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CUTTING EDGE IN ORAL AND MAXILLOFACIAL SURGERY-A REVIEW

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ABSTRACT

The vision for the future with advanced technology and science for easy and better treatments outcome motivating the clinicians to look-forward to practical the cutting edge tactics in the Oral and Maxillofacial Surgery. The results will be providing the patients with first-class medical services with reduction of the treatment morbidity. Greater progress has been made in the field of the Oral and Maxillofacial Surgery. In the last decades, the researchers were concentered on the improvement of the preoperative planning as it plays a vital role in the success rate of the surgical procedures. Now, as a result of the advanced computer technology, the researches extend beyond the scope of planning and moving toward the surgical procedures itself. Evolution over the last decades focused toward improvement of the preoperative planning, minimally invasive approaches, and minimizing the operation time. All aiming to decrease surgical complications and less post-operative pain and rapid return to normal life-style activities. As a result; remarkable recent advances in surgical and computer technology are evolving every day. Innovations in Oral and Maxillofacial Surgery have allowed the professions to progress at a very fast rate and looked-for for more every day. The increased accuracy and speed of treatment, along with reduced discomfort, and decreased the complications will be the actual advantages to our patients. The aim of the current review is to give an insight about the cutting edge in the field of oral and maxillofacial surgery to provide a more detailed physical manifestation of your mental picture and a new dimension of insight into the clinical situations you encounter every day.

KEYWORDS: 3D virtual imaging; 3D printing; Stereolithographic models; Customized implants; Navigation systems; Robotic surgery.

INTRODUCTION

3D virtual imaging

Preoperative treatment planning plays a vital role in the success rate of the surgical procedures. Preoperative planning requires the collection of huge data for a precise diagnosis and devises a treatment plan which is then relevant in the operating room. A detailed history and clinical examination are vital in establishing diagnosis; nevertheless, the value of radiographic imaging cannot be neglected. The keystone in the preoperative treatment planning is the radiographic evaluation. Advanced imaging not only plays an important role in oral and maxillofacial surgery diagnosis and treatment planning but also its affect the treatment outcome. Form my opinion, radiographic evaluations considering as the third eye for the surgeons and the most important tools in the diagnostic field.

With advanced Revolutions technology, the Computer has become a vital part of our daily life. Several diagnostic images have been available for diagnosis of different disorders; however, computer technologies advancements provided an unbelievable benefit to the diagnostic filed. Advancement in computer technologies related to oral and maxillofacial surgery was specific to the treatment planning phase of patient care. With time the advancement in computer technologies is moving beyond the treatment plan and come in contact with the surgical interventions. Advances in Three-dimensional (3-D) imaging technology have given rise to sequences of projects proposed to deliver new computerized tools for use in preoperative planning.

Conventional treatment planning require a set of obtain data that can be obtained from different studies (radiographs, models and articulators, face bow, etc.) and to interpret the data in correlation with the disorder with the purpose of developing a treatment plan. On the other hand; 3D planning, provide much more information that can be easily provided in a sequence of images which can be manipulated by the computer.

Computed tomography (CT) and, more recently, cone-beam computed tomography (CBCT) provide volumetric images of the anatomic structure of a patient's face. These data can be converted into 3D images of a patient's craniofacial skeleton and the soft tissue covering it by using a sequence of computerized mathematical algorithms.[1] It is also possible to interact with these 3D images simulating the surgery that will take place and provides information about the surgical outcome predictions in soft and hard tissues. At the beginning of the 1970's, 3D studies started to be used in the field of medicine.[2] The cross-sectional imaging capability of computed tomography (CT)[3] and 3-D reconstruction have led to a wonderful leap in diagnostic radiology. The cross-sectional slices of the CT avoid the superimposition of adjacent structures and permit highresolution details of bone, while 3-D imaging provides highly willingly identifiable images of complex anatomic structures. Moreover; it can exactly record and represent the actual size and shape of bone for precise preoperative treatment planning and simulation of various surgical procedures. 3D virtual can predict the soft-tissue changes after surgical procedures.

