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Augmented Reality in Plastic Surgery Education

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ABSTRACT

Background: Mixed reality devices have made a big impact on the medical profession by creating a virtual world. Visual perception methods and 3D Touch can be used in teaching institutions to import knowledge and help perform plastic surgery easily.

Methods: This study has been done to evaluate the systematic scoping review and merits of Aumented Reality Technology in Plastic Surgery for 3 years in the Department of Burn and Plastic Surgery in All India Institute of Medical Sciences, Rishikesh using PubMed Ovid and Google Scholar. This is a review to compare the advent and utility of mixed reality platforms in plastic surgery in the world by searching the PubMed database.

Results: The records of 55 articles could be retrieved in plastic surgery from Pubmed and Ovid database. 26 were review articles, 10 were on haptic devices, 13 on 3D printing, 15 case reports, and one randomized controlled trial. Haptic devices are a part of training skills such as bone drilling, burring, and cutting. Education is enhanced by virtual reality platforms incorporating learning soft tissue skills with haptic devices.

Conclusion: Technological advancement in imaging modalities provides a convenient way of teaching anatomy, mapping of perforators to design flaps, and perform virtual osteotomies. Virtual consoles can be designed to teach endoscopic plastic surgery with 3D scanning.

INTRODUCTION

Virtual reality is a term named by Jaron Lanier in 1986. New headsets like oculus rift and games like PubG have introduced the concept of mixed reality platforms on a big scale. Google Glass is a platform developed by Google on the basis of virtual reality. Augmented reality can bring a 3D effect of surroundings. Haptic technology is a type of 3D Touch i.e. use of forces, vibrations, or motions to the user by haptic devices. The literature lacks articles which highlight the usefulness of this modality in patient care in the field of plastic surgery.

This platform can be used to teach and design flaps on a virtual dissector. This simulates a cadaveric dissection lab. A virtual reality based web cleft lip model can be used for teaching undergraduates and postgraduates. The use of robotics relies on the same 3D principles which can be implemented as a teaching tool to spread awareness of this modality in residents. These devices with haptics can create tactile refinement in designing various CAD/CAM constructs in 3D for maxillary and mandibular reconstruction. Craniofacial models can be printed and designed to help students learn operative procedures, markings of osteotomy sites and virtual surgical demonstration. There is a scope of Virtual Reality based teleconsultations in rural or hilly areas of Uttarakhand for surgery.

This technology has been added in our department for the first time in a teaching tertiary institution to use mixed reality platforms as a clinical teaching tool. This can act as an aid in health communication imparting preoperative and postoperative visualization of results in 3D. This article will delineate the role of virtual reality platforms in planning, Recording and assessment of postoperative results in teaching institutions of India. The purpose of this scoping review was to investigate articles of augmented reality published in refereed journals for training, education and printing purpose in plastic surgery.

MATERIAL AND METHODS

This study has been done to evaluate the systematic scoping review and merits of Augmented Reality Platforms in Plastic Surgery for 3 years in the Department of Burn and Plastic Surgery in All India Institute of Medical Sciences, Rishikesh, India using PubMed Ovid and Google Scholar. Based on PRISMA ScR guidelines and Arskey Malley framework we have reviewed a total of 55 publications on Pubmed and 5 commercial systems.

The number of publications that dealt with plastic surgery were 14. There are no articles from this part of the globe on this emerging new technology. Inclusion criteria were based on the PCC approach, study design, and date. Exclusion criteria were unrelated, duplicated, or incomplete texts. The articles were reviewed on basis of role in plastic surgery education, haptics and anatomy skills based on the number of citations. A two-part study selection process was used: (1) A title and abstract review and (2) Full-text review. Table (1) depicts PRISMA diagram of scoping review.

The system installed in the aesthetic skill lab of our department is an Artec scanner with a haptic simulator provided by Maveric systems Ltd, Gurugram, India.

