AC 2009-295: GRAPHICAL SIMULATION AND COMMUNICATION OF KNEE-REPLACEMENT SURGERY INFORMATION

Patrick Connolly, Purdue University

Kimberly Batta, Purdue University

Alex Morgan, Purdue University

Eric Wack, Purdue University

Ben Wheeler, Purdue University

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Abstract

With an aging population, health issues are on the rise. It is projected that over half of the American population will develop arthritis in their knees, as well as other joints, during their lifetime. Many of these medical issues will result in the need for joint replacement surgery, but unfortunately there is no current visual method that adequately explains the operation to the potential patient. A research project was undertaken to develop a comprehensive website to provide thorough information on knee replacement surgery, and to display a 3D simulation of the procedure that the patient will undergo. A major focus of the effort was to communicate the information without the utilization of unnecessarily disturbing graphic images and details. The goal was to help patients understand what happens during knee replacement surgery and the benefits that come from having the operation, while alleviating their fears. Special emphasis was placed on 3D modeling accuracy and effective simulation presentation to allow for effective graphical communication. A survey methodology was used in the research to measure viewer perception of message effectiveness in both educating and alleviating concerns in potential patients. This paper will report on the techniques utilized to model the complex anatomical features of the knee joint and joint replacement mechanisms, the data translation and formatting strategies used to present 3D CAD information in both static and dynamic forms, and survey results and recommendations for future research.

Introduction

More than half of all Americans will develop arthritis in their knees and other joints at some point in their lives.[(1)] A significant number of these medical problems will require joint replacement surgery, an option for which clear and easily accessible information is limited. Many individuals put off having the necessary joint replacement surgery until they are in extreme pain and discomfort, sometimes due to lack of understanding about the operation and its potential impact. In the current digital age, many people turn to the Internet as a source of information. It would be helpful, therefore, to have reliable and easy to find information available on the web regarding joint replacement surgery. What is currently accessible is not adequate from either a visualization or explanation perspective. This information often uses terms that are difficult for a non-medically trained person to understand. Furthermore, the visual information that is provided often comes from live surgeries and is too graphic and disturbing for many viewers.[(2)] Doctors currently use literature, diagrams, and physical models to explain the procedure to their patients which often leaves them feeling uninformed and in need of more information before pursuing the operation.

In order for potential patients to make informed decisions regarding joint replacement options, they need to be able to review material, do in depth research, and learn from other individuals who have been through the experience of joint replacement. They would also benefit from understanding what happens during the operation, expected challenges, potential complications, and anticipated results. A more simplified graphical representation or simulation of joint replacement surgery could potentially provide a more effective way to communicate and inform

patients in this area.[2] One question that arises is whether or not a simplified graphical image would assist with calming patients' fears and concerns about the operation. In some cases, people may want a real video from surgery, which displays live and graphic images. For others, a simplified simulation may be sufficient. Still others may desire something even simpler and less graphical, such as a 2D illustration.

Research

The goal of this project was to create an informational website including a dynamic simulation that would describe the operation in a visual way to the viewer without showing possibly disturbing visual details. User feedback was gathered to determine if potential patients or caregivers perceived the website and the simulation as a useful resource. In the survey that was conducted, individuals' perceptions were measured by asking a series of questions that dealt with information content, level of comfort, and whether or not they would recommend the site to others.

As part of this perception gathering, two questions were asked regarding the comfort level of the user with the website ("Did the website ease pain and fears that are commonly associated with joint replacement surgery?" and "Did the simulation have an effect on their comfort levels?"). These questions were used to measure whether or not the viewer felt an increase or decrease in comfort based on the information received. Comfort levels are subjective and, like pain thresholds, they can vary from person to person. Their comfort response could be affected by a variety of factors, including how they think, feel, and react.[3] However, in spite of the subjective nature of these questions, it was anticipated that the rich nature of these data make them valuable to consider.

Adobe Acrobat 3D was used to display the simulation on the website. This software technology allows three dimensional objects and animations to be displayed in a PDF format. One reason that this technology was selected for the site is that Acrobat Reader is either preinstalled on most computers, or is free and easy to download if not preinstalled. One potential downside to using Adobe Acrobat 3D on the web is that 3D PDFs are not completely compatible with the Mac and Linux operating systems.

