Efficacy of 3D visualization in mobile apps for patient education regarding orthognathic surgery

Yeshwanth Pulijala [1] Minhua Ma [2] Xiangyang Ju [3] Philip Benington[4] Ashraf Ayoub [5]

1,2: School of Art, Design and Architecture, University of Huddersfield, Queensgate, Huddersfield, West Yorkshire HD1 3DH

3: Image Processing, Medical Devices Unit, Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow G2 3JZ

4. Department of Orthodontics, Glasgow Dental Hospital & School

5: Oral & maxillofacial Surgery, Glasgow University Dental Hospital & Scholl, 378 Sauchiehall Street, Glasgow G2 3JZ

Corresponding author:

Yeshwanth Pulijala

Email: u1475891@hud.ac.uk

Running title: Efficacy of mobile apps in patient education

Abstract

‘*Sur-face’,* is an interactive mobile app illustrating different orthognathic surgeries and their potential complications. This study aimed to evaluate the efficacy of *Sur-face* by comparing two methods of delivering patients’ information regarding orthognathic surgeries and their related potential complications: a mobile app with interactive 3D animations and a voice recording containing verbal instructions only. For each method, the participants’ acquired knowledge was assessed using a custom designed questionnaire. Participants of the ‘app’ group performed significantly better ($p<0.0034$) than the ‘voice’ group and retained more knowledge, suggesting that interactive visualizations play a key role in improving the understanding of the orthognathic surgical procedure and its associated complications. This study emphasizes the impact of 3D visualizations in delivering information regarding orthognathic surgery and highlights the advantage of delivering validated patient information through mobile apps.

Keywords: Orthognathic surgery, Mobile Apps, patient education, informed consent, interactivity, Unity 3D, mHealth, Medical education.

Introduction:

Orthognathic surgery is an elective procedure; hence it is essential to involve patients in the treatment planning and to obtain an informed consent. This allows them to play a more active part in the delivery of their surgical care.[1-2] However, the level of understanding that patients have of their planned surgery and its associated complications has often been underestimated.[3-4] Conventional techniques of delivering education to patients through verbal, illustrative and leaflet-based instructions may not be effective enough to adequately explain the surgical procedure and potential postoperative complications. The low efficiency of these methods in delivering the required information may be attributed to the educational and the cultural barriers between the patients and the clinicians. The use of complex scientific jargon as well as the mental state of the patients during their appointments acts as additional barriers for obtaining an informed consent. Williams et al., [5] found that patients' satisfaction levels varied according to the method of delivering the necessary information. Further research showed that multimedia resources were better than conventional techniques[6-7] in improving the patients' understanding of the surgery that they were about to undergo. The illustrations and the interactive manipulation of images in graphical resources help the patients to acquire a more satisfactory level of knowledge. Studies on multimedia showed that patients appreciate the use of video and moving images over other methods of delivering medical information.[8] Also, the use of videos for patients' education significantly reduced their anxiety.[9] Beranova and Sykes[10], studied computer-based patient education methods for congestive heart failure and suggested that patients are eager to know more about their health and computers are serving this purpose. Later, Mladenovski and Klieser[11] compared the effectiveness of information leaflets with multimedia methods of delivering education relating to the surgical removal of impacted 3rd molars. In their research 93% of the participants found graphic animations helpful. Supporting these findings, Cleeren et al.,[12] used 3D animations to explain periodontal conditions, described how patients preferred 3D

visualizations to sketches or written instructions. In case of orthognathic surgery, Azem et al.,[13] used 2D graphical illustrations of Le Fort I maxillary surgery on a tablet device. They evaluated the effectiveness of graphical illustrations by comparing the retaining capacity of the delivered knowledge by a group of volunteers using a questionnaire. Participants were divided into 'tablet' group and 'verbal' group based on the mode of instructions received. The tablet group outperformed the verbal group significantly ($p<0.001$) showing that the multimedia tablet devices helped the participants to retain more information than conventional verbal approach.