Our system has a pen-like haptic device with 6 camera based Artec scanner. Digital Imaging and Communications in Medicine (DICOM) has been used to create these reconstructions. Recently we have incorporated Finite element analysis in our system to design prosthetics and orthotics in hand injuries. 3D printing of mandibular models is done in our hospital.

RESULTS

55 articles were reviewed in plastic surgery from the PubMed database and Ovid database. 26 were review articles, 10 were on haptic devices, 11 on 3D printing, 15 case reports, and one randomized controlled trial. Design of mandibular skeleton defects with free fibula constructs have been designed with tissue deformation tools in software forming basis of haptic surgery simulator based on VR in our hospital. Crisalix software simulation enables a real time scenario for gynaecomastia patients who can benefit with this tool. The security and privacy concerns of the software can be a hindrance in its implementation. Zoom app has created a lot of controversy in the media for stealing of data and disclosure of private information.

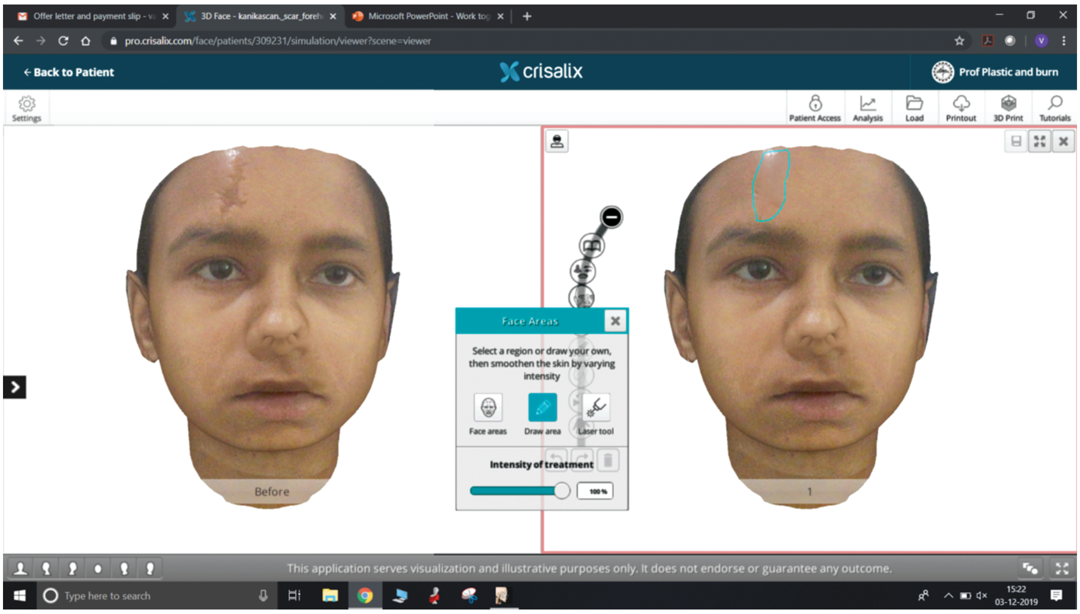
3D printing helps improve fixation points or plan osteotomy sites with precision and easy definition of anatomical landmarks or bone gaps. This virtual reality platform can be a useful adjunct in plastic surgery education, navigation tool and virtual dissector for flaps. Two thesis projects have been given in our hospital to outline the usefulness of this new modality.

The figures (Figs. 1,2) in this article depict the use of Crisalix software in patients of scar revision who can explain the prognosis of their result in OPD by preoperative and postoperative work ups. The patients can appreciate their results with voluminous correction in depressed scars preoperatively. This software is also being used in gynaecomastia patients to preoperatively assess the volume of correction and explain postoperative results (Fig. 3). Surgical training in plastic surgery involved 6 publications. Haptic devices were used on skull models to demonstrate bone drilling, guides and osteotomy cuts. Virtual consoles can be designed to teach endoscopic plastic surgery with 3D scanning.