Previous research included a survey which was conducted in 2002 to determine the influence of the Internet in an orthopedic practice. It was noted that a significant amount of individuals trusted at least some information that was delivered over the internet.[4] With that result in mind, it was decided that developing an online website would be an effective method for relaying joint replacement information to patients.

Model and Simulation Creation

A website containing a 3D user-manipulated model of a completed full knee replacement was created to test patients' opinions of the simulation. In order to begin modeling the simulation, actual knee replacement implant parts were obtained from medical suppliers. In addition to having the physical parts, brochures and photographs were used to assist with modeling accuracy. A functional knee joint model was also purchased for reference when constructing the

3D model of the leg bones. A combination of surface modeling techniques and solid modeling was used to create the models in the CATIA software package. Calipers were used to measure all implant parts to ensure the accuracy of the model. To begin the modeling process, a skeleton model was constructed using datum geometry to capture critical dimensional information. After the necessary datum references were completed, sketches of the cross section of each part were created. Guide curves were then used to connect the sketch cross sections to facilitate multi-section sweep operations to create solid and surface geometry. Due to the complexity of the artificial joint topography, multi-section solids were used (See Figure 1). Although the CATIA software was used to make the joint model, the organic nature of the bone outlines could also have been accomplished using a NURBS-based modeling software.

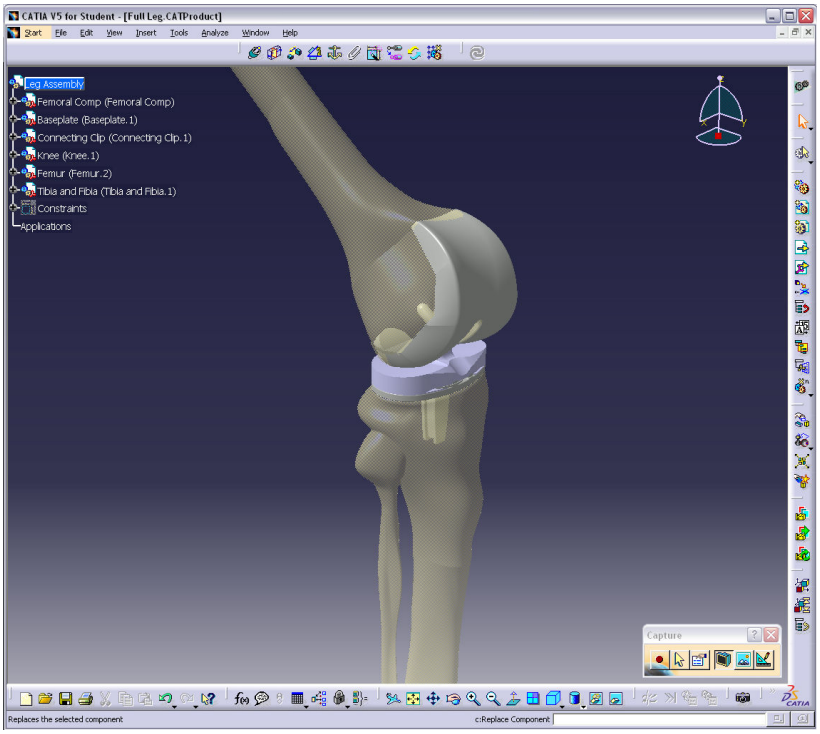

Figure 1. 3D Model of Knee Joint in CATIA

Once the model was completed in CATIA, it was imported into the Adobe Acrobat software (Adobe Acrobat 9 Pro Extended), and the desired viewing angles, lighting, and display modes were established to generate the 3D PDF for the simulation. There are multiple products available for viewing 3D images on the web (3DXML, JT2Go, DWF Viewer, etc.) but Adobe Acrobat 3D was chosen due to its unique method of displaying 3D data. Generally, with these other options, the user would be required to download additional software not commonly installed on computers in order to facilitate 3D viewing on the Internet. The Adobe Acrobat software that was used was also able to open CATIA assemblies directly. Due to this, no file conversion was required before importing the model into the program. The file was then saved as a PDF, and then embedded into the website using HTML code.

