



Contribution of Virtual Anatomic Models to Medical Education

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Abstract: Together with developing computer technology, a trail is also blazed in medical education. Virtual model formation by three-dimensional imaging and reconstruction is a technology used especially in anatomy education as well as surgery, pathology, biopsy, forensic medicine, sports medicine and plastic reconstruction. These models, as used in anatomy education of human and veterinary medicine, became a more attractive material for students by decreasing the number of cadavers. The models obtained are used in planning of surgery and biopsy, comprehension of pathology, in biopsy education and in measuring all organs and structures with high accuracy as a result of autopsy in forensic medicine. Moreover, several experiments and observations performed on virtual models in sports medicine are used in prevention of disablements, in the determination of deformations in structures and in revealing possible results of postoperative period in plastic reconstruction. Thus, virtual anatomic models benefited in education, diagnosis and treatment period in medical field will be more developed and commonly used in the future.

Key words: Anatomy, Education, Medical, Virtual model.

Sanal Anatomik Modellerin Medikal Eğitime Katkısı

Özet: Gelişen bilgisayar teknolojisi ile birlikte, medikal eğitiminde de bir çığır açılmıştır. Üç boyutlu görüntüleme ve rekonstrüksiyon ile virtual model oluşturma; başta anatomi eğitimi olmak üzere, cerrahi, patoloji, biyopsi, adli tıp, spor hekimliği ve plastik rekonstrüksiyonda kullanılan bir teknolojidir. Beşeri ve veteriner hekimlikte anatomi eğitiminde kullanılan bu modeller kadavra sayısını azaltarak, öğrenci için daha dikkat çekici bir materyal haline gelmiştir. Elde edilen modeller, cerrahi ve biyopsinin planlanmasında, patolojinin kavranmasında, biyopsi eğitiminde, adli tıpta otopsi sonucunda bütün organların ve yapıların yüksek doğruluklu ölçümlerinin yapılmasında kullanılmaktadır. Ayrıca, spor hekimliğinde virtual modeller üzerinde gerçekleştirilen birtakım deney ve gözlemler sakatlanmaların önüne geçilmesinde ve yapılardaki deformasyonların tespitinde, plastik rekonstrüksiyonda ise postoperatif dönemdeki muhtemel sonuçların ortaya çıkartılmasında kullanılmaktadır. Böylece, medikal alanda eğitim, teşhis ve tedavi sürecinde faydalanılan virtual anatomik modeller, gelecekte daha da geliştirilerek, kullanımı yaygın hale getirilecektir.

Anahtar kelimeler: Anatomi, Eğitim, Medikal, Sanal model.

INTRODUCTION

For medical students, learning the structure of human body being complex is very important (Kondo et al., 2007). The students should imagine dimensional and functional relationships of human body in order to learn anatomy (Ritter et al., 2002).

Modern medical imaging is important in providing anatomical and pathological information of the patient before operation. Three-dimensional (3D) models of patients obtained by computerised tomography (CT) and magnetic resonance (MR) images provide a developed surgery planning (Soler et al., 2004). They are also used in dentistry to develop the design of prosthetic implant (Tadepalli et al., 2010).

Virtual reality aims comprehension of a definite synthetic medium by people as real and also provides communication with the real world. It is observation centered and is structured as 3D computer production medium. In medical field, on the other hand, it is based on processing the real data obtained for the aim of education, diagnostic and treatment by the aid of computer and on supporting with other information and methods in medical processes (Özkurt, 2003).

Simulations are usually made in order to research and plan, to evaluate mastership and for the aim of education. In this way, they enable students to gain experiences by learning lessons from mistakes, by repeating and not damaging patients (Midik and Kartal, 2010). Moreover, the main target of dental simulators is to bring all students the information and experience involved in the same patient's scenario and treatment processes within the legislative framework of patients' rights just observing a real patient and to enable them to make equal evaluations (Uzun, 2006).

The 3D conformal radiotherapy has found a place of use by 3D observation of cancer patient anatomy and presenting the relationship of tumour

with normal tissue clearer via the CT and MR, modern imaging methods (Akfirat and Kurtman, 2001).

Computer simulations and 3D models, as also used in the studies related with animals, give little or no damage to animals. In addition to providing opportunity for students to learn more effectively and pleasurably, they also decrease the usage of animals in studies (Balcombe, 2001).

