ISSN 0001-6012 eISSN 2215-5856
Rev. Acta Médica Costarricense
Edited by: Colegio de Médicos y Cirujanos de Costa Rica
2024 / April-June; 66 (2):1-7

Original

Use of the Qlone™ application as a tool for the creation of low-cost 3D anatomical bone models and High anatomical fidelity

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Traducción original: Sánchez-Hidalgo Nelson, Murillo-Jiménez Julyana, Gonzales-Fernández Jéssica. Uso de la aplicación Qlone™ como herramienta para la creación de modelos anatómicos óseos en tercera dimensión de bajo costo y alta fidelidad anatómica Acta méd. Costarric. 2024; 66 (2): DOI: https://doi.org/10.51481/amc.v66i2.1399

Abstract

Objective: To describe a standard methodology for the creation of 3D anatomical bone models with high anatomical fidelity and low cost, using the Qlone™ application.

Methods: By means of a descriptive research, a standard methodology for the creation of three-dimensional bone models is proposed as follows: I. Assembly of the scanning module with light source, rotating base, mat and anatomical piece, and II. Model development with initial preparation, image capture, model editing, and completion and saving.

Results: By applying the standardized methodology, high anatomical fidelity is achieved by recognizing 100% of the minimum bone anatomical structures to be identified in the three-dimensional models of the sacral bones and lumbar vertebra. It is a low-cost method as it requires only an initial investment, after which an unlimited number of models can be produced at no additional cost.

Conclusions: Qlone™ is a useful application in the elaboration of anatomical models in three dimensions of low cost and high anatomical fidelity. It is a user-dependent tool that requires adjustments according to the part to be modeled, but by following the described methodology in detail, it reduces errors in the reconstruction of the model in three dimensions, increases the level of detail and guarantees anatomical accuracy.

Descriptors: Qlone, 3D model, digital anatomy, education, augmented reality.

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Abbreviations:
GIF; exchange format Graphics.
PRODOCU; Body Donation Program.
RA; augmented reality.
3D; Three dimensions.
2D; Two dimensions.

Funding: Project EC-538, Body Donation Program of the School of Medicine (PRODOCU) of the University of Costa Rica.

Conflict of interest: None of the authors have conflicts of interest.

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Cadaveric dissection is the method of teaching anatomy par excellence, despite this, with the advancement of technology, the lack of cadaveric sources and the cost of conservation in certain countries, teaching resources have emerged such as 3D visualization educational models (three dimensions) that include virtual reality (VR) and augmented reality (AR).[1] Evidence shows that the use of 3D technology has proven to be a teaching/learning tool superior to learning with 2D images (two dimensions) and not significantly different from the traditional method of learning with human biological material, in addition to this, it improves enjoyment and satisfaction during the teaching process, thus resulting in a valuable complementary tool.[1-3]

Both the traditional teaching of anatomy with cadaveric dissection and the models created with 3D technology have multiple advantages and disadvantages with respect to the others; however, the joint use of these two tools has proven to be very useful and has been well accepted by the new generations of health sciences students.[4-6]

These techniques are not new; photogrammetry, for example, saw its beginnings shortly after the invention of photography, around 1900.[7,8] Scanning, on the other hand, is more recent and both techniques are used in multiple disciplines, such as archaeology, cartography, geometry, military and others. In medicine they have great potential in areas such as diagnosis, treatment and teaching. Over time, new 3D technologies have developed exponentially.[7, 9]

There are several methods for creating 3D models that can be divided into two basic categories: scanning (laser or structured light) and 3D modeling software from 2D images such as photogrammetry or medical imaging, although the techniques can be combined.[5]

One of many examples of these new implementations of 3D technology is Qlone™ (EyeCue Vision Technologies LTD, California, USA), which is a free application with a *premium* version of a one-time payment, for mobile devices with iOS™ (Cisco Systems, Inc., California, USA) or Android™ (Google LLC, California, USA) operating system developed by *EyeCue Vision Technologies LTD,* through which it is possible to create exportable 3D models in various formats and compatible with model reproduction platforms as well as 3D printing, by capturing the 360° video of the piece.[10] This quality differentiates it from other techniques such as traditional photogrammetry in which a camera is used to take photographs in numerous perspectives and, subsequently, reconstruct the image in 3D for which the use of paid software such as Agisof PhotoScan™ (Agisoft LLC, St. Petersburg, Russia) and a computer with high capacity is required. which implies a disadvantage due to the high cost.[11.12]

The objective of the study is to describe a standard methodology that allows the creation of anatomical models in 3D with high anatomical fidelity, at low cost, quickly and easily, through the Qlone™ application, as well as to describe the advantages and limitations for their development.

