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A Study on the Hamate Bone Learning Effect Using DICOM Images and 3D Printing

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ABSTRACT

Background/Objectives: This study compared the characteristics and the anatomical learning effects of a hamate bone model printed from DICOM images on a 3D printer.

Method/Statistical Analysis: After printing a hamate bone model from DICOM images obtained from a wrist joint examination using a 3D printer, this study examined the anatomical understanding of 102 university students in public health departments.

Findings: The intuitive awareness and the morphological awareness of the students on the protrusion, front and back of the hamate bone, and 5-way joint contact surfaces which were difficult to identify in conventional 2D and 3D medical images were improved by 60.7% and 58%, respectively.

Improvements/Applications: The experiment showed that instrumenting of shape through 3D printing as a knowledge transfer method for students learning anatomy can improve the learning effect.

Keywords: *DICOM, 3D Printer, hamate bone, learning effect, anatomy*

Introduction

Recently, 3D (Dimension, D) printing technology is developing as it has been applied to various fields such as industry, education, and medical care. In particular, the synergy is increasing as 3D printing is integrated with medical images used for diagnosing the human body for surgical simulation and in the production of implants in the bio-industry[1]. This is an integrated technology of methods for planning the location and extent of the tumor using 3D printing, after 3D CT(Computed Tomography) and MRI(Magnetic Resonance Image) examinations of the patient's surgical site[2-4]. This is based on the study results that 3D structure of a human body can be formed by 3D printing based on DICOM(Digital Imaging and Communications in Medicine)[5]. In addition, the recent social structure has increased a human-centered lifestyle, increasing individual sports activities for promoting health, while golf, tennis, and baseball lovers experience many hamate bone fractures in the wrist joint due to the stress of repeated impact[6]. This is a risk that reflects the protruding characteristics of the hamate bone, which increases the frequency of injuries. This requires the necessity of learning for students majoring in human anatomy. Therefore, this study used DICOM wrist joint images to extract the hamate bone into a 3D image, and performed STL(STereoLithography) modeling to print the shape on a 3D printer for conducting a survey on the students' understanding. The intention is to examine the learning effect of the students' intuitive and morphological understanding by 3D printing the actual hamate bone rather than using 2D or 3D medical images. The purpose of this study is to compare the anatomical understanding of 102 university students in public health departments majoring in human anatomy.

Materials and Method

Study Direction: This study extracted only the hamate bone from the acquired wrist joint DICOM images and created the same shape through 3D printing to evaluate the anatomical understanding of the characteristics by conducting a survey[Figure 1].

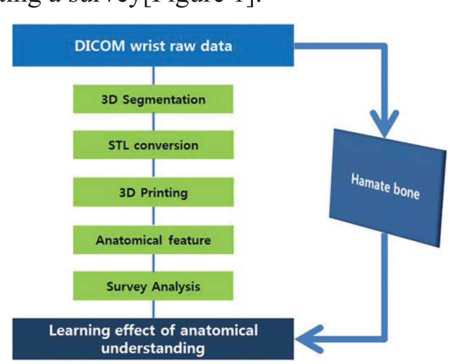
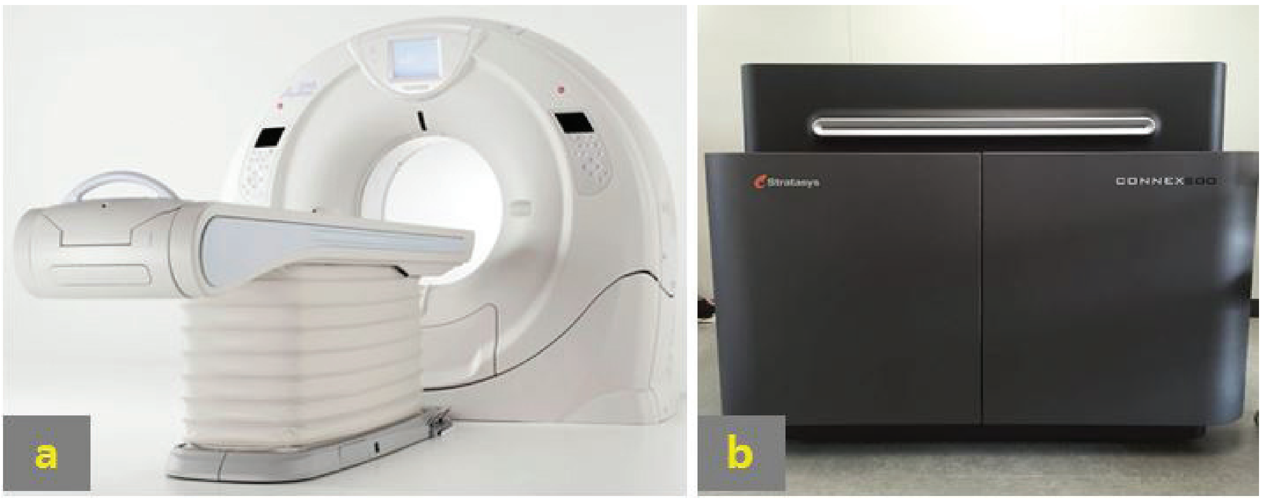