VIRTUAL MODEL USAGE

Virtual Model Usage in Anatomy Education

An opportunity can be found for practice by using medical education based on computers without a necessity for cadavers used in traditional anatomy education (Özkadif and Eken, 2012). Compatibility of cross-sectional data together with impressive development in technology and imaging methods makes it possible for development of 3D anatomic models (Sergovich et al., 2010). Visualisation of organs and synchronisation as well as various functional modules are revealed by 3D models (Choi et al., 2005).

Natural dimensional complexity of human cerebral ventricular system and its deep position within the brain make difficulties in revealing the anatomy of this system (Adams and Wilson, 2011). Direct studying of 3D skull model helps young medical students to learn the anatomic structures in the skull easier and more rapidly than traditional methods (Chien et al., 2010).

Dimensional relationship can be discovered with interactive 3D computer graphs based on computerised 3D models. The aim of virtual anatomical models (VAM) is to develop the comprehension of medical students using plotting and direct manipulation. The object can be grabbed directly by the user via the VAM and a research can be performed. The 3D jigsaw is composed of a set of simple objects in order to give a shape to a special

model just like a jigsaw. The shapes of these objects indicate which pieces come together (Ritter et al., 2002).

Patient simulations are used in education programmes of many schools in America and Canada (Hubal et al., 2000). Virtual patients are usually used to teach clinical theoretical abilities, bioethics, basic patient communication, taking the case history and talents for clinical decision-making (Saleh, 2010). Real patients having constant physical symptoms or educated individuals to simulate patients can be used for this target. By using simulated patients, it can be provided for students to take education about histories, communication and a talent for physical medical examination (Midik and Kartal, 2010).

By using computer technologies, 3D reconstructions can be obtained via various softwares of 2D images derived from the CT and MR due to difficulties of automatic segmentation. Manual segmentation softwares are still widely used. However, manual segmentation is substantially inconvenient (Xiao et al., 2010). For the latter, examples are given for reconstruction processes by using 3D Doctor programme (Figure 1-2).

The 3D reconstruction is not only used for investigation of bony tissue but also for searching soft tissues such as muscle and fatty tissues. Locations of kidneys in the body and their positions with respect to each other are indicated metrically (Figure 3) with a virtual model obtained from the multidetector computerised tomography images (MDCT) of rabbit kidney (Eken et al., 2009).

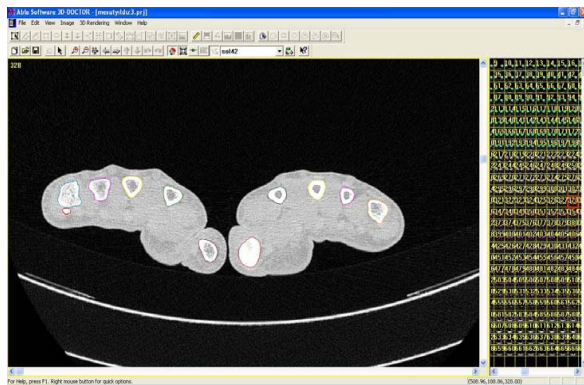


Figure 1. Manual determination of the limits in the working area of 2D image (Kalaycı, 2008).

Şekil 1. 2B görüntü çalışma alanında sınırların manuel olarak belirlenmesi (Kalaycı, 2008).

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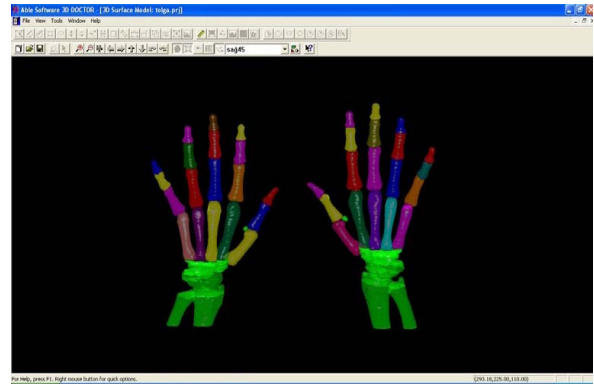


Figure 2. The 3D reconstruction of Phalanx and metacarpal bones (Kalaycı, 2008).

Şekil 2. Falanks ve metacarpal kemiklerin 3B rekonstrüksiyonu (Kalaycı, 2008).