Methods

This is a descriptive study of the methodology of the creation of 3D anatomical bone models; The method has as its starting point the manual for the use of the application added to the authors' experience with its use, the final optimized methodology presented below is the result of a process of trial and error in which the variables were modified until an optimal result reproducible with the available materials was obtained.

Materials: For the realization of the models 3D digital was required:

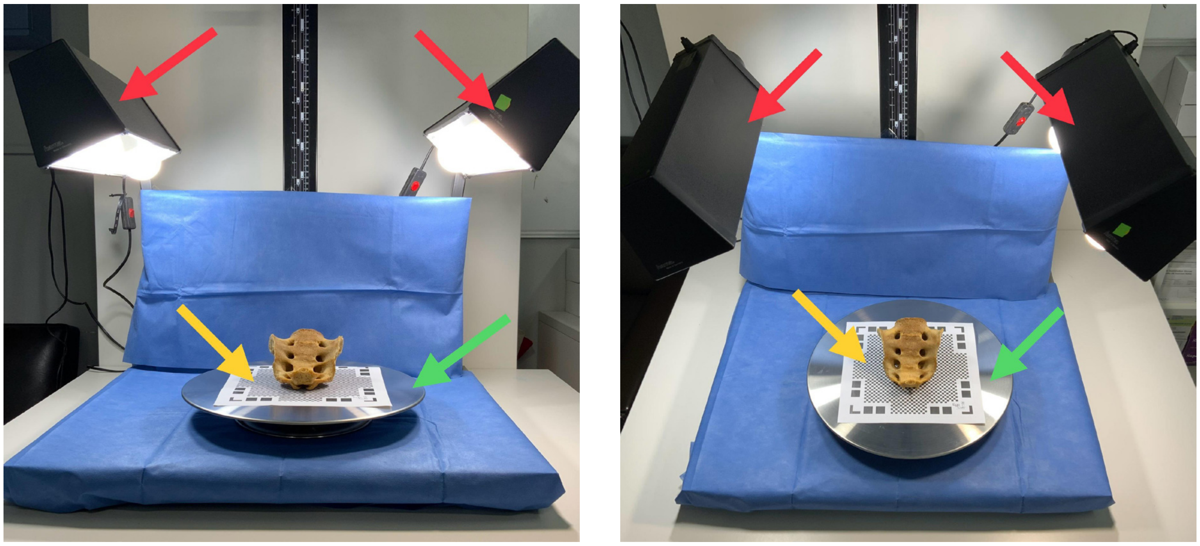
- *Horizontal mat (*grid base that isdownload when entering the application).
- *Vertical mat* (optionally used on tall objects, downloaded when entering the application).
- Mobile device with android or IOS operating system, in this case an iPad Pro™ (Apple Inc., California, United States) 11” from 2019 (12 MP camera, f 1.8) was used.
- Two white light sources.
- Swivel base.
- Anatomical pieces (sacral bone, lumbar vertebra).
- Qlone™ app (version 3.16.1).

Method: It is carried out in a sequence of stages.

