Software to Browse the Pictures of Two Knees in Diverse States of Dissection, Flexion and Rotation

Programa para Navegar las Imágenes de Dos Rodillas en Diversos Estados de Disección, Flexión y Rotación

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SUMMARY: The aim of this study was to produce pictures of the knees from an embalmed cadaver and another fresh cadaver with various levels of dissection, flexion, and rotation, consequently to aid medical students and doctors in studying knee anatomy. In this study, we intended to improve the accessibility of the numerous knee photographs, by entering them into our own made browsing software. This software could be downloaded for free from the website (anatomy.co.kr). In the software, a displayed array consisted of four pictures: a knee at three different depths of dissection and the same knee in flexed state. The knee could be rotated interactively at every 5° angle. Annotation of important knee structures could be seen at 90° angle intervals. With the browsing software, users were able to observe detailed and realistic features of the dissected and flexed knees. Furthermore, the comparison of embalmed and fresh knees enhanced understanding of the genuine appearance of the knee. The software and extractable image data can be used as anatomy education materials for various purposes.

KEY WORDS: Anatomy; Cadaver; Knee; Medical education; User-computer interface.

INTRODUCTION

When medical students study and examine the knee in an anatomy class, realistic knee photographs are needed (Rohen *et al*., 2011). Particularly, pictures of the knee in different depths of dissection and diverse angles are helpful for the students' comprehensive understanding of knee anatomy. In addition, medical doctors may benefit from the pictures of flexed knee which resemble that of a living patient for clinical and functional anatomy. However, the previously available image resources failed to meet such needs so we prepared detailed images of the knees; after dissecting and flexing the embalmed and fresh knees, our team took consecutive photographs of them rotated at every 5° angle (Park *et al*., 2007).

The problem is that the prepared pictures are too many to be displayed in a printed book or in ordinary viewer programs which show pictures one by one. Among the several commercial and noncommercial browsing software

consisting of such pictures, one package works only on Macintosh (Apple Inc., Cupertino, CA) and has excessive functions which is rather inconvenient to general users (Rosset *et al*., 2004). Another package does not allow users to upload the knee pictures by themselves (MeAV Anatomie, 2015).

In the "Visible Korean" project, we programmed browsing software for sectional anatomy education. One array of images displayed together in the software, consisted of computed tomography scans, magnetic resonance images, sectioned images, and outlined images of cadaver at the same level (Shin *et al*., 2011, 2012a, 2013). In current study, this software was reprogrammed in order to add more viewing functions and then was used as the viewer of knee photographs. One array was composed of three dissected knees and one flexed knee of the same subject; we added 72 arrays (5° angle rotation) from the embalmed knee and other 72 arrays from the fresh knee to the software.

Our purpose in developing and providing the browsing software containing the knee pictures was to assist users in studying knee anatomy and other developers in making educational tools for digital anatomy. The software that enhances viewing experience of the knee will be conducive not only to student learning, but also to clinical practice.

MATERIAL AND METHOD

The specimens of the present study were the two right knees from two male cadavers. Their bodies were donated for medical education and research in Stanford University School of Medicine by their wills. One of the pair was conventionally embalmed, while the other was immediately frozen in a freezer without fixation process (Park *et al.*).

After amputating the knee from the embalmed cadaver, spongy bones of the tibia and fibula were drilled to construct two canals. Two screws were inserted into the two canals, while the opposite ends of the screws were fixed on a plate that was equipped with a circular protractor. Simultaneously, the rotating axis of the knee was determined to show the reasonable viewing field. Consequently, the knee was mounted on the plate and could be manually rotated with reference of the circular protractor (Park *et al.*).

A digital camera (Canon EOS D60; resolution, 3,072 x 2,048 pixels) was installed to photograph the knee. The location and direction of an illuminator (Elinchrom 1000) were decided and fixed to illuminate the knee appropriately with an adequate amount of shadow (Park *et al.*).

We dissected the embalmed knee marginally and took photographs of it, rotating it every 5° angle. Number of the resultant images of the slightly dissected knee was 72. This procedure was repeated to prepare numerous knee images in eight depths of dissection. After full dissection, a thin thread was attached to the knee, which enabled stepwise flexion of joint. Likewise, we also produced knee images in four degrees of flexion rotating the knee every 5° angle (Park *et al.*).