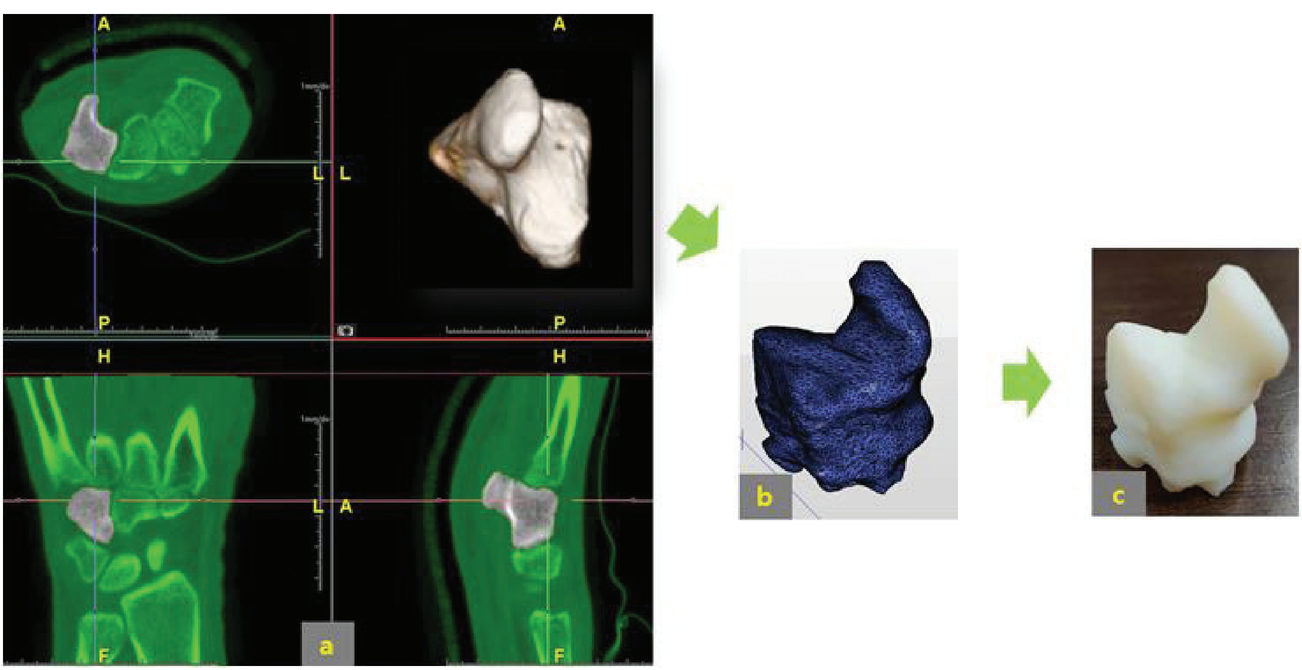
Figure 1: Overall schematic diagram of the experiment