I. Mounting the module for scanning

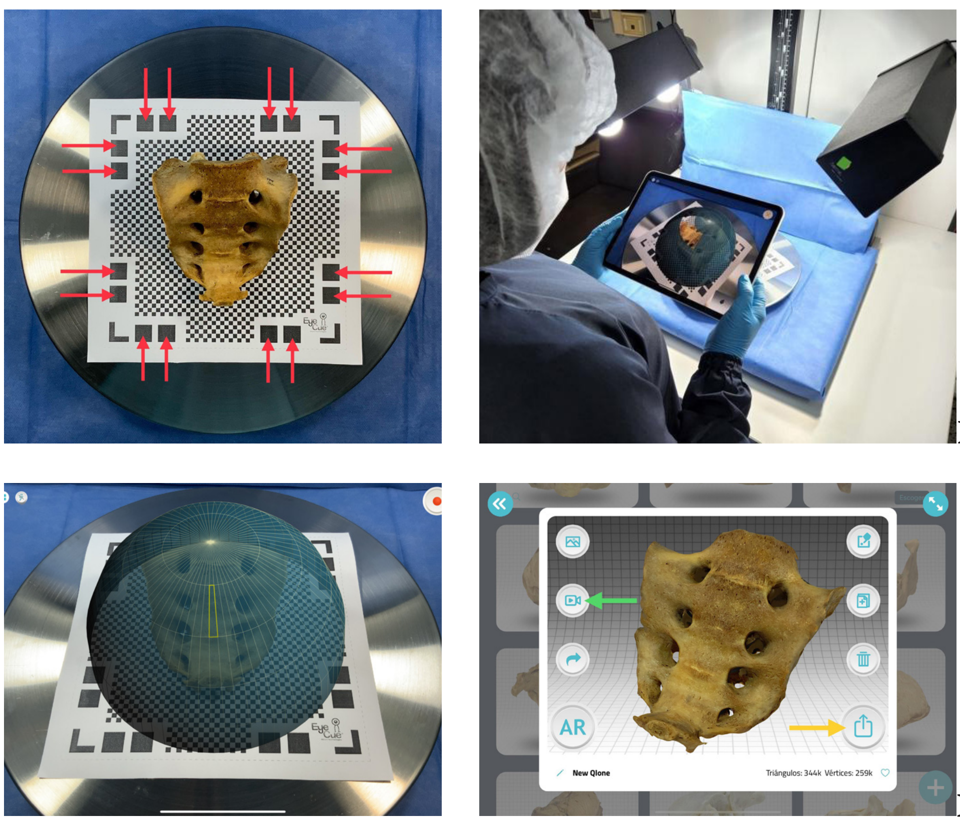
- **Controlled light conditions:** an environment was built with 2 fixed white light sources, located in such a way as to ensure uniform lighting that avoids shadows, in addition to an adjustment in the intensity of the light to each bone, whose objective is to prevent overexposure or underexposure (Figure 1).
- Use of the mat: a mat adjusted to the size of the part to be scanned was printed. 1.5 times the size of the part to be scanned is recommended to avoid obstruction of the reference frames during scanning (Figure 2).
- Rotating surface: a rotating base for manual use was used, of adequate size for the anatomical part and a flat surface located in the center of the module (Figure 1).
- Positioning of the anatomical piece: the piece must be centered on the internal frame of the mat. Only two sides of the part can be taken, therefore it is recommended to mark reference points to guide its rotation after the first scan (Figure 2).

ISSN 0001-6012 • eISSN 2215-5856 / Acta Médica Costarricense. 2024 / April-June; 66 (2): 1-7



A. B.

Figure 1. Scanning module with controlled light source (red arrows), rotating base (green arrows) and mat (yellow arrows). A) Front view. B) Top view.
Source: Body Donation Program (PRODOCU) 2022.



A. B. C. D.

Figure 2. **I**mage taking process. A) Mat adjusted to the size of the anatomical piece, which leaves the reference boxes (indicated with red arrows) visible. B) Taking images that complete the dome as indicated by the application C) Complete dome indicating that the image taking of the model has been completed. D) The resulting model displayed in the application indicates export options: export symbol (yellow arrow) and camera symbol (green arrow)
Source: Body Donation Program (PRODOCU) 2022.

II. Model development

IIa. Application Login and Initial Preparation:

- Open the application and select the "+" symbol to display the image taking screen. Once on this screen, the proper visualization and location of the anatomical piece is corroborated, as well as the conditions of the module.

IIb. Image capture:

- The mobile device is positioned at an optimal distance from the workpiece as close as possible so that the four reference frames of the mat are visible (Figure 2). The closer the image is captured; the better results are obtained.
- Start taking images and complete frame by frame each level of the dome before moving on to the next, either starting at the top or bottom level (the app takes the 2 lower levels together).
- When taking the images, the device must provide a fixed position, in such a way that it varies only vertically when passing the level; On the other hand, the rotating base must move slowly to allow the shot frame by frame.
- Once the first side of the part is completed, a preview screen opens, where you can manipulate the model, and have the option to take that side of the model again or take the next one to complete it. To do this, the anatomical piece is rotated 180 degrees, keeping the piece within the reference points previously marked on the mat.
- Select "+" in the bottom right corner of the Qlone™ app screen to take the second side and proceed as with the first.
- Upon completion, the app automatically joins both sides in a preview.

IIc. Model editing: When completing the model, modifications such as brightness, saturation, and sharpness adjustments can be made, as well as unwanted areas can be removed.

IId. Finishing and saving: If you are satisfied with the result, select finish and the application saves the model with the name you assign it, or you can repeat the shot of that face.

IIe. Export:

Once the model is finished, when viewed in the application, it can be exported by selecting the lower right option (export symbol), in which the option to share it in different programs and formats is displayed; or you can select the second option on the left (camera symbol) to export as a graphics interchange format (GIF) or video. (Figure 2).