The first application of virtual imaging was in 1989 when the first virtual laparoscopic gallbladder operation was performed. COL Richard Satava, Professor of Surgery, a world-wide known expert of minimally invasive surgery stated that "In addition to minimally invasive surgery, virtual reality in the future will offer, among other benefits, remote surgery, greatly improved medical and surgical training, visualization of massive medical databases, and innovative rehabilitation techniques".

Virtual Reality (VR) is the term used to describe a novel human computer interface that enables users to interact with computers in a radically different way. The term "Virtual Reality" describes the experience of interacting with data from within the computer-generated data set. The computer-generated data set may be completely synthetic or remotely sensed, such as X-ray, MRI, PET, etc. images. VR consists of two main components, a computer-generated, multi-dimensional environment and interface tools. Due to its potential benefits, Virtual reality is quickly finding wide acceptance in the medical field.

The goal of a multispectral data visualization system is to provide enhanced diagnosis capabilities for use by the medical practitioner. Several pioneer research groups have already demonstrated improved clinical performance using VR imaging, planning and control techniques.

The system of the VR consists of the following: 1. multispectral data acquisition; 2. data management; 3. data reduction; 4. data analysis; and 5. stereoscopic visualization. The data acquisition and visualization systems will provide enhanced capabilities for representing multispectral data abstractions within a natural three-dimensional stereoscopic display system. The awareness of the need for adequate source imaging and the image processing steps required to create the final model is a vital issue when considering a virtual model. Imaging processing steps are performed by user interaction while some other steps are “hidden” procedures within the software. The accuracy of the final model is depending mainly on the image processing steps.

Being able to use a 3D-virtual environment for planning and simulating surgery, Computer Aided Surgical Simulation (CASS) provides surgeons with the best possible scenario for preoperative treatment planning. The possibility of generating a three-dimensional model from CT scans was first mentioned in 1980, and reconstruction of the first craniofacial foam model took place in 1987.[4] Due to the ability of VR to predict the soft tissue and bony changes, currently; most of the VR applications are related to the orthoganthic and reconstructive surgeries.

3D printing and customized implants

The term “3D Printing” is being used to refer to all Solid free form fabrication (SFF) technologies (e.g. fused deposition modeling, selective laser sintering, etc.). Stereolithographic bio-modeling is a modern technology that transforms three-dimensional CT data into solid plastic replicas of anatomic structures (bio-models).[5-10] Three-dimensional (3D) printing is a manufacturing method in which objects are made by fusing or depositing materials such as plastic, metal, ceramics, powders, liquids, or even living cells in layers to produce a 3D object.[11,12] This process is also referred to as additive manufacturing (AM), rapid prototyping (RP), or solid freeform technology (SFF).[13]

Medical applications for 3D printing are expanding rapidly day after day and start to be included in different branches of medicine.[11] Medical uses for 3D printing, including: tissue and organ fabrication; creation of customized prosthetics, implants, and anatomical models; and pharmaceutical research regarding drug dosage forms, delivery, and discovery.[14] The application of 3D printing in medicine can provide many benefits, including: the customization and personalization of medical products, drugs, and equipment; costeffectiveness; increased productivity; the democratization of design and manufacturing; and enhanced collaboration.[13,15-17]

The highest benefit that 3D printers offer in medical applications is the freedom to produce custom-made medical products and equipment. For example, the use of 3D printing to customize prosthetics and implants can provide great value for both patients and physicians and can associated with more precise results and less complications. In addition, Custom-made implants, fixtures, and surgical tools can have a positive impact in terms of the time required for surgery, patient recovery time, and the success of the surgery or implant.[18] 3D printing has been applied in medicine since the early 2000s, when the technology was first used to make dental implants and custom prosthetics.[13,19]

Since then, the medical applications for 3D printing have evolved considerably. Recently published reviews describe the use of 3D printing to produce bones, ears, exoskeletons, windpipes, a jaw bone, eyeglasses, cell cultures, stem cells, blood vessels, vascular networks, tissues, and organs, as well as novel dosage forms and drug delivery devices.[11,16,20-22] The current medical uses of 3D printing can be organized into several broad categories: tissue and organ fabrication; creating prosthetics, implants, and anatomical models; and pharmaceutical research concerning drug discovery, delivery, and dosage forms.[15]

Most SFF methods build 3D biomedical devices in a layer by- layer process. The general SFF process includes.