The application of these multimedia resources has gained further attention with the current rise in usage of smart devices with uninterrupted Internet access. According to Google,[14] one in every twenty searches on Google is regarding health related information. Internet and American Life Project[15] reported that 59-80% of internet users browse topics related to health care. More than 43000 healthcare apps were found on Apple's iTunes store[16,17] and over 35000 apps were found on the Google Play store.[18] Despite these studies clearly suggesting that patients are increasingly considering information on internet and mobile apps for healthcare purposes, a multimedia mobile app providing information on orthognathic surgery and its complications has not been developed yet. To meet this need, *Sur-face* was developed using computer generated interactive 3D visualizations. The aim of the study was to investigate the impact of this mobile app, which provides 3D visualizations in delivering patients education through a questionnaire-based analysis. The null hypothesis states there is no difference between the information retained by volunteers regarding orthognathic surgery when delivered by two methods; 'App' and 'Voice'. This paper presents the steps in design, development, and evaluation of *Sur-face*.

Methods

Design of the App

In the design of *Sur-face*, information was divided into pre-surgical preparation, surgical procedure(s) and post-surgical changes. For pre-surgical preparation, scenes illustrating the doctor-patient appointment (fig.1) and preparation of the patient for surgery were shown. In addition to the 3D models, an image of the consent form was included to reinforce the responsibility of patients in taking an informed decision. The surgery section consisted of interactive 3D animations illustrating orthognathic surgical procedures including Le Fort I maxillary osteotomy, sagittal split mandibular osteotomy and bi-maxillary osteotomies, as well as augmentation genioplasty (fig.2) and hip graft procedures (fig.3). The post-surgical changes section was on the potential side effects of the surgical procedure which included swelling, pain, nose bleeding and restricted mouth opening (fig. 4). This section also provided information on complications including numbness, devitalisation of teeth and post-surgical relapse.

Development of the App

Autodesk Maya[19] software was used to create realistic visualizations of the surgery through 3D animations. To represent the anatomy of the head and neck accurately, a customizable Zygote human body[20] model was chosen. Additional effects including eye blinks and hair were added to enhance the realism of its appearance. The appearance of jaw retrognathism or prognathism was created using lattice deformation of the model. Correction of these

deformities using surgical cuts and movements of the bones was then demonstrated by applying key frame animations as shown in the fig. 5.

To enhance the interactivity of the existing animations and to export them to the mobile platform, Unity 3D[21] game engine was used. In Unity, C# Programming language was used to control the animations intuitively. The user was provided with the facility of moving a slider showing pre and post-operative changes in facial appearance. Navigation buttons and verbal instructions, without scientific jargon, were added with the help of software such as Garage Band[22] and Avid Pro.[23]

The developed application was then exported for use on mobile devices through specific software development kits (SDK) based on the operating systems (OS). The first version of this app was made available for tablets running Android.[17]

Evaluation of the App

Fifty non-patient volunteers from multiple ethnic groups were recruited after being given a brief overview of the purpose and scope of this research. 24 participants were male (48%) and 26 participants were female (52%). The mean age of the participants was 25.03 at the time of their participation in the research. All the participants had previous bachelor degrees and were undertaking higher degrees at the time of the study. There was no difference in their level of education except the courses. The participants willingly took part in the study after explaining the need for proper patient education. Additionally, ill consequences following poor understanding of consent process by the patients before a surgery were highlighted. More details regarding jaw surgery procedure, potential complications and the conventional methods of patient education including printed leaflets were presented. Following this, the participants were randomly divided into “app” and “voice” groups, based on the method used

for delivering the information regarding the orthognathic surgical technique and its associated complications. Members of the ‘app’ group were provided with *Sur-face* on a 10.1-inch Motorola Zoom tablet along with instructions for use, whereas ‘voice’ group participants were provided with only audio information on the same device, along with a printed leaflet containing the same content. The participants completed a questionnaire at the end of the session which consisted of 13 questions.[13] Twelve of these focused on topics related to the process, side effects and post-operative complications of orthognathic surgery, whilst the thirteenth question concerned the signs and symptoms of infection after surgery. None of the participants left the study in the middle. A student t-test was applied to assess the differences between the two groups in the percentage of correct and completed answers.