Due to diversity of criteria in terms of number and nature, they were divided into three categories. Based on the scoping review the categories included intervention-related criteria, teaching tool, and cost effectiveness criteria. The largest number of criteria belonged to the first category Table (1).

Table (1): Determinant criteria of augmented reality in plastic surgery.

Category	Criteria	Frequency (references)
Intervention related criteria	Navigation	3 (6,9,10)
	Training/haptics	11 (25,9)
	3D printing	15 (3,21,22,17,18,19,20)
Effectiveness as teaching tool/content validity	Good or average	10
Cost effectiveness	Feasibility	2
	Quality and realism of setting	



Figs. (1,2): Depict the use of Crisalix software in patients of scar revision who can explain the prognosis of their result in OPD by preoperative and postoperative work ups.

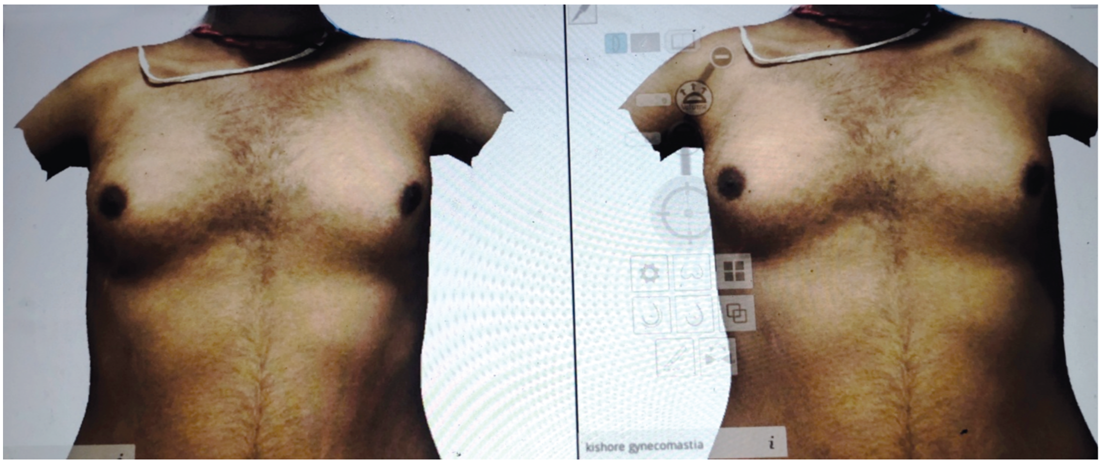


Fig. (3): This software is also being used in gynaecomastia patients to preoperatively assess the volume of correction and explain postoperative results.

DISCUSSION

The author has made 3 groups according to the clinical application i.e. surgical planning imaging (patient-specific simulations), haptic tools for surgical navigation, and surgical training. Subcategories for each clinical application were developed in terms of the surgical domain and device used.

Surgical imaging and training applications:

Preoperative assessment, planning and evaluation of postoperative failure and complications of cosmetic surgery techniques can be documented with imaging. 3D surface modeling helps in understanding exact concerns of the patient and to precisely plan the procedure.

Proximie, is a software providing a cost-effective and reproducible remote telesurgery solution. AR platforms are useful in educational activities tool, generating new skill acquisition and less dependence on tertiary centers **[1]**.

Mitsumo D and others demonstrated the role of virtual reality in fibrous dysplasia in clearing the defect with ease and precision. Simulated bone image constructs can be useful in patients with complex facial fractures. Bony osteomas on forehead can be easily visualized on 3D scans **[2]**. Cleft lip repair can be demonstrated by simulation based tools in the laboratory.

Hololens is a tool to display 3D image during surgery using MRI **[3]**.

Microsoft has devised Hololens to give plastic surgeons a hands free access to mixed reality data to improve decision making and workflow [4].

Fluorescent based imaging will help in the execution of lymphaticovenous anastomosis on an online display using virtual reality [5].

Robot, based augmented reality platform was created to improve the effectiveness of mandibular surgery and make surgery easy and faster [6].