1) Creating a 3D computer model (can be generated from medical imaging data such as CT scans, MRI or X-rays)
2) Slicing the 3D computer model into a build file of 2D images with software,
3) Fabricating the build by a computer-controlled layer-by-layer process, and
4) Finishing with any post processing such as surface modification for nano-architecture.[20]

The mean error of accuracy of stereolithography in planning craniofacial bone replacement was found to be less than 2 mm, representing a percentage error of 5% with the greatest error occurred in the mid-face, wherein the thinness and complexity of the bone are prone to misreads in the data acquisition phase during the initial scan.[4] Although a highly accurate model can be constructed using this technology, the main limitation is the high cost to the patient and practitioner, making it a secondary choice for most surgeons. Some of the limitations associated with Stereolithographic bio-modeling include precision of details in the reconstructed models, the artifacts of CT scanning, the representation of bone structures without contact with surrounding bone structures, postproduction resin shrinkage of the models, increased exposure to radiation, and the cost of Stereo lithographic models.[4]

The ability to design and fabricate complex, 3D Stereolithographic model motivate the clinicians to think beyond the treatment plan. applications, their flexibility in creating complex three-dimensional shapes make SFF technologies attractive candidates for biomedical engineering. Since its initial use as pre-surgical visualization models and tooling molds, 3D Printing has slowly evolved to create one-ofa- kind devices, implants, scaffolds for tissue engineering, and drug delivery systems. Applications for 3D biomedical devices are restoration of 3D anatomic defects, the reconstruction of complex organs with intricate 3D microarchitecture (e.g. liver, lymphoid organs), and scaffolds for stem cell differentiation.[20] The integration of SFF technologies with patient-specific medical imaging data enables the aseptic manufacturing of tissue engineering grafts that match precisely to a patient’s contours can be produced by. These technologies enable the fabrication of multifunctional scaffolds that meet the structural, mechanical, and nutritional requirements based on optimized models.[4]

The individual variances and complexities of the human body make the use of 3D-printed models ideal for surgical preparation. The ability to quickly produce custom implants and prostheses solves a clear and persistent problem in orthopedics, where standard implants are often not sufficient for some patients, particularly in complex cases. Previously, surgeons had to perform bone graft surgeries or use scalpels and drills to modify implants by shaving pieces of metal and plastic to a desired shape, size, and fit. This is also true in neurosurgery: Skulls have irregular shapes, so it is hard to standardize a cranial implant.[3] In victims of head injury, where bone is removed to give the brain room to swell, the cranial plate that is later fitted must be perfect.[9] Although some plates are milled, more and more are created using 3D printers, which makes it much easier to customize the fit and design.[16-21]

Bio-printing tissues and organs

Tissue or organ failure due to aging, diseases, accidents, and birth defects is a critical medical problem. Current treatment for organ failure relies mostly on organ transplants from living or deceased donors.[10] However, there is a chronic shortage of human organs available for Transplant.[11,22] This problem could likely be eliminated by using cells taken from the organ transplant patient's own body to build a replacement organ. This would minimize the risk of tissue rejection, as well as the need to take lifelong immunosuppressant.[11,22]

Although tissue and organ bio-printing is still in its infancy, many studies have provided proof of concept. Researchers have used 3D printers to create a knee meniscus, heart valve, spinal disk, other types of cartilage and bone, and an artificial ear.[13-21]