Out of the eight depths of dissection of the specimen, three appropriate depths (slightly, moderately, much dissected knees) were selected. Concurrently, out of four degrees of flexion, almost right angle (flexed knee) was chosen. To speed up the image loading time, resolution of whole images was reduced from 3,072 x 2,048 pixels to 1,000 x 689 pixels, and their file format was converted to joint photographic experts group (JPEG) files with 24-bit color.

The slightly, moderately, much dissected knees and the flexed knee, which were photographed in one direction, were grouped into an array (Fig. 1). Among 72 arrays, the anterior, medial, posterior, and lateral arrays were chosen as the representative views; in these four views, the prominent anatomical structures, such as the muscles, ligaments, and blood vessels, were annotated (Fig. 2. top row).

The same procedures were performed with the fresh knee of the frozen cadaver to acquire the additional 72 arrays of images. The pictures from the embalmed and fresh subjects were adjusted to have similar brightness and contrast.

We added the knee pictures to our browsing software (Shin *et al.*, 2011), which was reprogrammed for the convenient presentation of images in this research (Fig. 1). We processed the software to be installed in one step by the users.

Fig. 1. Browsing software displaying an array of the slightly, moderately, much dissected knees and the flexed knee from an embalmed cadaver. From the start-up screen of the software (left), slightly dissected knee in the upper main window is replaced with much dissected knee (center), which is then zoomed-in (right).

RESULTS

Our browsing software was downloadable from our website (anatomy.co.kr) without any charge or registration. A method of distribution via Internet was ideal due to the relatively small size (70 MBytes) of the setup file. Once the software was downloaded and installed, it ran off-line and displayed the pictures immediately without downloading time.

The software always showed the four knees which belonged to an array. Among them, the slightly dissected knee was displayed in the main window, whereas the other three knees were in the accessory windows (Fig. 1, left). The knee in the main window was able to be replaced with other knees by dragging the mouse (Fig. 1, center). The size ratio of the main and accessory windows was able to be modified. Each knee image could be magnified to see its details by mouse wheel forward (Fig. 1, right). The whole images could also be shifted by dragging.

By clicking the up and down buttons of the software or by pressing the up and down arrow keys of the keyboard, neighboring arrays were continuously displayed as if the knees were rotating. The 72 arrays of embalmed knee were followed by those of fresh knee. The users were also capable of selecting the images either by using the scroll bar or by typing an image number into the program. The operation method and brief orientation of this software appeared when pressing F1 on the keyboard or on the screen.

Annotations in the four arrays served as references to identify the anatomical structures even in other arrays. For example, by referring to the annotations on the posterior view and lateral view (Fig. 3, top row), it was possible for the user to label the components on the intervening posterolateral view (Fig. 3, bottom).

By comparing much dissected and flexed fresh knees, known knee joint movement could be demonstrated. For instance, during knee flexion, posterior rolling movement of the condyles of the femur induced the posterior glide of the lateral and medial menisci (Fig. 4).
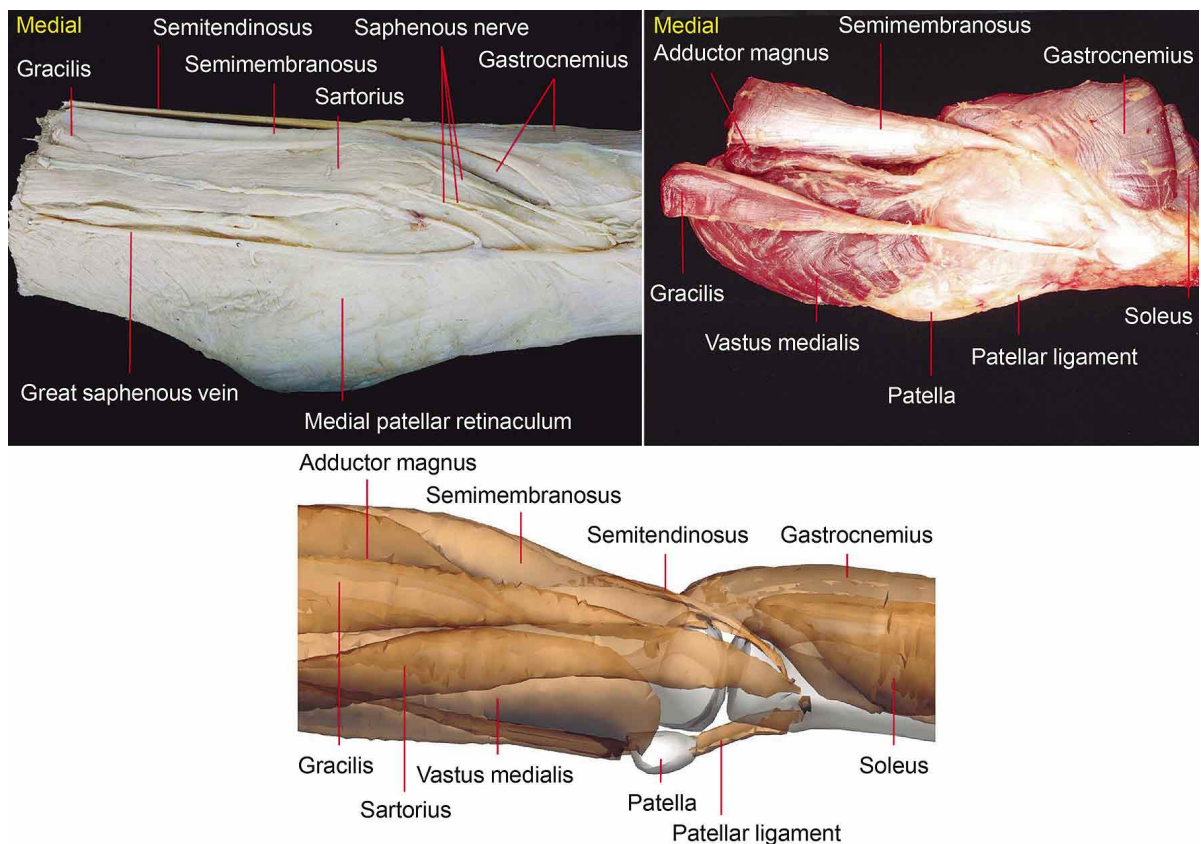