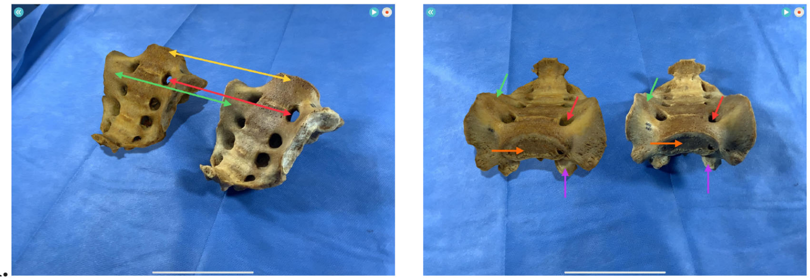
2 3D models were made, selectedbones Irregular Given the complexity of their Structures: lumbar vertebra and sacral bone. The pieces were obtained from the osteotheque of the School of Medicine of the University of Costa Rica.

Anatomical fidelity for this study was defined as the identification of at least 90% of minimal structures to be identified in the 3D anatomical model compared to the structures identified in the actual anatomical model. The list of structures was taken from the book Anatomy used in the anatomy laboratories of the School of Medicine of the University of Costa Rica.

Results

With a user with experience in the use of the Qlone™ application, it was possible to completely complete each anatomical model in an average of 45 minutes to 1 hour, therefore creating models in which it is possible to identify at least 90% of the minimum structures to be identified of each anatomical piece (figures 3 and 4).

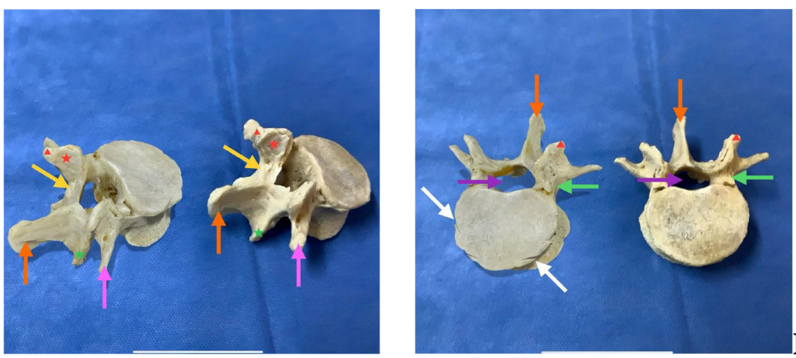
ISSN 0001-6012 • eISSN 2215-5856 / Acta Médica Costarricense. 2024 / April-June; 66 (2): 1-7



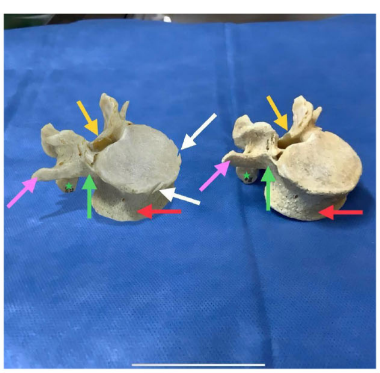
A. B.

C.

Figure 3. Comparison of the sacral bone (right) and anatomical model in augmented reality (left). Bone accidents are identified: sacral promontory (yellow arrow), sacral foramina (red arrow), sacral wing (green arrow), sacral base (orange arrow), superior articular process (purple arrow). A) Previous view. B) Top view. C) QR code for display of GIF sample of the model.
Source: Body Donation Program (PRODOCU) 2022.



A. B.



C. D.

Figure 4. Comparison of the lumbar vertebra bone (right) and lumbar vertebra bone model in augmented reality (left). The following bone accidents are identified: vertebral body (red arrow), vertebral pedicle (green arrow), vertebral lamina (yellow arrow), vertebral foramen (purple arrow), spinous process (orange arrow), transverse process (pink arrow), superior articular process and superior articular face (red star), inferior articular process and inferior articular face (green star), mammillary process (red triangle). Reconstruction error is shown in the vertebra body in the 3D model (white arrow). A) Back view. B) Top view. C) Side view. D) QR code for video display on the model sample.
Source: Body Donation Program (PRODOCU) 2022.