Navigation systems: from diagnosis to intervention

The introduction of CAD/CAM software provides the surgeon an opportunity to perform virtual manipulations of the CT datasets preoperatively. This includes repositioning of the patient into true orthogonal planes, segmentation, and mirroring of the facial skeleton bas well as virtual osteotomies and bony reductions. CAD/CAM bsoftware programs have some utility in isolation (ie, presurgical planning, teaching, illustrations, and so on) but have limited clinical application until some type of interactive tool is applied for use in the operating room. Initially, this interactive tool was a stereo lithographic model.[20,23]

An exact replica of the repaired facial skeleton could be fabricated, sterilized, taken into the operating room, and used as a template for the actual repair. Although stereolithographic models are efficacious, they are only a guide. They do not confirm the "real-time" bony reduction. Intraoperative navigation provides this "real-time" update. Imaging procedures are increasingly being used for navigation and for guiding intervention, controlling therapy, monitoring the course of illnesses, etc. The result of this is that imaging procedures are being used not only by diagnosticians usually radiologists but also increasingly by surgeons during interventional procedures different terms are currently used to describe surgery guided by real-time imaging: computer assisted surgery, image-guided surgery, navigational surgery, and surgical navigation (SN).

Tracking of instruments during an operation is being used more and more frequently to increase precision, reduce the risk of injury, plan optimal access routes preoperatively, find and follow them intraoperatively, and finally, to increase the quality of interventional procedures.

Two kinds of navigation techniques are practiced in maxillofacial surgery: template-guided navigation (TGN) and real-time image guided surgical navigation (SN). TGN uses computer-aided design/manufacture (CAD/CAM) or rapid prototyping technology to produce surgical templates. SN has a wide variety of indications in reconstructive and maxillofacial surgery. SN consists of 3 components: (1) an infrared camera, (2) advanced images of the patient on computer using the navigation software, and (3) an interactive display monitor.

The infrared camera acts as an optical passive connection (tracking system) between the patient, surgical instruments, and computer. The link between instruments and computer varies between companies: optically active, electromagnetically, or via ultrasound. The software calculates the current positions of the patients and instruments, chooses the correlating images of the patient together with the preoperative planning, and displays all on the screen. The display can have touchscreen function for input and control.[24]

The area of interest has to be scanned and uploaded into a computerized planning system. It is possible to use several scanning methods, with the data sets combined via data fusion techniques. The final objective is the creation of a 3D data set that reproduces the exact geometric situation of the normal and pathologic tissues and structures of the patient. Among the available scanning methods, CT is often the first choice. MRI data sets are known for having volumetric deformations that may lead to inaccuracies. The next step after image creation is image analysis. When using special planning software, a data set can be rendered into a virtual 3D model of the patient; this involves the manipulation of the patient 3D model to extract relevant information from the data. Based on differing contrast levels, the varying tissues within the model can be changed to show more hard structures or soft tissues. By doing so, the surgeon can better assess the case and improve the diagnostics. Before surgery occurs, the intervention can be planned and simulated virtually. The best way to document the SN process in the operating room (OR) would be through video streaming. Unfortunately, in most current SN systems only screenshots are available.[25,26]

The accuracy of SN is exceedingly important for the operating surgeon. The highest accuracy can be achieved with image slices of 1 mm or less, and is reported with approximate sizes of 1.5 mm. The intraoperative precision of SN systems depends on the accuracy of the following factors.[27]

- CT data set
- SN system
- Pointer localization

- Patient registration system
- Patient registration procedure

Advantages of SN; Decrease invasiveness of surgery, Decrease morbidity, Faster recovery, shorter hospital stay, Better disease or cancer control, High flexibility and adaptability, Modifications during surgery, Templates not always necessary, Unplanned is possible if appropriate imaging available, Versatile and universal applicable and Excellent teaching tool Current advantages of SN in tumor surgery and reconstruction are as follows. Find the areas of interest for biopsies, staging, and especially restaging in the deep layers of tongue and floor of mouth, Real time with high accuracy to control resection margins, Documentation of resection margins for further diagnosis and therapy (pathology, radiotherapy), Measurements, planning, and template construction for bone and soft-tissue reconstruction, Assistance in search for suitable vessels, especially for microsurgical secondary reconstructions after primary tumor resection, neck dissection, and radiotherapy, Assistance in CAD/CAM reconstruction of tumor-associated defects.

