue.





(d) (c)

Figure 3. Experimental and theoretical comparison of Young's modulus of liver cancer tissue
(a) rectangular cantilever (b) dagger cantilever (c) V-shaped cantilever (d) all three cantilevers

5. Verification of results

In this article, the range of Young's modulus of liver cancer tissue was investigated using atomic force microscope using three types of cantilevers with rectangular, V-shaped and dagger geometries. Also, the results obtained from the experimental work were compared with the results obtained from the simulation with the Hertz contact model for all three mentioned cantilevers. In this section, using references [1] and [2], the validity of the results of this article has been discussed. Figure 4 shows the average Young's modulus in this study compared to references [1] and [2]. As can be seen from Figure 9, the Young's modulus obtained in this study is close to the Young's modulus obtained in previous studies.

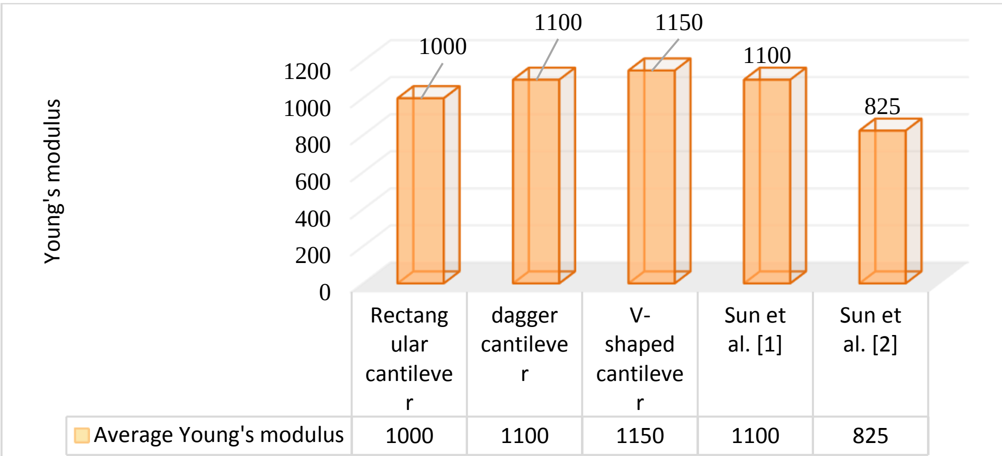


Figure 4. Validation charts

6. Conclusion

In this study, Young's modulus of liver cancer tissue has been investigated. At first, Young's modulus was extracted by experimental method based on atomic force microscope using three types of cantilevers with rectangular, V-shaped and dagger geometries. Using the Hertz contact model, Young's modulus was simulated for each of the atomic force microscope cantilevers, and at the end, the graphs obtained from the experimental work were compared with the theoretical graphs. It was observed that by using the V-shaped cantilevers, the range obtained for the Young's modulus of the liver tissue is more accurate than the rectangular and dagger cantilevers. Finally, Young's modulus for liver cancer tissue was obtained in the range of 800 to 1500 pascals.

7. References

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