Experimental Equipment and Materials: The wrist joint DICOM image used in the experiment was acquired as a 0.5mm volume image of 640 MSCT (multi-slice computed tomography, Aquilion ONE, TOSHIBA, JAPAN)[Figure 2. a]. This study used a 3D printer(Objet CONNEX 500, Stratasys, USA) to print the shape of the hamate bone by irradiating the liquid resin to solidify the form, and Endur RGD 450 from Stratasys was used as the material[Figure 2. b].



The computed tomography(a) and 3D Printing (b) device
Figure 2: Hamate bone image acquisition device and 3D Printer

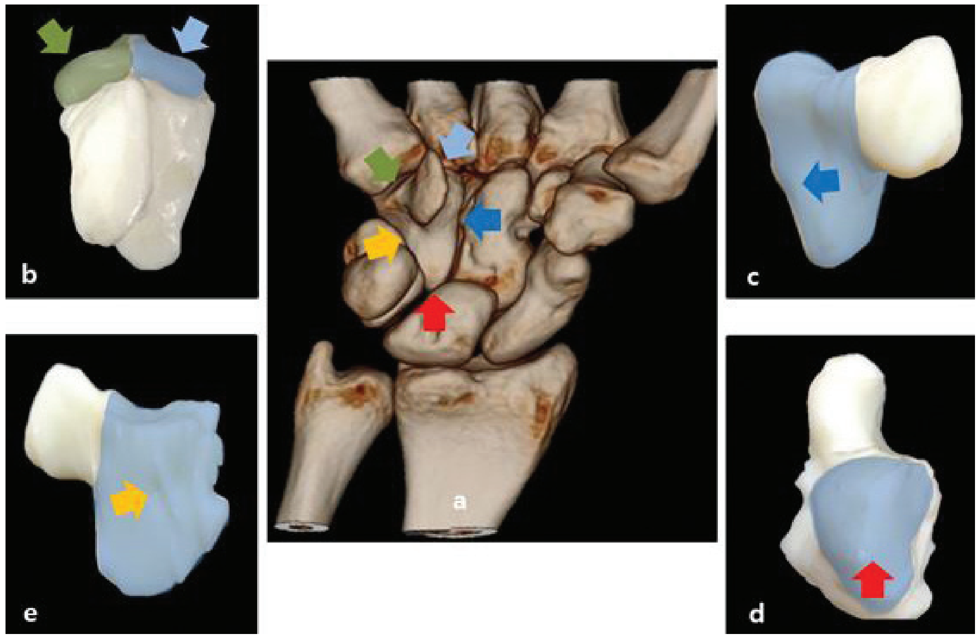
Experimental Method: The wrist joint images acquired by DICOM imaging was segmented using the dynamic region growing tool and free ROI tool of the Aquarius NET (TERARECON, USA) 3D program. Then, after converting to a stereolithography file, 3D printing was performed using the basic G-code of the hamate bone confirmed in STL View [7] [Figure 2. a, b, c]. The survey was performed by a preliminary survey showing only the DICOM image followed by a post-survey showing the image and 3D printed shape using a 5-point Likert scale for 102 university students in public health departments who completed human anatomy classes and compared the results[8].