The 3D PDF simulation is a detailed representation of the completed partial knee replacement. The capabilities of the software allow for user control of the 3D image, including real time

rotation, panning, zoom functions, default viewing angles, walk-through and fly-through options. The user can also define 'cameras' to look at the model in various ways and with various parameters such as field of view and roll. The viewer also has the option of selecting parallel or perspective projection to view the image. There are multiple rendering and lighting schemes that can be selected to highlight the model as desired. Finally, the capability exists to do cross-section images of the object. The user can orient and align the cutting plane as desired, and manipulate the cross-section display with real time commands to provide cut-away images.

Website Creation

Concurrent with the development of the joint model, preliminary design and implementation of the website was begun. After the initial design was reviewed by industry professionals and adjusted per their recommendations, the website was created using PHP and CSS technologies and was placed online for initial error review with a sample simulation in place (See Figure 2).

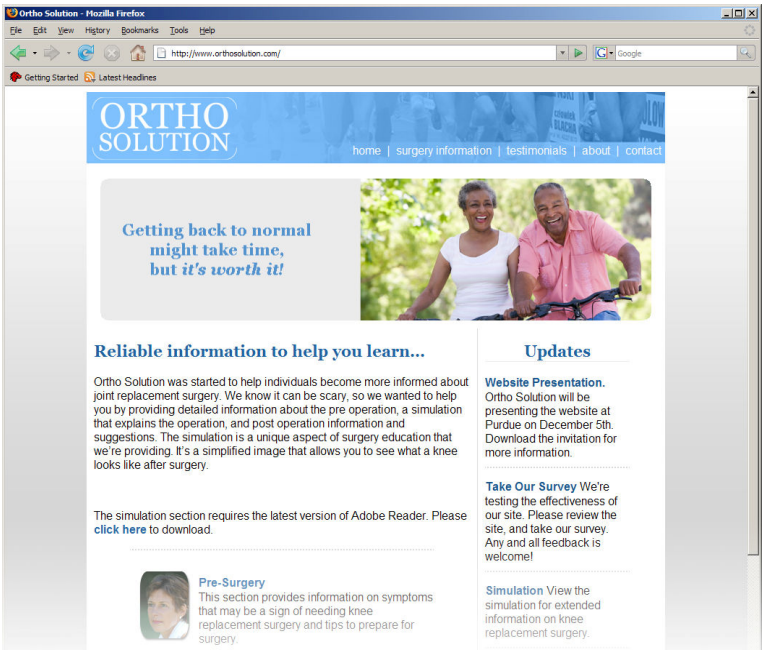

Figure 2. Screenshot of the Website

The website was populated by informational data obtained from online research and sources and testimonials gathered anonymously from individuals who had previously undergone joint replacement surgery. The website was tested at this point in development for errors, preliminary usability issues, and general aesthetic appeal. After the finished simulation was loaded onto the website (See Figure 3), the project was reviewed a second time by professionals recruited from the joint replacement field, and also by potential users for additional content errors and further design suggestions.

Figure 3. Screenshot of Simulation on Website

Survey

A survey (See Appendix A) was conducted to collect qualitative data on the perceived effectiveness of the webpage with the Adobe Acrobat 3D simulation. The survey contained questions regarding the patient's preferences regarding sections of the site, their opinion on the effectiveness of the simulation, and whether or not their comfort level was affected by website interaction.

Participants

The survey was e-mailed to a list of individuals, posted on an online blog, and sent to faculty members at a large Midwestern university. Participants were also asked to forward the survey to other individuals who might be interested in assisting with the research. Some demographic data was collected from the survey, including age range, whether or not they had experienced joint replacement surgery, how they researched medical information, and how frequently they used a computer. For initial testing purposes, no specific user group or demographic was targeted. It was a goal to collect information from individuals from a variety of different age groups and demographic strata. Since it has been shown that younger individuals rely on the web more than the elderly for information gathering, it was important to test whether or not the simulation might be more effective with specific age groups.

100 individuals responded to the survey. 42% of individuals were in the 20-29 age range. 15% were between the ages of 30-39. 13% were in the ages of 40-49. 17% were between the ages of 50-59. 10% were in the age range of 60-69, and 3% were above the age of 70 (See Figure 4).