SN has led to the development of a navigable Temporo Mandibular Joint (TMJ) arthroscope with integrated working channel produced and offered by Karl Storz Company, Tuttlingen, Germany. This arthroscope could help in avoiding complications during TMJ puncture, or give additional information during surgical treatment of high condyle fractures of the mandible. A correlation of MRI and the arthroscopic position in the joint could be of scientific interest.[28] Disadvantages of SN; Cost of the equipment, Need for education and training, Sometimes more time consuming, Soft-tissue reconstruction is limited.[26]

Robotic surgery

Robotic surgery, computer-assisted surgery, and roboticallyassisted surgery are terms for technological developments that use robotic systems to aid in surgical procedures. Robotically-assisted surgery was developed to overcome the limitations of pre-existing minimally-invasive surgical procedures and to enhance the capabilities of surgeons performing open surgery. The rationale behind the use of robotic surgery is to move the concept of precision and accuracy from manufacturing processes towards medical applications. In 1985 a robot, The first robotic-assisted surgery was performed by Kwoh et al. in 1985 who modified a standard industrial robot (The PUMA 560) to hold a fixture next to a patient’s head so drills and biopsy needles could be inserted at a desired location for neurosurgery.[29] The PUMA 560 was used to place a needle for a brain biopsy using CT guidance. In 1988, the PROBOT, developed at Imperial College London, was used to perform prostatic surgery.

In 1991, Davies et al. used a similar industrial robotic arm coupled with a stereotactic frame to perform a transurethral resection of the prostate.[30] Named the ‘Probot,’ this marked the first time that an active robot was used to automatically remove soft tissue from a patient. Near the same time, Taylor et al. developed the ROBODOC® (Integrated Surgical Systems, Sacramento, CA) as an industrial arm that would accurately core out the femur for hip replacements.[31] This marked the first commercially available surgical robotic system. Further development of robotic systems was carried out by Intuitive Surgical with the introduction of the Da Vinci Surgical System and Computer Motion with the AESOP and the ZEUS robotic surgical system.

- In 1997 a reconnection of the fallopian tubes operation was performed successfully in Cleveland using ZEUS.
- In May 1998, Dr. Friedrich-Wilhelm Mohr using the *Da Vinci surgical robot* performed the first robotically assisted heart bypass at the Leipzig Heart Centre in Germany.
- In October 1999 the world’s first surgical robotics *beating heart* coronary artery bypass graft (CABG) was performed in Canada using the ZEUS surgical robot.
- In 2001, Prof. Marescaux used the *Zeus* robot to perform a cholecystectomy on a pig in Strasbourg, France while in New York.
- The first unmanned robotic surgery took place in May 2006 in Italy.

Advantages: Surgical robotic platforms like the da Vinci® offer many advantages as they overcome several of the obstacles inherent in laparoscopic surgery by providing improved visualization, increased dexterity, restored proper hand-eye coordination, and an ergonomic position. With the binocular vision provided by the optical system surgeons can regain the depth perception they forfeited with conventional laparoscopy. Additionally, the system offers 6 to 12 times magnification (depending on the distance from the tissue), thus providing views that allow meticulous dissection to be performed.

Since the camera is controlled by the surgeon, he or she can maintain an always stable, optimal view of the surgical field without concern for camera-driver fatigue. There are three different kinds of robotic surgery systems: supervisory-controlled systems**,** telesurgical systems and shared control systems. The main difference between each system is how involved a human surgeon must be when performing a surgical procedure.