The segmentation process of the acquired image (a), converted STL shape (b), and3D Printing shape(c).
Figure 3: The process of creating a shape of the hamate bone

Results

Morphological characteristics of the hamate bone



Wrist volume rendering image (a)and various articular surfaces of the hamate bone(b-e).
Figure 4: The joint correlation of the hamate bone within the carpal bone

The front, back, and side of the hamate bone, which is difficult to distinguish visually with 2D and 3D images, were confirmed in 3D printed shape. This shows the 5 characteristic joint surfaces of the hamate bone that are in contact with the 5th metacarpal, 4th metacarpal, Capitate, Lunate, and Triquetrum. As shown in Fig. 4, (a) is the DICOM volume rendering image, and (b) to (e) show the contact surfaces of the hamate bone in the clockwise direction of image (a). Anatomically, (b) is the distant part of the wrist joint, and the hamate bone is divided into the form of a seagull(green and sky-blue arrows), forming a joint in the metacarpal bone. (c) is the articular surface parallel to the long axis of the body, forming the longest articular surface in the hamate bone and a flat boundary with the capitate bone. (d) is the part forming a joint with the lunate, showing a pointed shape in front of the abdomen. (e) is the part forming a joint with the triquetrum and pisiform bone, showing a hollow shape in the center of the articular surface. As such, the overall shape of the hamate bone shows the characteristics of forming an inverted triangle, protruding hook, and 5 joints in an anatomic position[Figure 4].

Evaluation on the hamate bone learning effect: After preparing a questionnaire for 102 university students in public health departments to examine the learning effect of recognizing the hamate bone shape, this study examined and analyzed the preliminary evaluation in which the survey was performed with only the images and the post-evaluation showing 3D printed shape as well [Table 1].

Table 1: Survey questions and evaluation results

Item	Survey analysis N(%) N = 76, 102						
	Score	Very bad	Bad	Mediocre	Good	Very good	Total
Can you recall the structure of the hamate bone from the wrist bone in 3D?	Preliminary	9(8.8)	38(37.3)	40(39.2)	11(10.8)	4(3.9)	102(100)
	Post	0(0)	6(5.9)	19(18.6)	54(52.9)	23(22.5)	102(100)
Can you distinguish the front and back of the hamate bone in an anatomical position?	Preliminary	1(1.3)	29(38.2)	29(38.2)	10(13.2)	7(9.2)	76(100)
	Post	0(0)	6(5.9)	14(13.7)	52(51)	30(29.4)	102(100)

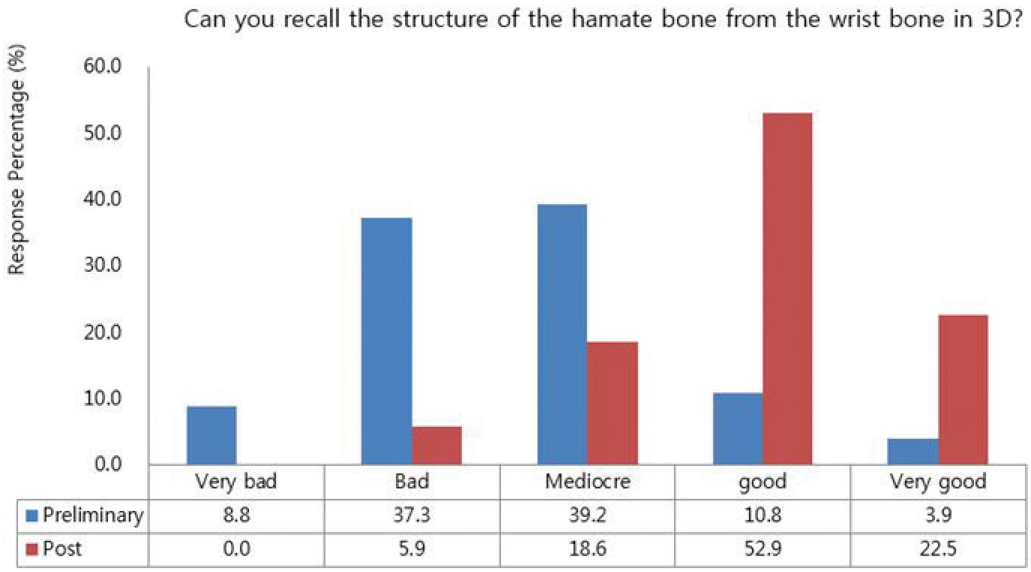
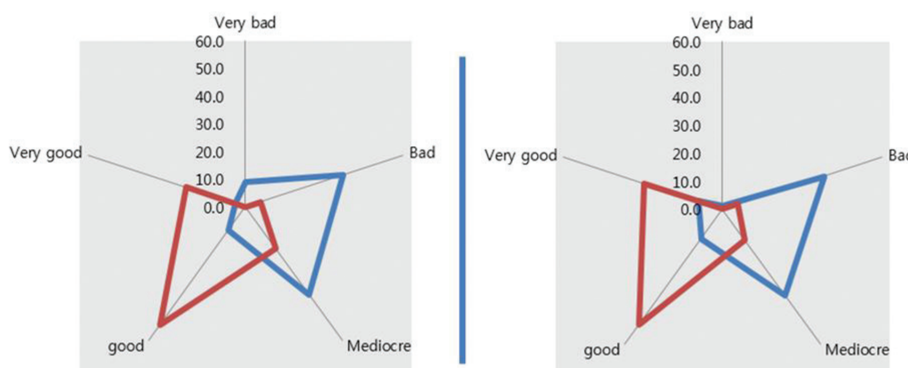