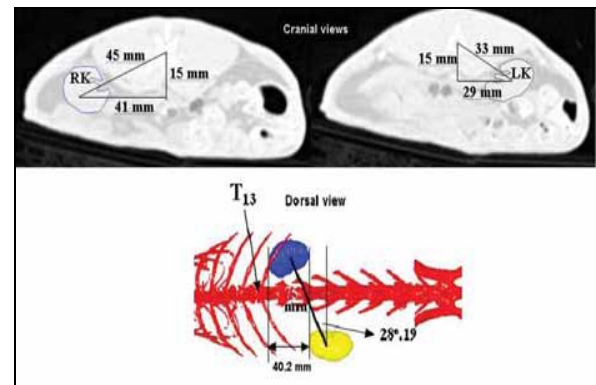


Figure 3. Measurements describing the location of rabbit kidneys with respect to one another. RK: right kidney; LK: left kidney (Eken et al., 2009).

Şekil 3. Tavşan böbreklerinin birbirine göre yerinin ölçümlerle tarif edilmesi. RK: sağ böbrek, LK: sol böbrek (Eken et al., 2009).

By using mimics computer programme, the organs of digestive system (Dayan and Beşoluk, 2011) and paranasal sinuses (Özkadif and Eken, 2013) in

rabbits are indicated with different colours via automatic segmentation (Figure 4-5). Since this programme allowed us to revolve the image in the desired direction, it provides an opportunity to understand the organs of digestive system and paranasal sinuses easier with various viewpoints. Moreover, making the organs and components in different colours eliminates the complications in the regions.

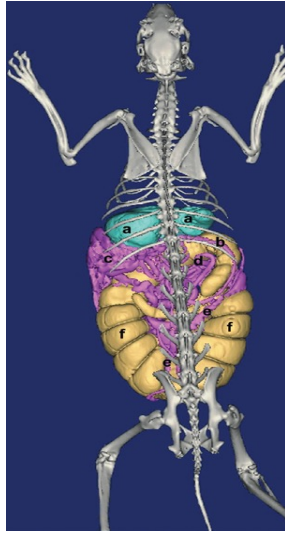


Figure 4. Dorsal view of three-dimensional imaging of gastro-intestinal organs. a: stomach, b: duodenum, c: jejunum, d: ileum, e: colon, f: caecum (Dayan and Beşoluk, 2011).

Şekil 4. Gastro-intestinal organların 3B görüntülerinin dorsal görünümü. a: mide, b: duodenum, c: jejunum, d: ileum, e: colon, f: caecum (Dayan and Beşoluk, 2011).

Virtual Model Usage in Surgery, Pathology and Biopsy

Virtual anatomy images, providing surgeons a detailed model formation directly according to private anatomy of the patient in order to think surgical choices and compare them, were developed for surgical planning. Thus, deformed part can be determined transparently and surgical planning is performed gradually (Rossignac et al., 2007).

By means of virtual observation, the anatomic structures of internal organs in body cavity can be evaluated non-invasively via computer and simulation of a fiber optic endoscopy can be performed. Virtual colonoscopy, bronchoscopy, gastroscopy, angiography,

laparoscopy, thoracoscopy and stethoscopy applications can be carried out in this way (Indrajit et al., 2006). Computer-aided design methods for pediatric surgery and retractable coronoid surgery instruments, named as pylorohooks and evaluated as virtual reality model for laparoscopic pyloromyotomy, were developed as modern bioengineering instruments (Decou et al., 2002).

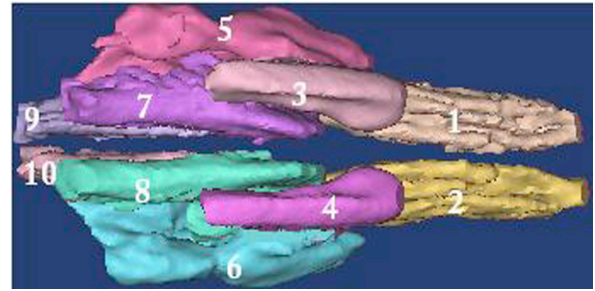


Figure 5. Dorsal view of three-dimensional imaging of paranasal sinuses. 1: Left ventral nasal concha, 2: right ventral nasal concha, 3: left dorsal nasal concha, 4: right dorsal nasal concha, 5: left maxillary sinuses, 6: right maxillary sinus, 7: left middle nasal concha, 8: right middle nasal concha, 9: left endoturbinalia, 10: right endoturbinalia (Özkadif and Eken, 2013).

