Development of Improved Panoramic Image Generation System Using Computed Tomography Data

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***Abstract*— This study aims at building a system to generate improved panoramic images using computed tomography data without the need for dental panoramic radiograph equipment. To reduce the difference between the output images of the generation system and the panoramic radiographs from the equipment, the characteristics of the panoramic equipment such as magnification factor were concerned. In addition, improving output images by excluding unwanted tissues and including only the areas necessary for diagnosis was applied. As a result, the generation of clean panoramic images with a higher resolution was depending on the size of the system input.**

Keywords —computed tomography; panoramic dental x-ray; image improvement technique;

I. INTRODUCTION

In dental practice, panoramic radiographs are usually used as an initial diagnostic tool for dental treatment planning [1]. Some studies have shown that the panoramic radiographs were reliable tools for the dental treatment planning, but these panoramic images contain irrelevant body parts such as cervical vertebra and are less accurate than Computed Tomography (CT) images[2]. Therefore, CT is used for more detailed practices.

Our study aims to build a system that generates improved and high accurate panoramic images simultaneously during CT taking without the need for a separate dental panoramic radiograph equipment.

II. METHOD

A. Data

The 3D Facial CT data, which were taken from July 3, 2019 to October 17, 2020 at Seoul National University Dental Hospital, were collected. The study was approved by the Institutional Review Board of Seoul National University Dental Hospital (IRB: ERI20012). The data were composed of 0.6mm^3 voxels and were filmed with Siemens (Germany) devices. In this study, images of 56 randomly selected patients were used.

B. Preprocessing

The Average Photon Energy (APE) of the panoramic radiograph equipment and CT equipment are different. Widely used panoramic dental x-ray equipment is using 30keV APE for generating images while 60keV APE is used for normal CT equipment[3].

In order to convert CT to a panoramic image, the APE level of the two different images must be adjusted to match the same range of the pixel values. This means that the Hounsfield Unit (HU), the pixel value of CT, should be converted to images using 30keV. For this purpose, HU should be converted to Linear Attenuation Coefficients (LACs, μ) using (1) and (2).

$$HU_{60k} = 1000 \times \frac{\mu_{60k} - \mu_{water,60k}}{\mu_{water,60k} - \mu_{air,60k}} \quad (1)$$

$$\mu_{60k} = \frac{HU_{60k} \times (\mu_{water,60k} - \mu_{air,60k})}{1000} + \mu_{water,60k} \quad (2)$$

The LAC is obtained by multiplying the Mass Attenuation Coefficient by the density[4]. After converting CT into an array of 60keV LACs, this array also can be converted into an array of 30keV LACs with (3), (4) as follow:

$$\mu_{30k,Tissue} = 4.7723\mu_{60k}{}^4 - 14.45\mu_{60k}{}^3 + 1.5362\mu_{60k}{}^2 - 0.8329\mu_{60k} - 0.0007 \quad (3)$$

$$\mu_{30k,Metal} = 0.0364\mu_{60k}{}^2 - 2.985\mu_{60k} + 3.3341 \quad (4)$$

The LAC conversion equations were derived by approximating the differences between the LAC values each from different APE from the same human body parts. Like (3) and (4), the conversion equations are divided into two different equations. The reason why the LAC conversion equation is divided into two types is that the LAC values of the Metal group are almost ten times larger than those of the Human-tissue group. After converting the 60keV LAC array into 30keV LAC, convert the LAC array into HU type as follow (5):

$$HU_{30k} = 1000 \times \frac{\mu_{30k} - \mu_{water,30k}}{\mu_{water,30k} - \mu_{air,30k}} \quad (5)$$

C. Panoramic Image Generator

Projecting the previously processed CT image along the z-axis and locate the parabolic line, which is the midline of the dental arch obtained by using morphology methods[5,6]. Moving along the corresponding parabolic line, capture the CT image with the perpendicular line to the points on the parabola [Fig. 1]. The captured point on the parabola is determined by dividing it into four sections by the variation of x and y (Δ x and Δ y).