Fig. 2. Medial views of the embalmed knee (top left) and fresh knee (top right) in the browsing software. As a supplement, medial view of 3-dimensional surface models of the knee is prepared from the PDF file (bottom).
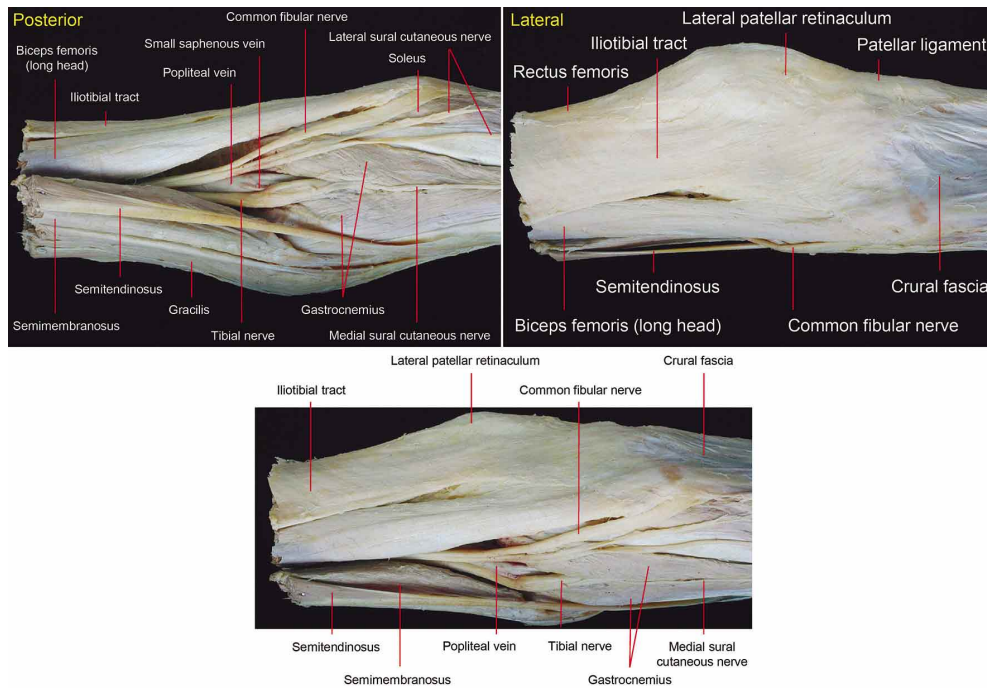
Fig. 3. Annotations on posterior view (top left), lateral view (top right), and posterolateral view (bottom) of the slightly dissected embalmed knee. Annotations on posterior and lateral views are included in the browsing software, while those on posterolateral view are manually appended by user, consulting the two reference views.
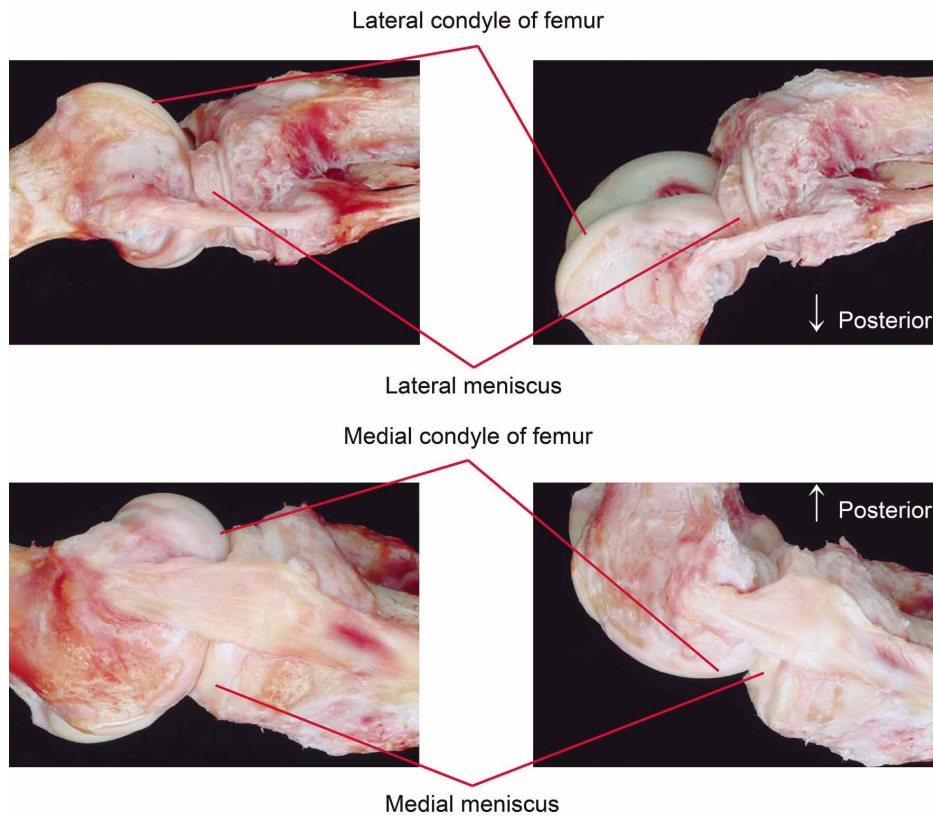