Şekil 5. Sinus paranasales'in 3 boyutlu görüntüsünün dorsal görünümü. 1: Concha nasalis ventralis sinister, 2: concha nasalis ventralis dexter, 3: concha nasalis dorsalis sinister, 4: concha nasalis dorsalis dexter, 5: sinus maxillaris sinister, 6: sinus maxillaris dexter, 7: concha nasalis media sinister, 8: concha nasalis media dexter, 9: endoturbinalia sinister, 10: endoturbinalia dexter (Özkadif and Eken, 2013).

Biopsy of spinal cord is a non-invasive surgical operation used in determination and examination of myelomas. However, such biopsy operations require more attention since many critical organs are present by the side of spinal cord. Simulation is useful in planning and education of complicated 3D needle biopsy process (Ra et al., 2002).

In ultrasound-controlled biopsy for liver, simulator based on virtual reality provides a feedback related with a realistic vision and contact (Ni et al., 2011; Villard et al., 2011). These simulations plays an important role in obtaining 3D images necessary in making practice in the order that should also be followed in biopsy of prostate (Deguchi et al., 2006).

The electrical activity of heart and uterus tissue was detailed by computer models in the form of

virtual tissue and their reconstructions were performed afterwards. Virtual tissues are detailed biophysically and anatomically and physiological and pathophysiological properties of organ tissues are indicated. Cardiac virtual tissue was well established and regenerated as being an example for normal and pathological cardiac stimulation in artery or ventriculus of human heart. Virtual uterus models formed from adult females set light to performing tissue biopsies and to the methods developed for premature labour (Holden, 2010).

Virtual Model Usage in Forensic Medicine

Modern cross-sectional imaging technologies revealed recently have revolutionised in forensic medicine. The usage of MR imaging and especially the MDCT in autopsy examination becomes wider day by day (Grabher et al., 2009). As well as the CT and MR techniques, 3D photogrammetric techniques are also used. Using photogrammetry and radiology techniques together has some advantages such as being independent observer, non-subjective and non-invasive (Thali et al., 2003).

In forensic anthropology, different tasks require the usage of 3D modeling of forensic objects (Santamaria et al., 2006). Virtual skeletons are the most suitable collections presented for anthropological studies. It is now tried to form an anthropologic database obtained with the CT of many patients in Forensic Medicine Institution of Lausanne University. The data should have a content that can be used in anthropological studies in order to apply anthropological methods in the best way such as age, gender, illness and origin including virtual skeleton or to develop new techniques (Grabherr et al., 2009). It is one of the most common methods used for examination of coxae and sacrum of adults and for prediction of gender from bones. The CT provides an opportunity for clinical investigation of skeletons of individuals *in situ*. Thus, more *in vivo* data can be obtained for gender determination standards from the pelvis present and increasing accuracy of characterisation (Decker et al., 2011).

The main advantage of multidimensional imaging adaptation in forensic medicine is to; i) make quantified and non-invasive investigation, to make measurements of whole body, organs, objects in autopsy, ii) analyse and evaluate functional parameters, iii) make simulations of pathophysiological conditions of the body before death, and consequently iv) demonstrate virtual autopsy results acutely (Takatsu et al., 2007). Moreover, it was considered that virtual reconstruction models are quite useful in terms of forensic medicine for the analysis of trauma within the skull (Kettner et al., 2011).

Virtual Model Usage in Sports Medicine

Biomechanical modeling and computer simulations reveal supplementary observations and experimental design. Models can be used clearly and be reused frequently in multidisciplinary researches (Seth et al., 2011). Moreover, simulations provide an opportunity for interrelating cause and effect relation and understanding them. Maybe the most thrilling property of simulations is that they have a potential for testing hypothesis, predicting functional results and identifying developed behaviours (Reinbolt et al., 2011).

The computer model of muscle and skeleton system gives kinematics of joints and motion line (Arnold and Delp, 2011). Moreover, muscular forces and soil reaction forces can be calculated as well as the relation harmonisation between the motion and posture during the exercise in order to decrease the risk of mutilation by making mobile simulation of human (Reinbolt et al., 2011). In shedding some light on deficiently understandable subjects such as knee extensor mechanism and patellafemoral pain, modeling of muscle and skeleton are utilised (Besier et al., 2011).