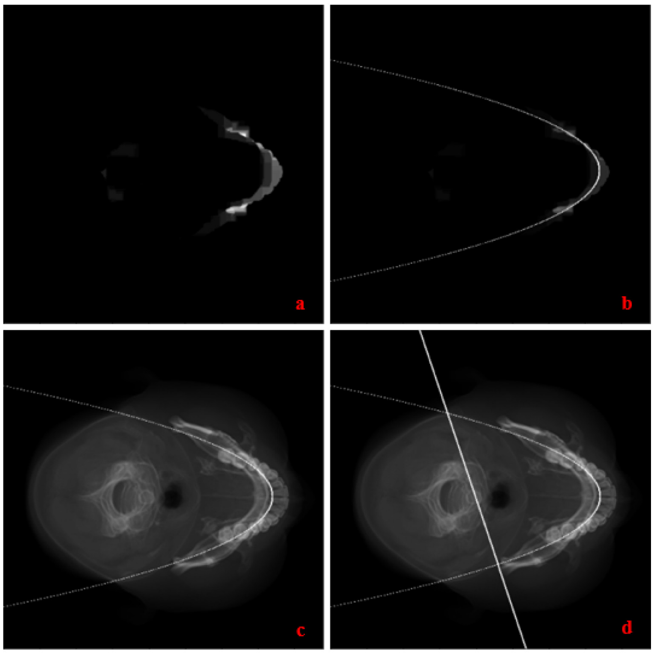

Fig. 1 a-d) The process of finding the midline of the dental arch.

The image captured by the above method is 2D, and after projecting it on one axis as a line, concatenate all lines to generate a panoramic image.

Before projecting the captured 2D images, these images can be projected only with the required range for a dental practice to produce a 'clean' panoramic image. In addition, the HU value can be adjusted to produce improved panoramic images that do not include irrelevant soft tissues.

III. Result

In this study, the preprocessed CT images (512x512xN) were uploaded into the panoramic image generator and the same results were obtained as Fig. 2a. Before the projection of 2D slice images captured from points on the midline of the dental arch, the result shown as Fig. 2b was obtained when considering the magnification factor (M) of objects in the image. The magnification factor represented the phenomenon in which the size of the object is magnified on the resulting image due to the divergence of the x-ray beam, which can be calculated by the following formula:

$$M = \frac{Focus-Film\ Distance}{Focus-Object\ Distance} \quad (6)$$

This lead to obtain an improved panoramic image that is easier to diagnose than the conventional panoramic x-ray image, showing the region of interest and excluding the irrelevant area such as the cervical vertebrae region [Fig. 2c]. In addition, adjusting the LAC values of the 2D slices to remove certain soft-tissues images as showing in Fig. 2d.