Fig. 4. Lateral view (top row) and medial view (bottom row) of the right fresh knee in extended state (left column) and flexed state (right column).

DISCUSSION

We have combined the raw images of knees in diverse states and the suitable browsing software to achieve the educational effect. The software presented here may aid medical students and doctors in various ways. During a cadaver dissection, students can refer to the pictures of the embalmed knee, which is dissected exemplarily. In preparing surgery, doctors can observe realistic structures of the knee from the pictures of fresh subject (Fig. 2).

Photographs of the flexed knee of the fresh cadaver assist in understanding functional anatomy. The posterior movement of menisci during flexion can be observed (Fig. 4). There are two factors that trigger the movement. First, the condyles of femur roll backward during flexion and push the menisci posteriorly (Pinskerova *et al.*, 2004). Second, the semimembranosus and popliteus pull the menisci posteriorly during flexion (Last, 1950; Kim *et al.*, 1997). These two factors help the menisci avoid getting stuck under the condyles of the femur, after flexion (Vedi *et al.*, 1999). Observing this movement enables the users to comprehend pathological conditions such as the case of entrapment of the meniscus in tibia fracture (Burstein *et al.*, 1988).

Users can simultaneously access this browsing software and the three-dimensional models from Visible Korean project to study knee anatomy extensively. The models of a male cadaver's whole body are provided in a portable document format (PDF) file, which is downloadable at the same site and can be opened with Adobe Reader (Adobe Systems, Inc., San Jose, CA, United States) (Shin *et al.*, 2012b). Users can match the real features of the knee in the browsing software (Fig. 2, top row) with the stereoscopic models of the knee and adjacent structures in the PDF file (Fig. 2, bottom).