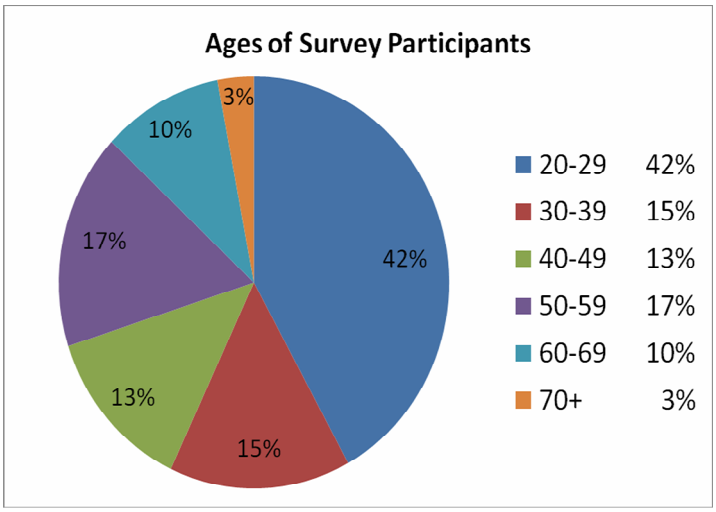

Figure 4. Age Range of Participants

Only one individual who took the survey had experienced knee replacement surgery prior to taking the survey. 54% of individuals who took the survey reported using the internet first when seeking information on medical issues, and 97% of participants used the computer on a daily basis. Participants were instructed to view the website and specifically the 3D simulation. They were then asked to complete the survey. All data was voluntarily submitted and anonymously collected.

Results

Mean response scores were compared using a one-way ANOVA with the age of the survey participants as the factor. The results of the ANOVA analysis determined that age was not a factor for any question. This result allowed the researchers to conclude that an informational website of this nature could be an effective tool for all age ranges. Other answers given showed that the majority of viewers had an increase in comfort level and general knowledge after website interaction. Likert scale responses for three of the questions showed that 84% of users reported an increase in information from using the website. 55% of users found the simulation the most effective way of communicating information, and 95% would recommend the site to others (See Figures 5-6).