A set of variations may also be observed in the bodies of sportsmen playing sports actively according to the field of sports they do. One of them is deformations on the spinal coloumn of weight lifters depending on the load they lift. In the study of Ince

(2010), the 3D data and models were obtained by photogrametric methods from the columna vertebralis cross-sections of elite male weight lifters and sedentary (control) group with the MDCT. The spinal columns of elite weight lifters and sedentary group were compared. According to the results of measurements and statistical calculations, it was determined that the variation was just in the lumbar region and there was a proliferation in this region's vertebra of weight lifters.

Virtual Model Usage in Plastic Reconstruction

It was claimed that the combinations of computerised virtual reconstruction and geometric morphometric model have many advantages over traditional reconstruction (Benazzi et al., 2009). This might be helpful for doctors to minimise the risks and to develop the surgical results. For example, it is benefited from computer technology in the formation of a new breast with anaplasty for a woman who lost her breast as a result of a critical disease such as cancer. According to the 3D modeling from the MR images, the calculations of the shape, area, volume together with muscle and depth of skin for the breast of which the reconstruction will be carried out can be done using the healthy breast as a base (Huang et al., 2007).

By planning the result of esthetics, selection of a more attractive face shape is a very important activity for the future of the face. This necessitates a careful and polite interaction between the ability of surgeon and expectation of the patient. Many suggested computer tools support the esthetics judgement of the patient and the surgeon at this stage. Various shapes that can be formed after anaplasty planning of face and nose operations esthetically with these computer tools are revealed. Thus, the most suitable shape of face for the patient is selected and a surgery in that direction might be carried out (Bottino et al., 2012).

RESULT

The usage of virtual anatomical models in medical field has substantially become wider and

wider. This is a desirable alternative especially at the point of finding enough human cadavers and killing animals for anatomy education. The courses become more pleasurable and they provide an opportunity for taught part to be repeated again and again. Virtual anatomical modeling has become quite useful technique in education of students in surgery together with planning and application of surgery. Making models in forensic medicine after autopsy and allowing for keeping the measured values have become a good data generation source for forensic medicine. They are also very useful in the determination of faults and disabilities that might occur in sports medicine and in taking precautions.

The benefits of computer technology and the extensity of its area of usage are indisputable. This will increase as the day goes on. Computer technology has taken its place in medical field, as this is the case in every other field. Usage of virtual anatomical models is not limited within the fields of education, basic sciences, surgical sciences, forensic medicine and sports medicine as well as for the aim of diagnostic treatment and it will become widespread in other medical fields by developing.

REFERENCES

- Adams CM., Wilson TD., 2011. Virtual cerebral ventricular system: An MR-based three-dimensional computer model. *Anatomical Sciences Education*, 4, 340-347.
- Akfirat C., Kurtman C., 2001. Üç boyutlu konformal radyoterapi planlanması. *Ankara Üniversitesi Dikimevi Sağlık Hizmetleri Meslek Yüksekokulu Yıllığı*, 2, 69-75.
- Arnold EM., Delp S., 2011. Fibre operating lengths of human lower limb muscles during walking. *Philosophical Transactions of the Royal Society B*, 366, 1530-1539.
- Balcombe JD., 2001. The scientific case for alternatarnatives. *Journal of Applied Animal Welfare Science*, 4, 117-126.
- Benazzi S., Stansfield E., Milani C., Gruppioni G., 2009. Geometric morphometric methods for three-