Our knee pictures are to be modified in the installed folders of this software (Shin *et al.*, 2011). The pictures can be sorted to yield the new array including the corresponding knee pictures of embalmed and fresh cadavers. Then the side-by-side display will facilitate their comparison (Figs. 2 and 5).

Moreover, the pictures could be replaced with those of other regions. For example, serially rotated images of the elbow joint could be viewed with the same software. The technique to produce the serially rotated images is described
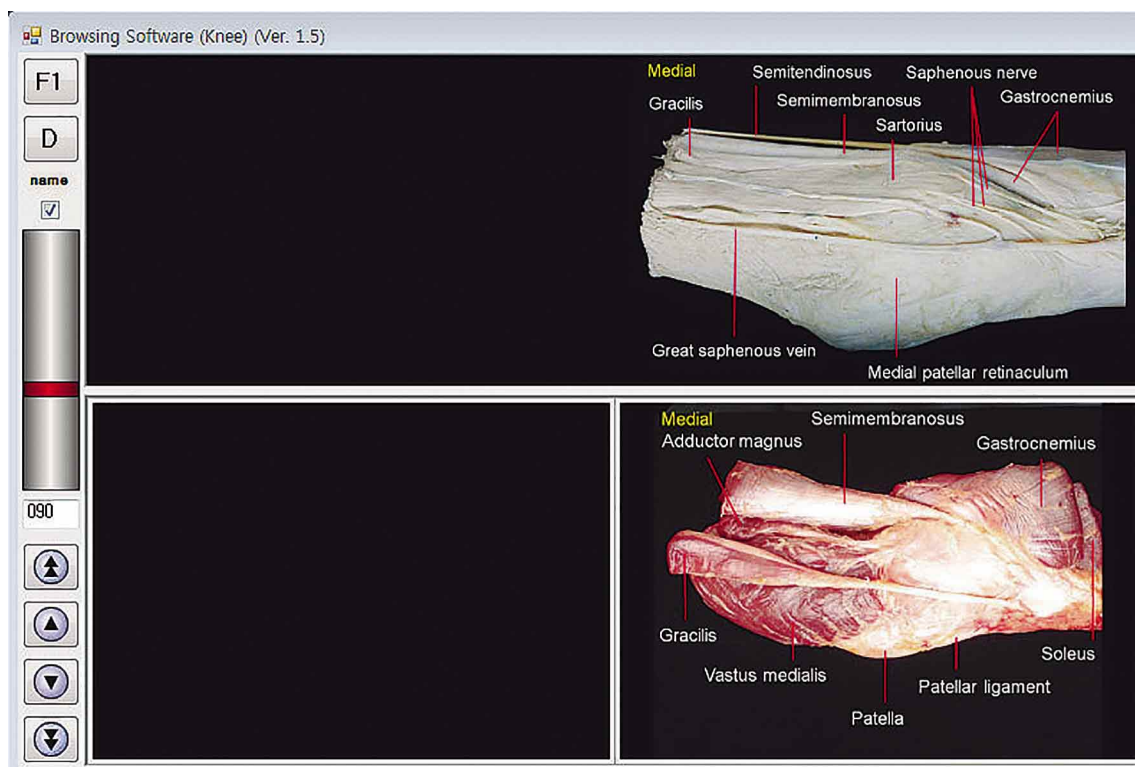

Fig. 5. Part of the other browsing software, where the embalmed knee and fresh knee are compared. Overall, the texture looks more solid in the embalmed one, but soft in the fresh one.
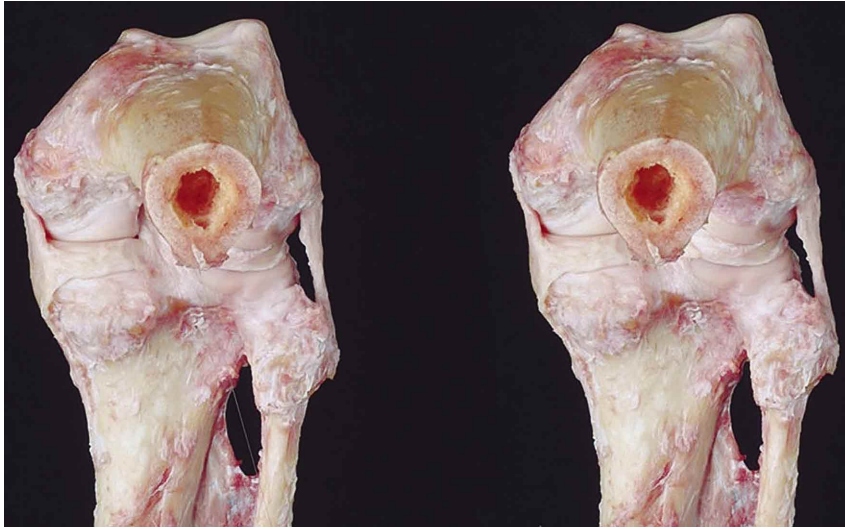
Fig. 6. Two pictures of the flexed fresh knee between 5 degree angle for autostereography without any instruments. By putting the hand vertically on the paper to divide the photos, one perceives them stereoscopically.