Figure 5: Hamate bone pre- and post-survey learning effect analysis graph

The students who answered "Good" and "Very good" to the question "Can you recall the structure of the hamate bone from the wrist bone in 3D?" increased from 14.7%(preliminary survey) to 75.4%(post-survey), and the students who answered "Good" and "Very good" to the question "Can you distinguish the front and back of the hamate bone in an anatomical position?" increased from 22.4%(preliminary survey) to 80.4%(post-survey). Fig. 5 is a bar graph comparing the 5-point Likert scale survey questions, and Fig. 6 is a radial graph that compares the results of the survey, which shows the preliminary negative opinion(blue) in contrast with the post-positive opinion(red) [Figure 5] [Figure 6].

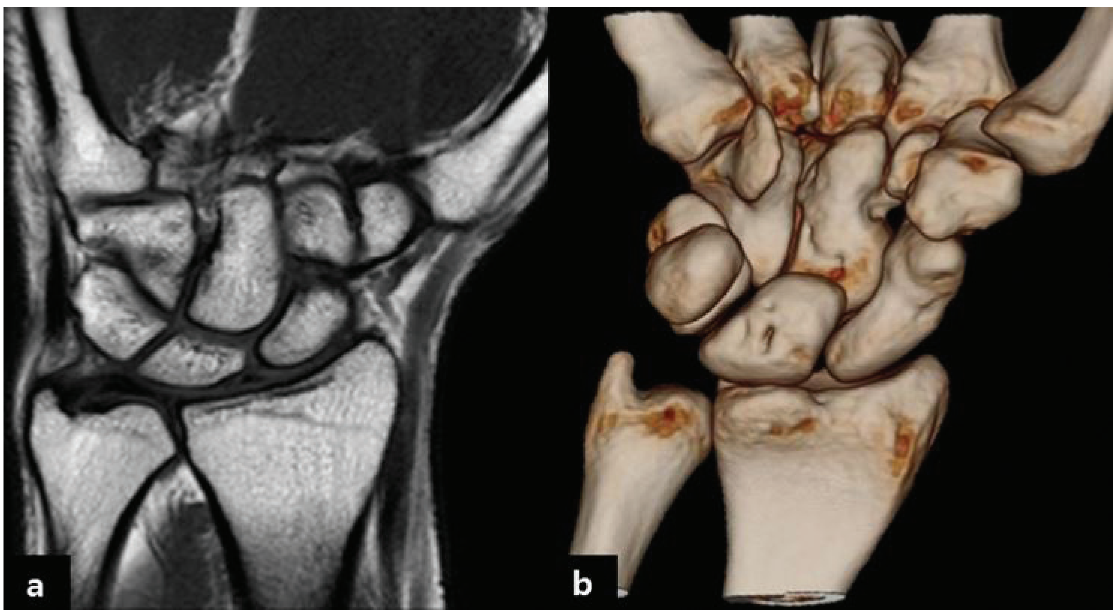


Evaluation on the ability to recognize 3D shape of the hamate bone(left) and the ability to distinguish the front and back of the hamate bone(right).

