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Comparative study of MicroCT images for ex vivo human specimens

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1. Introduction

X-ray computed microtomography is an imaging technique with great analysis potential and is widely used in industry, biology and in several areas of knowledge. Besides being non-invasive and non-destructive, it allows the tridimensional reconstruction of objects, forming high-resolution 3D images. It is based on the physical principle of X-ray attenuation with the various materials that make up the sample, suffering attenuation according to the atomic number, density and thickness of each material, resulting in hundreds of projections from interactions with the various directions that surround the object, which rotates about the same axis in analogous rotational steps. After the acquisitions, a mathematical algorithm makes the reconstruction of attenuation coefficients data of the elements that make up the cross section. At the end of the process, slices are generated in three dimensions (axial, sagittal and coronal) allowing for the qualitative and quantitative analysis of the object's internal microstructures [1-4].

The analysis of the microstructure of biological samples is often performed using optical microscopy, a technique that has limitations in the conservation of the sample's anatomy. When making histological slices, changes in tissue structure can occur due to fractures and compressions resulting from microtome tractions and frictions. In microCT, the chemical characteristics and proportionality of tissues are preserved [5], but there is still a limitation in relation to biological samples (soft tissue), as they have very close densities and small absorption of X-rays [6]. However, some strategies are used, such as use of radiodense contrasts and the characterization of parameters [7]. Facing this frontier, the X-ray computed microtomography technique was applied to human specimens (ex vivo) in order to form high-resolution images, allowing the visualization of specimens microanatomic structures and detailing the tissues that compose them. For that, two different microtomographs were used, in order to compare the final quality of the images formed, and thus contribute to the advancement of research in the medical field, impacting the control and cure of pathologies.

2. Methodology

In this study two human tissue specimens were used, one gastrointestinal - the appendix - and one gynecological – the uterine cervix -. The hospital University of Vassouras (Vassouras – RJ, Brazil) granted the samples with the approval of the Ethics Committee of the University of Brooms. The two specimens were removed under benign conditions and were preserved in a 10% concentrated formaldehyde solution at room temperature, for the preservation of tissue and cell structures. After 24 h, they were placed in concentrated Lugol's solution ($I_2(1\%)$ solution in equilibrium $KI_2(2\%)$ in distilled water) at 10%, radiodense contrast used, in order to increase the concentration of the samples. To carry out the acquisitions, two different microtomography systems were used and their images were

qualitatively compared. Each sample was scanned in both systems and the acquisition settings were optimized, as show in table I. After the acquisition, the images were reconstructed and analyzed using each system software.

Table I - Acquisition Settings

Microtomography System	System A		System B	
Sample	Appendix	Uterine Cervix	Appendix	Uterine Cervix
Voltage (kV)	125	125	110	120
Current (μA)	64	64	240	270
Effective Pixel Size (μm)	20	28	26	34
Filter	1.00 mm (Al)	0.50 mm (Cu)	1.50 mm (Cu)	0.50 mm (Sn)
Time/Frame (ms)	1100	1650	500	333
Integration (Frames)	5	5	5	5
Projections	720	720	1200	1250
System Rotation	360°	360°	360°	360°

3. Results and Discussion

The image quality of the specimens was evaluated for the microtomographic systems A and B. For the appendix specimen (figure 1), a clear difference in details was perceived for system B, where a higher power setting directly influenced the good quality of the final image.

For system A (figure 1a), the microanatomy of the appendix is not clearly identified and some were not visualized. However, for system B (Figure 1b), microanatomic structures such as the peritoneal membrane and the mucous layer are well defined, in the peripheral region (in the portion of the muscle layer), the set of muscle fibers are identified and differentiated almost in isolation, the lymphoid follicles are well defined, and the mucous layer is well defined and well delimited.