Mixed reality platforms can delineate anatomy in a superfluous way and simplify things to accurately depict the network [7].

Kim and others proposed a system based on their observations in 35 studies on VR/AR based planning, navigation and training platforms for advancing the knowledge of plastic surgery [8].

In craniofacial surgery, full automation will involve computer vision-driven diagnosis of an abnormal head shape, an artificial intelligence based determination of an ideal head shape for a given patient, and software-driven surgical maneuvers that will reshape the skull to match the artificial intelligence-designed platform.

Three of the studies used head-mounted displays, one study used a display monitor, and one study demonstrated AR using spatial navigation technology in reconstructive microsurgery training.

Augmented reality based technologies are finding a new role in evaluation and screening for orthognathic surgery, face contouring, bone tumor resection, and neurosurgery.

Navigation systems based on this virtual reality platforms have been introduced for orthognathic surgery, providing overlaid images of real surgical simulation based training.

Badiali et al., used head mounted display for designing and repositioning of patient bones after maxillofacial osteotomies [9].

The authors have used maxillofacial imaging, diagnosis, planning of virtual treatment, and intraoperative surgical transfer using an IGV display for manipulation of maxillary segments in maxillofacial reconstruction [10].

Mischkowski et al., used portable displays with a camera to use system easily during surgery and display overlaid images on it [11].

The authors have evaluated the accuracy of perforator mapping with infrared thermography and augmented reality using a portable projector. Three volunteers anterolateral thighs were assessed for the presence and location of cutaneous perforators using infrared thermography and mapping the perforators for easy flap raising [12].

Student training:

This system can track patient's limb movements and show the anatomical muscle groups, nerves, and vasculature in real time motion [13].

We have this system in our Simulation lab which is a virtual dissector to aid first year students to mimic dissection on a cadaver. This can also be a valuable teaching tool in anatomy dissections for plastic surgery residents and orthopaedic residents.

This software has been used to construct osteocutaneous free flaps using free fibula flaps based on augmented reality localization of perforators and design skin paddles. The guide can be used to predict length of vessel. Virtual planning for mandibular defects can be used as teaching tool in medical colleges.

Residents exposed to VR simulators for temporal bone surgery, when compared with residents who were not trained using the VR system, were more proficient and required less intraoperative instructions [14].

In a patient with a complex facial fracture, the simulated bone image was useful as a reference for reduction [15].

This Augmented Reality application has been useful in designing a LeFort I osteotomy, to demonstrate positive clinical outcomes of this technology. X scope is a virtual reality tool to control maxillary movement in orthognathic surgery, fronto orbital advancement and cranial remodelling.

Augmented Reality based navigation system was used in hypertelorism to project preoperative reconstructed CT images onto the surgical plane. For all patients, the surgeon achieved a better appearance using the Augmented Reality device [16].

3D imaging tools play an important role in patient education, surgical planning and assessment of surgery outcomes.

Haptic based devices and 3D printing:

3D printing has been described as a tool which can be printed off and sterilized, allowing the surgeons to manipulate and plan with an exact replica of the surgical specimen [17]. We are using this method in our institution in designing mandibular specimens for free fibula harvest by 3D printing as a part of thesis.

This simulates a Virtual Reality rehab setting by having subjects perform repeated goal-directed wrist/hand reaching tasks. Subjects held a cup-shaped color-marker in the paretic hand and, reach out for a virtual fruit target in this study [18].

A haptic based training simulator was proposed for bone-sawing in this study. Bone density, feed velocity and spindle speed of the saw were considered to compute the haptic forces.

3D printing can be a valuable aid in creating patient specific auricular frameworks. This concept has been exploited to construct fibular bone constructs using prefixed models.

Sayadi et al., proposed a deep insight in exploring and promoting this platform as an educational tool in research institutions [19].

Omran and others devised a new augmented reality score in reconstructive microsurgery and high-lighted role of this novel innovation in microsurgery [20].