Figure 6: Comparison of hamate bone pre- and post-survey learning effect

Discussion

This study used DICOM images and 3D printing technology to fabricate the hamate bone of the wrist joint in the human anatomy structure[9-11]. With the hamate bone model printed by 3D printing technology, the 5-joint surfaces and the front and back of the protruding hook were examined, which are difficult to identify in 2D and 3D images. This hamate bone is one of the 8 wrist bones and has a distinctive hook of hamate in the front in the shape of a wedge. It also forms a joint with the 4th and 5th metacarpal bone, triquetrum, capitate, and lunate [12]. The various shapes of bones in the human body result from the ligaments and muscles attached to function the human body, and the hamate bone was applied to this study because an important ligament that holds the wrist tunnel is attached to this bone, and recently many injuries have occurred in this area due to the increase of sports activities. This study aimed to explore the understanding of anatomy students by modeling the characteristics of the hamate bone with 3D printing. With the application of 3D printing, 2D medical images can be instrumented and visualized, which can draw curiosity and interest of the students in future. Designing human anatomical structural models for learning and printing them on a 3D printer will provide a variety of applications for learning [13].Recently, DICOM imaging has the technology to acquire a thin section of less than 0.5mm. Through this technology, the synergies will increase by visualizing the reconfiguration of multiple sections and integrating with 3D printers. As shown in the wrist joint image of this study, it is possible to distinguish several bone shapes and boundaries to some extent, but to understand the 5 articular surfaces of the hamate bone, a lot of time along with 3D reconstruction technology and environment must be accompanied to continuously view and understand many cross-sectional images[Figure 7].As shown in Fig. 8, there are many limitations in enhancing the academic understanding of the various shapes of the hamate bone with DICOM images only [Figure 8].Furthermore, it is more difficult to understand for students with a low level of human anatomical knowledge.



2D coronal section(a) and 3D volume rendering(b) images.

Figure 7: Carpal bone coronal images

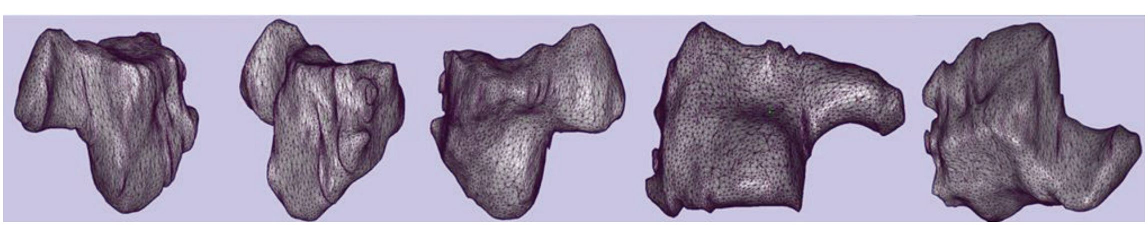


Figure 8: Various shapes of the hamate bone

In the questionnaire survey of this study, only 76 students responded to the question "Can you distinguish the front and back of the hamate bone?", which is considered to be the result of students in lower grades were unable to answer the question. These students are familiar with the term 'hamate bone' but have a low human anatomical understanding of the front and back of the bone. As a result, although this study was limited to 102 university students, the learning effect of showing the actual shape of the hamate bone was high. Therefore, if DICOM technology that is capable of describing the human body and 3D printing technology that can copy the same shape are integrated, the educational effect for students learning human anatomy will increase significantly[14].