Results

Participants in the 'app' group attempted to answer more questions than those in the "voice" group ($p=0.0366$) and gave a significantly higher number of correct answers ($p=0.0034$) (fig.6, tables 1, 2)

When asked about the presence of scar after the surgery, all the participants of the app group answered correctly in comparison with only half of the voice group. Questions related to post-operative complications, limited mouth opening and discoloration of teeth, were answered correctly by most of the participants in the "app group". Questions related to the site of the postoperative numbness and its duration were answered correctly by most of the participants in the "app" group. Most of the participants in the "voice" group gave the correct answer regarding the duration of postoperative numbness but could not identify the affected region of the face. The number of symptoms answered by the app group was significantly higher than those of the voice group. Questions concerning post-operative symptoms, including pain, swelling and nose bleeding, received equally correct responses from the participants in the two groups. Question on relapse as a potential complication of surgery was acknowledged correctly by both groups. The length of discomfort after the surgery was also correctly answered by most of the participants of the "app" group. Interestingly, two of the 'voice' group members correctly answered all the 12 questions about the surgery.

Question regarding the possible change in the color of tooth following surgery suggesting its damage was correctly answered by most of the app group members unlike the voice group.

The additional question on the symptoms of infection was attempted and answered correctly by most of the participants in the ‘app’ group while it was left unanswered by the participants in the ‘voice’ group.

4. Discussion

The results clearly showed that participants of the ‘app’ group retained more information than those in the ‘voice’ group. Thus the null hypothesis was rejected, emphasizing the role of 3D visualizations and interactive applications in improving the participants’ understanding of the surgical procedures and potential postoperative complications. However, not all the questions attempted by the “app” participants were correctly answered, suggesting that further guidance from the surgeon during the consenting process is necessary. This also highlights the fact that, while mobile apps are a useful adjunct to the informed consent process, they cannot substitute for the information delivered by the surgeon. Written consent is mandatory for orthognathic surgery[25] and surgeons are authorized to perform a procedure only with the patient’s explicit informed written agreement.[26] Complications, including altered sensation or complete numbness of the lower lip, are commonly reported after lower jaw surgery.[27] Patients who do not fully appreciate the risks of these complications might find it challenging to deal with this. Krause et al.,[28] have reported that the majority of litigation cases in orthognathic surgery are secondary to misunderstandings between patients and the surgeon.

This research highlights the need for redesigning the consent process using 3D visualization to improve the interaction with patients. An earlier study by Azem et al.,[13] also suggested that interactive visualizations are effective in delivering information regarding orthognathic surgery and its associated complications.

Non-patient volunteers participated in the evaluation of *Sur-face* in this study, they had no prior knowledge of orthognathic surgical procedures, it is logical to assume that *Sur-face*

would have had at least the same positive impact on patients if not more. However, this requires further investigation.

The addition of interactive animations describing the nature of dentofacial deformity and post-surgical instructions is desirable. Utilizing the functions of mobile smart phones, such as camera, accelerometer and gyroscope, can further enhance usability and access. A camera on a mobile device can be used to track the skeletal landmarks and predict the outcome of the surgery and thereby help patients to envisage post-surgical changes. Access to the internet is one of the key advantages of smart devices. Search functionality helps users to find answers to their questions regarding surgery, making the app more user friendly. New applications such as Calendar, Evernote and Health kit[29] would help the user to integrate their medical data and doctor's appointments on the same "app". These could also play a key role in reminding the patient of postoperative instructions and prescribed medications.