in the materials and methods above and in the previous report (Park *et al*.).

Any interested researcher may improve the annotation system in the browsing software. The improvement can be achieved by outlining the structures on the pictures. After the procedure, when the mouse cursor is placed on a certain structure, its name will appear on our software (Shin *et al*., 2011).

Our browsing software could be further reprogrammed with beneficial functions by computer engineers. In the current software, the number of pictures to be displayed is fixed at four (Fig. 1). However, with further programming, the number could be adjusted freely by the user (Rosset *et al*.). As a result, more detailed states of dissection and flexion of the knee could be simultaneously observed.

On the new software, users might rotate the knee not only vertically but also horizontally (MeAV Anatomie). For horizontal rotation, the software requires additional pictures of the knee, taken in much more viewpoints. To accomplish this, photography system consisting of a sphere around the knee should be devised.

The engineers may produce the online version of our software, which also allows mobile access. The original version of our software requires downloading and installation; the software can run off-line, processing high quality images without delay. In order to eliminate the downloading and installation steps, on-line version is the solution using object virtual reality based on hypertext mark-up language 5 (HTML 5) (Trelease & Nieder, 2013). In this

case, the pictures will be naturally seen on mobile devices such as smart phones or tablets. The last choice of programming is to make the clients install the browsing software and operate it off-line in the mobile environment.

Our knee pictures can be taken out of this software to produce various educational resources. They can be simply used for anatomy lecture and examination. The pictures can be selectively put in the electronic book such as computer dissection manual (Chung & Chung, 2015) and even in other educational software for digital anatomy (Dev *et al*., 2006). On request, we can send the data set containing all of the eight depths of dissection and the four degrees of flexion at their original resolution (3,072 x 2,048 pixels) (Park *et al*.). We are also willing to supply others with the PowerPoint file of annotations, so that they can use or revise the labels (Figs. 2 and 3).

Autostereogram could be another application of the knee photographs. The viewing angle difference of 5° is optimal for autostereography. So as to be perceived, two knee pictures should be rotated to the vertical state. They could be printed on paper to make a stereoscopic atlas book (Fig. 6) (Yokochi, 1997). Alternatively, the three-dimensional scene can be conveniently viewed with appropriate software and special glasses. The system for the stereoscopic experience of several body regions has been developed in other trial (MeAV Anatomie).

This report doesn't include users' responses. The educational effect of our software needs to be evaluated by learners in the succeeding investigation. Further development of the software and applications of our raw data will hopefully be achieved by other anatomists.

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RESUMEN: El objetivo de este estudio fue producir imágenes de las rodillas de un cadáver embalsamado y otro de cadáver fresco, con diversos niveles de disección, flexión y rotación, con el fin de ayudar a los estudiantes de medicina y a los médicos, en el estudio de la anatomía de la rodilla. En este estudio, la intención fue mejorar la accesibilidad de las numerosas fotografías de la rodilla, mediante la introducción de éstas, producidas en nuestro propio programa de navegación. El programa se puede descargar de forma gratuita desde la página web (anatomy.co.kr). En el programa, una matriz que constaba de cuatro fotografías: una rodilla a tres profundidades diferentes de disección y la misma rodilla en el estado flexionado. La rodilla podía girar de forma interactiva en cada ángulo de 5°. Anotación de las estructuras importantes de la rodilla podían ser vistas a intervalos de 90° de ángulo. Con el software de navegación, los usuarios pudieron observar características detalladas y realistas de las rodillas flexionadas y disecadas. Además, la comparación de las rodillas embalsamadas y frescas mejora la comprensión de la apariencia real de la rodilla. Los datos del programa y de imagen extraíble se pueden utilizar como materiales de educación en anatomía para diversos fines.

PALABRAS CLAVE Anatomía; Cadáver; Rodilla; Educación Médica; Interfaz de ususario.

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