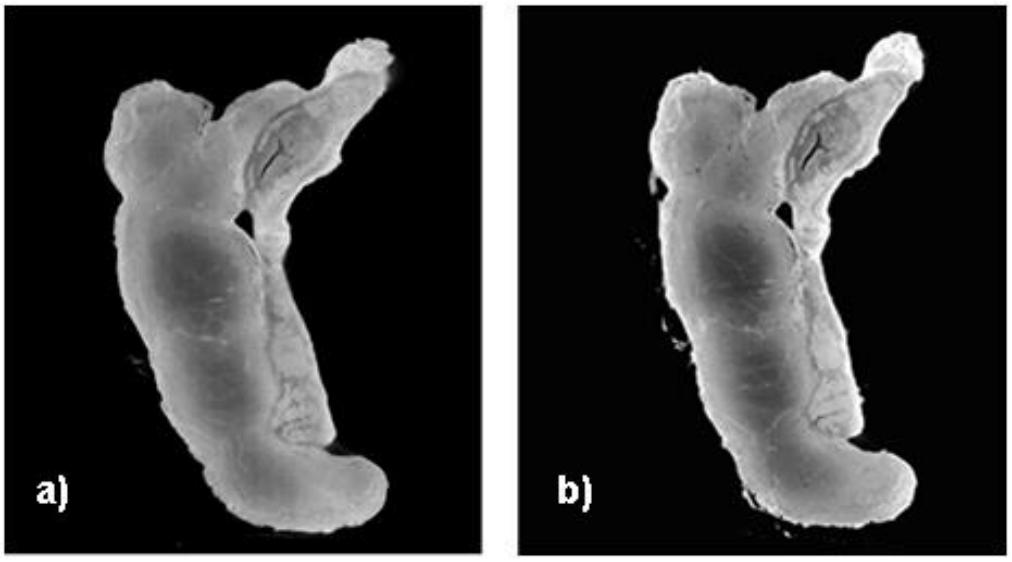

Figure 1 – CT slices for the appendix specimen: a) system A and b) system B

Figure 2 shows the uterine cervix specimen images for both systems. The uterine cervix is basically composed of dense fibrous tissue, which hinders the impregnation of contrast (Lugol) within the specimen, making it difficult to anatomically identify the microstructures within the tissue. Even with little contrast enhancement in the specimen, the images acquired with system B showed a good resolution of details due to the highest power used for the scanning, with a better definition of the uterine cervix microanatomy. Microstructures such as the mucosa of the ectocervix, the glandular tissue with irregular appearance, the transition from the glandular tissue to the fibrous tissue (with different contrasts of cervical mucus), Naboth's cysts, the organ cavity (lumen) with presence of mucus, the

fibrous tissue vessels (in the transition area from the fibrous tissue to the ectocervix), and the internal orifice of the uterine cervix were identified.

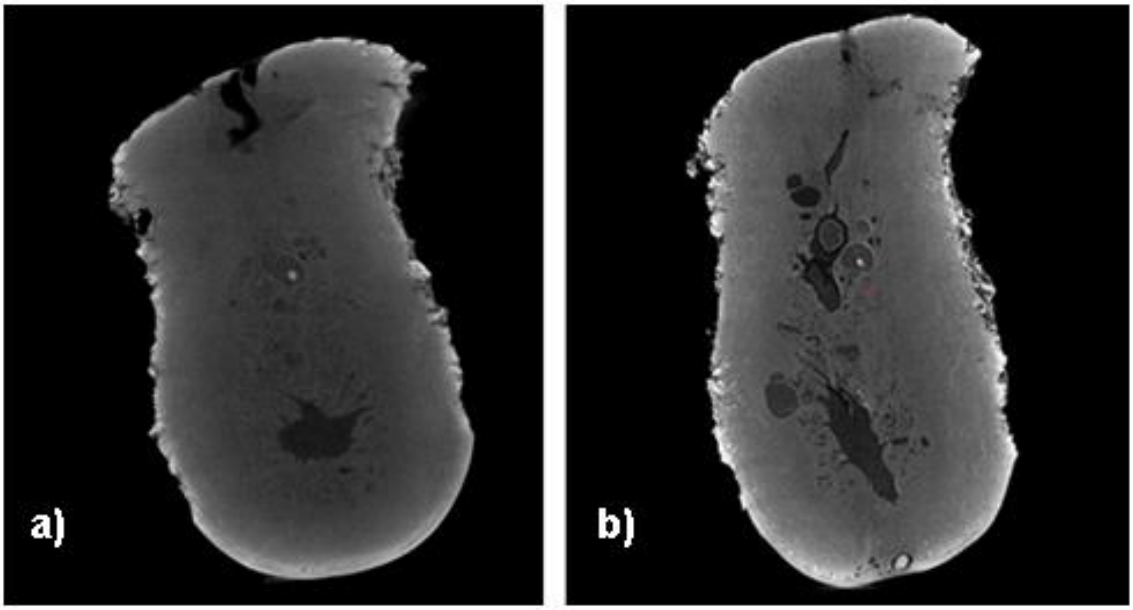

Figure 2 – CT slices for the uterine cervix specimen: a) system A and b) system B

4. Conclusions

In this work, the image quality generated by two microtomographic systems was compared for the analysis of two human specimens. The qualitative evaluation for both specimens showed that system B had better image quality since the microanatomic structure of the specimens could be better visualized. Even with a smaller effective pixel size, the power settings for system A is limited to 8 W, generating images with lower contrast. Since the soft tissues have very close densities to each other, a wider contrast range is required to obtain good image results. So, the power is the main factor that controls the contrast, which enhances details in the image. In human pathological specimens, the addition of a 3D microscopic technology may add important information for the comprehension of the structural arrangement of the diseases. However, the preservation of the specimens is also critical for further studies of the specimen by traditional histological technique, to provide the clinical information for the patient. To improve the quality of the images in human specimens, this work demonstrates that a wider range of power is required for the reconstruction of microscopic 3D images of human soft tissue specimens.

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