A haptic device based craniomaxillofacial surgery planning system was applied for the reconstruction of skeletal anatomy in complex oncology defects of the mandible [21]. Various static guiding systems have been developed based on the CAD/ CAM technology which includes Easy Guide, GPIS, Impla 3D, etc.

Kamali et al., introduced the application of three-dimensional printing to trauma, and the benefits are decreased cost and operative time. It decreases the need for revision surgery, and expedites healing [21].

Fabrication of mandibular models with computer-aided design and computer-aided manufacture (CAD/CAM) techniques, have better symmetry and contour in the treatment of head and neck cancers [22].

Shenaq and Matros outlined number and cutting plane of the osteotomies in free fibula, design segment lengths and achieved better bone to bone contact. Osteotomies were made on native fibula based on the septocutaneous perforator that supplied the skin island [23].

Lo et al., developed a 3D anterolateral (ALT) model for demonstrating' virtual dissection' of the anatomy of the ALT flap [24].

Maxillofacial surgery procedures can be taught by these virtual training platforms to learn and imbibe osteotomy cuts in Le fort 1 osteotomy [25].

3D models help in planning complex reconstructive surgeries with design templates for planning final shape of postoperative or traumatic defect. This also helps in moving bones virtually for different approaches, options or outcomes. Aesthetic outcomes can be visualized by positioning and fixation of segments of template. Prefitting implants can be designed to fit the specific anatomy of the defect. 3D printed models can help plan rhinoplasty surgery more efficiently.

These virtual reality platforms have to be facilitated to promote medical education and conduct more research on scientific and validated AR related study designs.

Crisalix software helps the patient to view themselves in real time with virtual body parts and plan their surgeries. This tool has been employed in planning gynaecomastia surgeries in our hospital. Patients can be primed about their postoperative results.

Facial Plastic surgeons can use this Crisalix platform to document results, use this technology in sharing information on internet and advance cosmetic surgery practice by their cloud platform.

The surgeon can view a virtual image superimposed on a real patient to allow the device to work as a virtual mirror. This can help patients to evaluate results of augmentation mammaplasty both preoperatively and postoperatively.

Augmented Reality platform is used to visualize the 3D postoperative look after correcting sagging, loose, drooping, or wrinkled skin on the face with fillers or fat grafting. With this AR technology women choose the size and shape of their implants easily. AR can help the doctors to take an idea how the patient would look like after liposuction. AR system enhanced in planning and confirming reconstruction of the underlying bones of the selected body part.

Patient with a congenital bone development disorder and another patient with a complex facial fracture can take advantage of this technology.

Planning, navigation and training are three novel aspects of augmented reality which can be incorporated in teaching institutions in India to make residents and doctors aware about this new technology.

This study confirmed that AR technology can be a useful tool to understand these positional relationships. This can be a useful tool in oral and maxillofacial complex reconstructions of mandible and maxilla. Use of the haptic device can enable analyze, test and document the planning of bony segmental defects.

Our findings are not only useful for body surface evaluation but also for effective utilization of augmented reality technology in the field of plastic surgery. Plastic surgery is a branch dependent on visual data, where images help convey patient outcomes and procedures. It is a field that is well positioned to harness the features of mixed and augmented reality in the clinical setting.

Training institutions can use this technology to easily generate video teaching libraries for plastic surgery education. Residents can record themselves to identify areas that need improvement through self-reflection, and track progress over time. It can be a useful tool in planning maxilla and mandibular bony defects.

It can be used as a navigation tool to place the osteotomy segment in correct anatomical alignment for craniofacial reconstructions.

Conclusion:

Image resolution of the simulator can be used as a teaching aid for trainees of plastic surgery who can refine their surgical techniques. Virtual surgical planning is useful in precision guided oncology reconstructions, maxillary defects and devising osteotomy guides. It has become an effective tool for training and skill assessment of surgery residents, nursing residents, or students.

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