Conclusions

A hamate bone printed with 3D printing technology has increased the students' understanding of the 5 articular surfaces and the front and back of the protruding hook that are difficult to identify in 2D or 3D medical images. This was the result of comparing visual medical images with an actual shape printed on a 3D printer, which resulted in a 60.7% improvement in the intuitive awareness and a 58% improvement in the morphological awareness through a hamate bone shape. This is a result that shows modeling through 3D printing is effective for students learning human anatomy.

Ethical Clearance: Not required

Source of Funding: Self

Conflict of Interest: Nil

REFERENCES

1. Hyeong-Gyun Kim, Jun-Gu Choi, Gha-Jung Kim. A Research regarding the Figuration Comparison of 3D Printing using the Radiation DICOM Images, The Korea Contents Society. 2016;16(2):558-565.
2. Go BS, Clinical Application of Three-Dimensional Printing Technology in Breast Surgery. Proceedings of the Medical Society of fusion for 3D printing. 2017;1:24-25. http://www.amc.seoul.kr/asan/healthtv/video/videoDetail.do?videoId=1882
3. Shin YM, 3D Printing Medical Application. Proceedings of the Medical Society of fusion for 3D printing. 2017;1:50-52. http://3dpm.or.kr/html/
4. Ferreira, A., F. Gentil, and J. M. R. S. Tavares, “Segmentation algorithms for ear image data towards biomechanical studies”, Computer Methods in Biomechanics and Biomedical Engineering, Vol. 17, No. 8, pp. 888–904, 2014. https://www.ncbi.nlm.nih.gov/pubmed/22994296
5. Hyeonggyun Kim. Effect of the Change of the DICOM Image Thickness on the Shape Surface of the Hearing Aid Ear Shell Manufactured by 3D Printing, Journal of Engineering and Applied Sciences, 2017;13(2):3001-3006. http://blog.daum.net/drstone/6014328.
6. Wang Kyun Oh, Ki Seon Lim, Tea Soo Lee. Additive Manufacturing of Patient-specific Femur Via 3D Printer Using Computed Tomography Images. Journal of the Korean Society of Radiology. 2013;7(5):359-364.
7. Wonsik Kim. The Effect of Observation Program of Cadaver Dissection for the Paramedical Students. The Korean Journal of Physical Anthropology. 2012;25(2):77-86.
8. J. R. Honiball. The Application of 3D Printingin reconstructive surgery. Dissertation presented in fulfillment of the requirements for the degree MscIng in Industrial Engineering at the University of Stellenbosch. South Africa, 2010
9. M. Frame and J. S. Huntley. Rapid Prototyping in Orthopaedic Surgery: A User”s Guide. The Scientific World Journal. Article ID838575, 2012.
10. W. K. Oh, K. S. Lim, and T. S. Lee. Additive Manufacturing of Patient-specific Femur Via 3D Printer sing Computed Tomography Images. Journal of the Korean Society of Radiology. 2013;7(5):359-364.
11. Hyeong-Gyun Kim, Joon-Koo Choi, Gha-Jung Kim, Dong-Hee Hong and Ki-Moo Lim: A Study on Outputting the Shape of Carpus using Medical Image and 3D Printer. Indian Journal of Science and Technology, 2016; 9(2), 1-5
12. WoongSeo Park. Effects of Students’ Spatial Visualization Capability andAffective Attitude through Three-dimensional Geometric Learning,Based on 3D Printer [dissertation]. [Department of Mathematics EducationGraduate School]: University of Dankook; 2006.
13. S. M. Fuller, D. R. Butz, C. B. Vevang, M. V.Makhlouf : Application of 3-dimensional printing inhand surgery for production of a novel bonereduction clamp, J Hand Surg Am, 2014 ; 39, 1840-1845