- dimensional virtual reconstruction of a fragmented cranium: the case of Angelo Poliziano. *International Journal of Legal Medicine*, 123, 333-344.
- Besier TF., Draper C., Pal S., Fredericson M., Gold G., Delp S., Beaupré G., 2011. Imaging and musculoskeletal modeling to investigate the mechanical etiology of patellofemoral pain. In "Anterior Knee Pain and Patellar Instability", Ed., V Sanchis-Alfonso, 2nd ed., 269-286. Valencia, Spain.
- Bottino A., Simone MD., Laurentini A., Sforza C., 2012. A new 3-d tool for planning plastic surgery. *IEEE Transactions on Biomedical Engineering*, 59, 3439-3449.
- Chien CH., Chen CH., Jeng TS., 2010. An interactive augmented reality system for learning anatomy structure. *Proc. International MultiConference of Engineers and Computer Scientists*, Hong Kong 17-19 March, 1, 1-6.
- Choi YJ., Choi SM., Rhee SM., Kim MH., 2005. Collaborative and Immersive Medical Education in a Virtual Workbench Environment. *Lecture Notes in Computer Science*, 3683, 1210-1217.
- Dayan MO., Beşoluk K., 2011. Three-dimensional reconstruction of stomach and intestines in New Zealand rabbits from computerized tomography images. *Israel Journal of Veterinary Medicine*, 66, 108-113.
- Decker SJ., Davy-Jow SL., Ford JM., Hilbelink DR., 2011. Virtual determination of sex: Metric and nonmetric traits of the adult pelvis from 3D computed tomography models. *Journal of Forensic Sciences*, 56, 1107-1114.
- Decou JM., Timberlake T., Dooley RL., Gauderer MWL., 2002. Virtual reality modeling and computer-aided design in pediatric surgery: applications in laparoscopic pyloromyotomy. *Pediatric Surgery International*, 18, 72-74.
- Deguchi D., Mori K., Mekada Y., Hasegawa J., Toriwaki J., Noguchi M., 2006. Development of a virtual needle biopsy simulation system for the virtual prostate. *Systems and Computer in Japan*, 37, 93-104.
- Eken E., Çorumluoğlu Ö., Paksoy Y., Beşoluk K., Kalaycı İ., 2009. A study on evaluation of three-dimensional virtual rabbit kidney models by multidetector computed tomography images. *International Journal of Experimental and Clinical Anatomy*, 3, 40-44.
- Grabher S., Cooper C., Ulrich-Bochsler S., Uldin T., Ross S., Oesterhelweg L., Bolliger S., Christe A., Schnyder P., Mangin P., Thali MJ., 2009. Estimation of sex and age of "virtual skeletons"-a feasibility study. *European Radiology*, 19, 419-429.
- Holden AV., 2010. Development and application of human virtual excitable tissues and organs: From premature birth to sudden cardiac death. *Alternatives to Laboratory Animals*, 38, 87-99.
- Huang P., Gu L., Yan J., Xu H., Dong J., Chen W., Liu J., Zhang J., Song J., Yu X., Zhang L., Zhou H., 2007. Virtual surgery planning of breast reconstruction using deformation modeling and curve shape approximation. *Proc. 6th International Special Topic Conference on Information Technology Applications in Biomedicine*, Tokyo 8-11 Nov. 127-130.
- Hubal RC., Kizakevich PN., Guinn CI., Merino KD., West SL., 2000. The virtual standardized patient simulated patient-practitioner dialogue for patient interview training. *Studies in Health Technology and Informatics*, 70: 133-138.
- İnce A., 2010. Elit erkek haltercilerde columna vertebralis'in multidedektör bilgisayarlı tomografi görüntülerinin üç boyutlu rekonstrüksiyonu. Selçuk Üniversitesi, Sağlık Bilimleri Enstitüsü, Türkiye.
- Indrajit IK., Souza JD., Pant R., Hande PC., 2006. Virtual scopy with multidetector CT. *Medical Journal Armed Forces India*, 62, 60-63.
- Kalaycı İ., 2008. 3D reconstruction of phalangeal and metacarpal bones of male judo players and sedentary men by MDCT images. *Journal of Sports Science and Medicine*, 7, 544-548.
- Kettner M., Schmidt P., Potente S., Ramsthaler F., Schrodt M., 2011. Reverse engineering-rapid prototyping of skull in forensic trauma analysis.