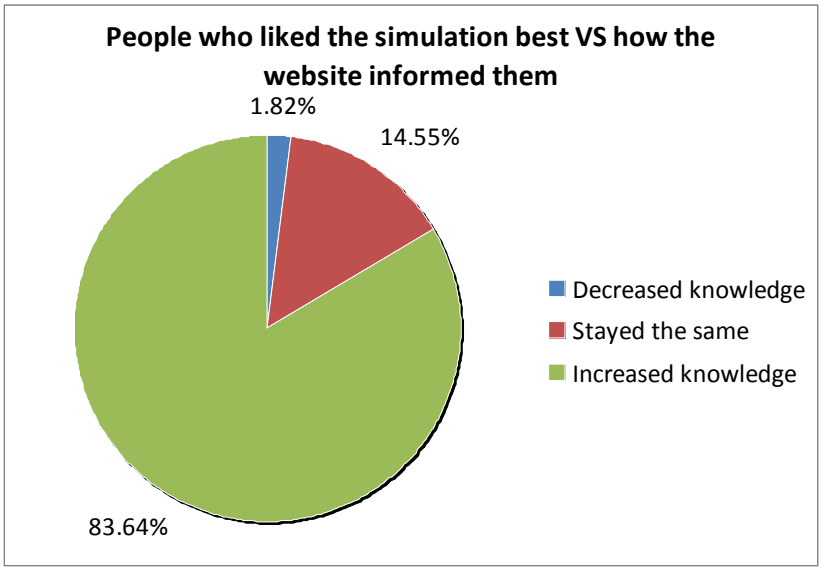

Figure 5. Informational Increase

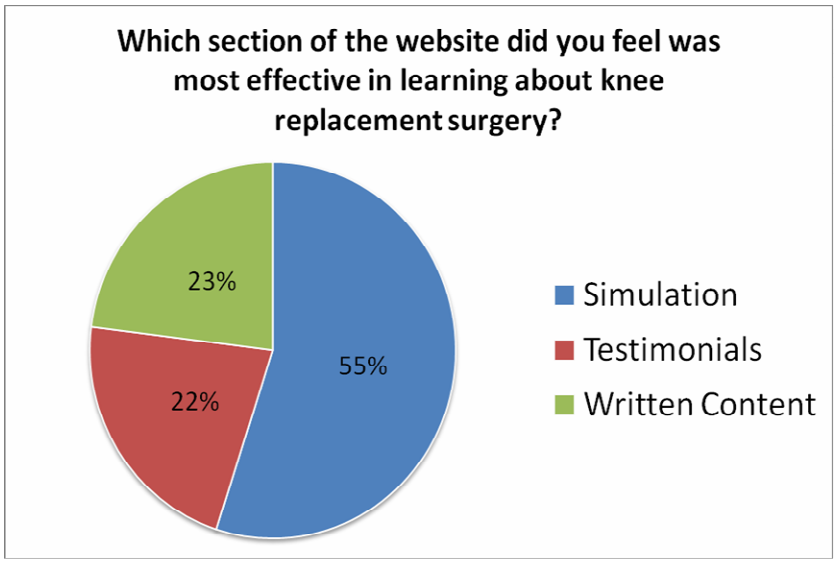

Figure 6. Website Content Preference

Discussion

These responses to these questions provided a baseline for future research and obtained useful information both specific to this website and medical websites and information delivery in general. It was interesting to note that the majority of participants found the simulation to be more informative and helpful than written information and 'been there' testimonials. Furthermore, several viewers commented that the site could be improved if additional surgeries were incorporated. Even though these results are promising, additional research is needed for more conclusive results to be determined. Because age was shown to not be a factor on these responses, it is assumed that this method of educating could be used for individuals in the age ranges tested. Further research should be conducted to validate this finding and to identify issues that users may have experienced with the interface. Follow-on research may also help identify

additional corrections and useful content that could increase the applicability and usefulness of the website.

Professional Review

The website link and description of the project was sent to a list of medical professionals in the orthopedic fields for their review, recommendations, and validation. Knowing that entering the medical field could bring about additional issues and complications, it was important to have feedback from professionals working in the industry. One useful response provided recommendations to update certain terminology to industry norms. In addition, this respondent noted that for a site to be referred to patients by individuals in the medical industry, it must be associated with a professional organization, company, or physician. This is important to note if the website were to be pursued beyond the scope of this research project.

Recommendations for Future Research

Further research is recommended on the application developed for this study. Additional corrections and revisions could be made to the project based on user input and subject matter expert recommendations. Significant addition of new materials and sections could be made to the website and further tested. Additional surgeries could be represented using similar simulation technologies. Future research could also compare the viability of these simulations to other methods of visually educating potential patients. The use of Adobe Acrobat 3D simulations as an educational resource could be another avenue of research, as well as determining the effectiveness of the software in other industry areas and applications.

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Appendix A

Survey Questions

This survey is for the use only of Ortho Solution, LLC. Your answers will be collected anonymously and will not be given to anyone else.

1. Age:
   a. 30-39
   b. 40-49
   c. 50-59
   d. 60-69
   e. 70 and above

2. Have you ever had a joint replacement surgery before?
   a. Yes
   b. No

3. Where do you look to first to gather information about medical issues?
   a. The Internet
   b. Personal doctor
   c. Friends
   d. Family
   e. Written sources

4. How frequently do you use a computer?
   a. Multiple times per day
   b. Once a day
   c. Once a week
   d. Rarely
   e. Never

5. After viewing orthosolution.com, what is your comfort level with the idea of knee replacement surgery? (1 = decreased; 3=no change; 5=increased)

   1 2 3 4 5

6. After seeing orthosolution.com, do you feel more informed about knee replacement surgery? (1 = decreased; 3=no change; 5=increased)

   1 2 3 4 5

7. Which section of the website did you feel was the most effective in learning about knee replacement surgery?
   a. Simulation
   b. Testimonials
   c. Written Content

8. How helpful was the simulation in understanding knee replacement surgery?
   (1 = not helpful; 5=very helpful)

   1 2 3 4 5

9. How did the 3D simulation affect your comfort level with the operation?
   (1 = decreased; 3=no change; 5=increased)

   1 2 3 4 5

10. Would you recommend this site to a person you know that is considering a knee replacement surgery?
    a. Yes
    b. No