The rising trend in smart phone and mobile tablet usage in the general population, with almost 59% of them owning a smart phone and 20% using health apps,[30] highlights the need for multimedia to facilitate the delivery of surgical and medical information. Highly accessible health-educating material on mobile apps would be also effective in delivering information to patients. In conjunction with the increasing daily influx of health care apps into the app store, there is an increased risk that medical procedures are falsely representated.[31] It is therefore essential for surgeons to provide validated patient education materials, leveraging on smart device technology. As more surgeons and app developers collaborate, it should only be a matter of time before each of the surgical procedures has its own dedicated app.

Declarations

Funding: This study was a part of Masters course in Medical Visualisation at Glasgow School of Art

Competing Interests: No conflicting interests

Ethical Approval: This work has been approved by the ethical committee of the Glasgow School of Art, Glasgow.

Patient Consent: Not required

References

1. Kaplan SH. Characteristics of physicians with participatory decision-making styles. *Annals of Internal Medicine* 1996;**124**(5):497-504. Doi: 10.7326/0003-4819-124-5-199603010-00007.
2. Huber J., Ihrig A., Yass M., Bruckner T., Peters T., Huber CG., et al. Multimedia support for improving Preoperative patient education: A Randomized controlled trial using the example of radical Prostatectomy. *Annals of Surgical Oncology* 2013;**20**(1):15–23. Doi: 10.1245/s10434-012-2536-7.
3. Waitzkin H. Doctor-patient communication. *JAMA* 1984;**252**(17):2441. Doi: 10.1001/jama.1984.03350170043017.
4. Falagas ME., Korbila IP., Giannopoulou KP., Kondilis BK., Peppas G. Informed consent: How much and what do patients understand? *The American Journal of Surgery* 2009;**198**(3):420–35. Doi: 10.1016/j.amjsurg.2009.02.010.
5. Williams AC., Shah H., Sandy JR., Travess HC. Patients' motivations for treatment and their experiences of orthodontic preparation for orthognathic surgery. *Journal of Orthodontics* 2005;**32**(3):191–202. Doi: 10.1179/146531205225021096.
6. Jones JM., Nyhof-Young J., Friedman A., Catton P. More than just a pamphlet: Development of an innovative computer-based education program for cancer patients.

Patient Education and Counseling 2001;**44**(3):271–81. Doi: 10.1016/s0738-3991(00)00204-4.

7. Mulsow JJW., Feeley TM., Tierney S. Beyond consent—improving understanding in surgical patients. *The American Journal of Surgery* 2012;**203**(1):112–20. Doi: 10.1016/j.amjsurg.2010.12.010.
8. Gagliano ME. A literature review on the efficacy of video in patient education. *Academic Medicine* 1988;**63**(10):785–92. Doi: 10.1097/00001888-198810000-00006.
9. Rossi M., McClellan R., Chou L., Davis K. Informed consent for ankle fracture surgery: Patient comprehension of verbal and videotaped information. *Foot & Ankle International* 2004;**10**(25):756–62.
10. Beranova E., Sykes C. A systematic review of computer-based softwares for educating patients with coronary heart disease. *Patient Education and Counseling* 2007;**66**(1):21–8. Doi: 10.1016/j.pec.2006.09.006.
11. Mladenovski A., Kieser J. The efficacy of multimedia pre-operative information for patients: A pilot study. *The New Zealand Dental Journal* 2008;**2**(104):36–43.
12. Cleeren G., Quirynen M., Ozcelik O., Teughels W. Role of 3D animation in periodontal patient education: A randomized controlled trial. *Journal of Clinical Periodontology* 2013;**41**(1):38–45. Doi: 10.1111/jcpe.12170.
13. Azem A El., Benington PCM., Khambay BS., Ayoub AF. Evaluation of an interactive multi-media device for delivering information on Le Fort I osteotomy. *Journal of Cranio-Maxillofacial Surgery* 2014;**42**(6):885–9. Doi: 10.1016/j.jcms.2014.01.004.
14. Kelion L. Google adds medical information to its search results. *BBC Technology* 2015 Available at: http://www.bbc.co.uk/news/technology-31426617 (2015) (Accessed: 12 February 2015)
15. PEW Research Centre Internet Policy Survey. Internet user demographics. PEW Research Center. Available at http://www.pewinternet.org/data-trend/internet-use/latest-stats/. Accessed 6 January 2016.
16. IMS Health. Patient Apps for improved healthcare: From novelty to mainstream. IMS Health; 2013.
17. Inc A. IOS 8- apple (UK). Apple. Available at http://www.apple.com/uk/ios/. Accessed 24 March 2015.
18. PULIJALA Y. Sur 'FACE' – Android Apps on Google play. Google Play. Available at https://play.google.com/store/apps/details?id=com.Gurukul.Surface&hl=en_GB. Accessed 24 March 2015.
19. Autodesk. 3D animation and Modelling software | maya. Autodesk Maya. Available at http://www.autodesk.co.uk/products/maya/overview. Accessed 24 March 2015.