- Journal of Forensic Sciences, 56, 1015-1017.
- Kondo D., Kijima R., Takahashi Y., 2007. Dynamic anatomical model for medical education using free form projection display. Proc. 13th Conference on Virtual Systems and Multimedia, Brisbane Australia 23-26 Sept. 142-149.
- Mırdık Ö., Kartal M., 2010. Simülasyona dayalı tıp eğitimi. Marmara Medical Journal, 23, 389-399.
- Ni D., Chan W.Y., Oin J., Chui Y.P., Qu Y., Ho S.S.M., Heng P.A., 2011. A virtual reality simulator for ultrasound-guided biopsy training. IEEE Computer Graphics and Applications March/April, 36-48.
- Özkadif S., Eken E., 2013. Three-dimensional reconstruction of multidetector computed tomography images of paranasal sinuses of New Zealand rabbits. Turkish Journal of Veterinary & Animal Sciences, 37, 675-681.
- Özkadif S., Eken E., 2012. Modernization process in veterinary anatomy education. Energy Education Science and Technology Part B, 4, 957-962.
- Özkurt A., 2003. Tıpta bir geliştirilmiş gerçeklik uygulaması ve başarıyı etkileyen faktörler. Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi, 5, 55-68.
- Ra JB., Kwon SM., Kim JK., Yi J., Kim KH., Park HW., Kyung KU., Kwon DS., Kang HS., Kwon ST., Jiang L., Zeng J., Cleary K., Mun SK., 2002. Spine needle biopsy simulator using visual and force feedback. Computer Aided Surgery, 7, 353-363.
- Reinbolt JA., Seth A., Delp SL., 2011. Simulation of human movement: applications using OpenSim. Proc. International Union of Theoretical and Applied Mechanics, Waterloo Canada 5-8 June, 2, 186-198.
- Ritter F., Berendt B., Fisher B., Richter R., Prein B., 2002. Virtual 3d jigsaw puzzles: Studying the effect of exploring spatial relations with implicit guidance. Mensch and Computer, 363-372.
- Rossignac J., Pekkan K., Whited B., Kanter K., Sharma S., Yoganathan A., 2007. Surgem: Interactive patient-specific anatomy-editor for hemodynamic analysis and surgery planning. Technical Report, GIT-GVU-O6-15, January 9.
- Saleh N., 2010. The value of virtual patients in medical education. Annals of Behavioral Science and Medical Education, 16, 29-31.
- Santamaria J., Cordon O., Damas S., Aleman I., Botella M., 2006. 3D forensic model reconstruction by scatter search-based pair-wise image registration. IEEE International Conference on Fuzzy Systems Sheraton Vancouver Wall Centre Hotel, Vancouver, BC, Canada July 16-21. 6006-6012.
- Sergovich A., Johnson M., Wilson TD., 2010. Explorable three-dimensional digital model of the female pelvis, pelvic contents, and perineum for anatomical education. Anatomical Sciences Education, 3, 127-133.
- Seth A., Sherman M., Reinbolt JA., Delp SL., 2011. OpenSim: a musculoskeletal modeling and simulation framework for in silico investigations and exchange. Proc. International Union of Theoretical and Applied Mechanics, Waterloo Canada 5-8 June, 2, 212-232.
- Soler L., Nicolau S., Schmid J., Koehl C., Marescaux J., Pennec X., Ayache N., 2004. Virtual reality and augmented reality in digestive surgery. Mixed and Augmented Reality. ISMAR Third IEEE and ACM International Symposium 2-5 Nov., 278-279.
- Tadepalli SC., Shivanna KH., Magnotta VA., Kallemeyn NA., Grosland NM., 2010. Toward the development of virtual surgical tools to aid orthopaedic FE analyses. EURASIP Journal on Advances in Signal Processing, 1, 1902931-1902937.
- Takatsu A., Suzuki N., Hattori A., Shigeta A., Abe S., 2007. High-dimensional medical imaging and virtual reality techniques. Rechtsmedizin, 17, 13-18.
- Thali MJ., Braun M., Wirth J., Vock P., Dirnhofer R., 2003. 3D Surface and body documentation in forensic medicine: 3-D/CAD photogrammetry merged with 3d radiological scanning. Journal of Forensic Science, 48, 1356-1365.
- Uzun Ö., 2006. Dış hekimliğinde bilgisayar destekli

eğitim (BDE): Sanal gerçek hasta simulatörleri. Cumhuriyet Üniversitesi Diş Hekimliği Fakültesi Dergisi, 9, 138-143.

Villard PF., Boshier P., Bello F., Gould D., 2011. Virtual reality simulation of liver biopsy with a respiratory component. Liver Biopsy, 315-334.

Xiao M., Soh J., Meruvia-Pastor O., Schmid E., Hallgrimsson B., Sensen CW., 2010. Building generic anatomical models using virtual model cutting and iterative registration. BMC Medical Imaging, 10, 1-15.