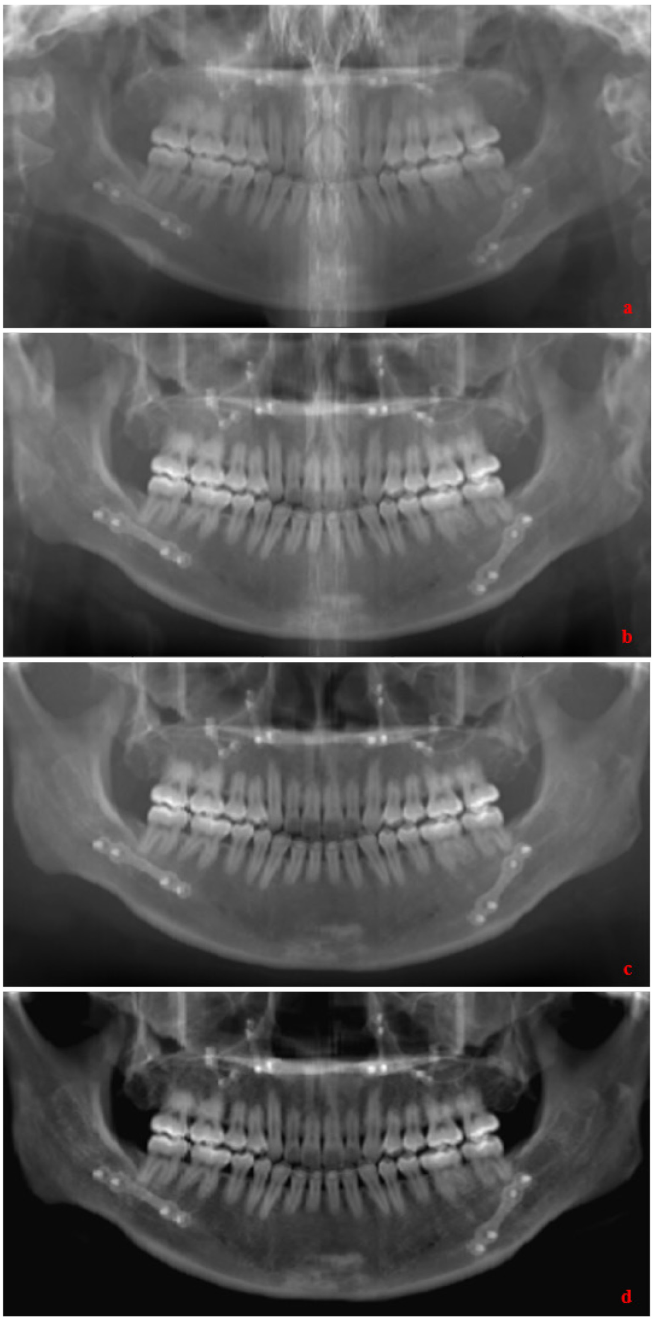

Fig. 2 a) Raw output of the generation system. b) Output image with magnification factor. c) Output image summing only ROI. d) Output image removing soft tissues.

IV. Discussion & Conclusion

The results of inputting CT data (512x512x250) to the generation system were proposed in the images shown as Fig. 2a-d. The pixels at the center of Fig. 2 were not smoothly connected, because less slice capturing was done on the part where the midline curvature of the dental arch was large. To solve this problem, we increased the size of the input image so that we could sample more than previously generated images. Through this method, it was confirmed that the pixels are not crushed in Fig. 3b, which were doubled the input image size compared to Fig. 3a.

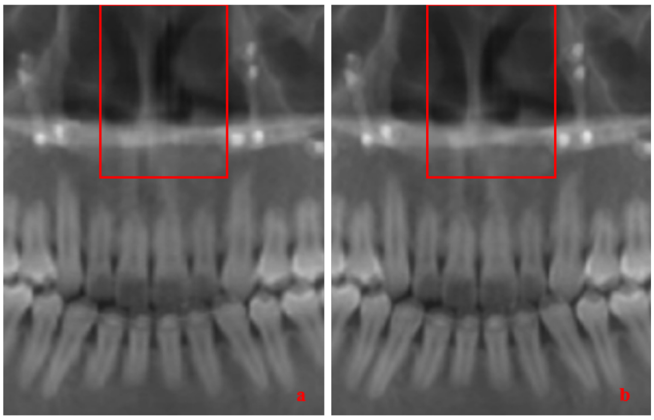

Fig. 3 a) Center part of output image when input image of 512x512xN was entered. b) Center part of output image when doubled the size of input image.

As a result, the proposed generation system could generate several different forms of improved panoramic images, using only CT. Also, higher resolution images can be generated when the size of the input images increased.

In the future, the results of the study will be used for training the encoder-decoder network or generative adversarial network (GAN) to develop a system that automatically generates improved panoramic images when the conventional panoramic x-rays are taken.

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