Discussion

The study of anatomy as a basic medical science has been a fundamental component of medical education throughout history, facilitating the examination of patients and orientation towards specific differential diagnoses.[13]

Recently, digital applications of anatomy have emerged in response to the need to complement medical education, especially with the growing digitization of resources, online exams, seminars and virtual congresses.[4,12,13] With this, applications on mobile devices that allow interaction with 3D anatomical models have become more popular and accessible, however, these are created through digital illustrations and lack realism and anatomical fidelity, despite this, it is a more useful resource in learning anatomy than the use of 2D images.[14]

Although 3D cadaveric models do not replace the traditional teaching model in the anatomy laboratory, they are effective as an educational complement, since they offer high anatomical fidelity and flexibility of access from electronic devices; they are also an important alternative educational tool in those institutions that cannot weigh the costs and requirements for cadaveric dissection and their conservation.[11.12]

The Qlone™ app is a free app with a one-time version option of $19.99 that allows the scarce 360-degree for creating 3D models on mobile devices. This application is remarkable for being intuitive and fast. It includes in-app guidance, editing options at the end of the model, AR view, and scanning in 4K/UDH (ultra-high definition) resolution.[10] In addition, it is low cost since the creation of 3D models requires only an initial investment, after which an unlimited number of models can be produced at no additional cost (see Table 1).

Table 1. 3D model creation costs*

Materials	Cost
Qlone™ App	$19.99
Mat Printing	$5
Mobile device (Ipad pro 11")**	$1119
2 Light Sources	$50
Swivel base	$6
Total:	$1219.99

* This investment is one-time.
** The price of the mobile device may vary depending on the model you are working on.

The 3D model can be viewed in the application and can also be viewed on different platforms such as Sketchfab™ (Sketchfab, Inc., Paris, France) and social networks, among others, since it can be exported in object file format (OBJ), standard triangle language (STL), filmbox (FBX), universal scene description (USDZ), binary gl transmission format (GLB), Extensible 3D (X3D), polygon file form (PLY), GIF, video, and portable network graphics (PNG), making it easy for models to access and manipulate by third parties, and even AR visualization is possible.[10]

As a fundamentally important and ethical feature associated with the use of human biological material, this application does not store and cannot observe any model made on its platform but is saved on the device used to be viewed or exported.[10]

Recommendations to improve the outcome of the 3D model:

Mat:

- The printing of a mat on non-reflective material is required to avoid problems in the capture of references.
- Keep the mat in good condition, without wrinkles, damage or discoloration.
- Adjust the mat size to the part to be scanned. A mat 1.5 times the size of the part is suggested to prevent it from protruding from the reference limits.

Light:

- Use a white light source with adjustable intensity, adjusting the intensity according to the color and size of the piece. Avoid overexposure or underexposure for optimal visualization of bone accidents.
- Use at least two light sources for an even distribution and avoid shadows that can alter the anatomical structure.

Rotating surface:

- It is suggested that two people perform the process, one to capture images and the other to rotate the surface homogeneously at a low and controlled speed.

Mobile Device (Mobile, Tablet):

The better the resolution of the camera used; the better results are obtained.

It is recommended to hold the device at a constant distance while rotating the surface to improve the resolution of the model.

User:

- It is recommended to practice the process repeatedly, considering all the variables described above, so that the user develops the necessary skill to obtain better results.

When comparing the AR anatomical models that were created together with the real anatomical model (Figures 3 and 4), it was determined that it was possible to identify 100% of the minimum structures to be identified from the checklist in each model,15 therefore, it is possible to say that the 3D model made using Qlone™ has a high anatomical fidelity despite having used complex anatomical pieces due to their irregular surface. Even so, the possibility is recognized that, as can be seen in Figure 4, there could be errors in the reconstruction of the anatomical structure that may be due to the reasons explained above; however, these do not imply a significant alteration in the anatomical structure.

Qlone™ is a versatile application that allows the creation of 3D cadaveric models not only of bones, but also of organs such as the brain that can be used both for teaching anatomy for undergraduate students and for highly realistic surgical simulation in the area of neuroanatomy, cardiovascular surgery and orthopedics, planning of surgical approaches, understanding of structural pathologies, among others.[Acts 16, 17]

The Qlone™ app offers an effective and low-cost solution for creating 3D cadaveric models with high anatomical fidelity, hence it is a valuable complement to anatomy education.

It is a user-dependent tool that requires adjustments according to the part to be modeled, but by following the described methodology in detail, it reduces reconstruction errors of the 3D model, increases the level of detail and guarantees anatomical accuracy.

The ability to export models to platforms such as Sketchfab™ expands access to interactive educational resources, which could benefit those interested in anatomy from any electronic device at any time, by creating an online repository of 3D cadaveric models.

Gratitude

The authors thank PRODOCU, the donors and the Morgue and Necrobiology Section of the University of Costa Rica for facilitating the use of biological material for academic and scientific purposes.

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