20. Zygote Media Group. 3D anatomy: 3D models of the human anatomy. 3D Science. Available at http://www.3dscience.com/3D_Models/Human_Anatomy/index.php. Accessed 24 March 2015.
21. Unity 3D. Unity 5. Available at http://unity3d.com/5. Accessed 24 March 2015.
22. Inc A. Apple (United Kingdom) - GarageBand for Mac. Apple. Available at https://www.apple.com/uk/mac/garageband/. Accessed 24 March 2015.
23. Avid. Pro tools — professional audio recording and music creation software. Pro Tools. Available at http://www.avid.com/US/products/pro-tools-software. Accessed 24 March 2015.
24. IBM. SPSS software - United Kingdom. Industries and Solutions. Available at http://www-01.ibm.com/software/uk/analytics/spss/. Accessed 24 March 2015.
25. Pirnay P., Foo R., Hervé C., Meningaud J. Ethical questions raised by the first allotransplantations of the face: A survey of french surgeons. *Journal of Cranio-Maxillo-Facial Surgery : Official Publication of the European Association for Cranio-Maxillo-Facial Surgery* 2012;**8**(40):402–7.
26. Gasparini G., Boniello R., Longobardi G., Pelo S. Orthognathic surgery: An informed consent model. *Journal of Craniofacial Surgery* 2004;**15**(5):858–62. Doi: 10.1097/00001665-200409000-00030.
27. Kim S-G., Park S-S. Incidence of complications and problems related to Orthognathic surgery. *Journal of Oral and Maxillofacial Surgery* 2007;**65**(12):2438–44. Doi: 10.1016/j.joms.2007.05.030.
28. Krause H-R., Bremerich A., Rustemeyer J. Reasons for patients' discontent and litigation. *Journal of Cranio-Maxillofacial Surgery* 2001;**29**(3):181–3. Doi: 10.1054/jcms.2001.0212.
29. Inc A. HealthKit - apple developer. Available at https://developer.apple.com/healthkit/. Accessed 22 April 2015.
30. Lewis TL., Vohra RS. Smartphones make smarter surgeons. *British Journal of Surgery* 2013;**101**(4):296–7. Doi: 10.1002/bjs.9328.
31. Paddock C. Life-saving Melanoma treatment delayed when Smartphone Apps get diagnosis wrong. *MNT* 2013. Available online <http://www.medicalnewstoday.com/articles/255084.php> accessed on 24th March 2015

Tables Legends

Table 1. Group Statistics

Table 2. Independent student t test

Figure Legends

Figure 1. Pre surgical appointment

Figure 2. Chin surgery procedure

Figure 3. Hip graft procedure

Figure 4. Post-operative nose bleeding

Figure 5. 3D visualization representing lower jaw surgery

Figure 6. Graph representing the mean number of correct answers given by the app and voice groups