Of the three kinds of robotic surgery, supervisory-controlled systems are the most automated. But that doesn't mean these robots can perform surgery without any human guidance. In fact, surgeons must do extensive prep work with surgery patients before the robot can operate. That's because supervisory-controlled systems follow a specific set of instructions when performing a surgery. The human surgeon must input data into the robot, which then initiates a series of controlled motions and completes the surgery. There's no room for error these robots can't make adjustments in real time if something goes wrong. Surgeons must watch over the robot's actions and be ready to intervene if something doesn't go as planned. The reason surgeons might want to use such a system is that they can be very precise, which in turn can mean reduced trauma for the patient and a shorter recovery period.

One common use for these robots is in hip and knee replacement procedures. The robot's job is to drill existing bone so that an implant fits snugly into the new joint. Because no two people have the exact same body structure, it's impossible to have a standard program for the robot to follow. That means surgeons must map the patient's body thoroughly so that the robot moves in the right way. They do this in a three-step process called planning, registration and navigation. In the planning stage, surgeons take images of the patient's body to determine the right surgical approach. Common imaging methods include computer tomography (CT) scans, magnetic resonance imaging (MRI) scans, ultrasonography, fluoroscopy and X-ray scans.

For some procedures, surgeons may have to place pins into the bones of the patient to act as markers or navigation points for the computer. Once the surgeon has imaged the patient, he or she must determine the surgical pathway the robot will take. The surgeon must tell the robot what the proper surgical pathway is. The robot can't make these decisions on its own. Once the surgeon programs the robot, it can follow instructions exactly.

The next step is registration, In this phase, the surgeon finds the points on the patient's body that correspond to the images created during the planning phase. The surgeon must match the points exactly in order for the robot to complete the surgery without error. The final phase is navigation. This involves the actual surgery. The surgeon must first position the robot and the patient so that every movement the robot makes corresponds with the information in its programmed path. Once everyone is ready, the surgeon activates the robot, which carries out its instructions. In the case of robotically-assisted minimally-invasive surgery, instead of directly moving the instruments, the surgeon uses one of two methods to control the instruments; either a direct telemanipulator or through computer control. A telemanipulator is a remote manipulator that allows the surgeon to perform the normal movements associated with the surgery whilst the robotic arms carry out those movements using end-effectors and manipulators to perform the actual surgery on the patient. In computer-controlled systems the surgeon uses a computer to control the robotic arms and its end-effectors, though these systems can also still use telemanipulators for their input. One advantage of using the computerized method is that the surgeon does not have to be present, but can be anywhere in the world, leading to the possibility for remote surgery.

During the 1990s NASA, along with the Stanford Research Institute, hoped to establish a programme to enable surgeons to do complex operations on wounded soldiers from a remote location. Intuitive Surgical produced the da Vinci® Surgical System (Sunnyvale, California, USA), which consists of a command console at which the surgeon sits and operates from a remote site, It controls a robotic surgical cart that houses an endoscope and three robotic arms with interchangeable instruments . The robotic arms work in a similar way to laparoscopic instruments used in abdominal surgery but are more intuitive, and the EndoWrist® (Intuitive Surgical, Inc.) instruments allow seven degrees of motion, which is ideal for minimally invasive complex surgery in confined areas. For this reason the system has been established in numerous surgical specialties and recently has been developed for the resection of tumors in the oropharynx without the need for mandibulotomy by transoral robotic surgery (TORS).[32-36]

CONCLUSION

Computer-aided “virtual surgery” and intraoperative navigation are viable techniques in maxillofacial surgery. Modern navigational systems guide us through the human body and can help to manage the impossible. Close cooperation with the radiologist is necessary to obtain appropriate medical imaging for use with SN. Everything is navigable, but only with proper imaging. Although in its infancy, robotic-assisted surgery is rapidly evolving. This technology appears to offer the greatest advantages in procedures requiring complex reconstruction or dissection as it allows surgeons skilled in open surgery to provide their patients with the known benefits of laparoscopy (decreased pain and more rapid convalescence). At present, these advantages continue to be countered by cost and the lack of long term results from prospective randomized trials evaluating its efficacy and safety. If and when these obstacles are overcome, the use of robotic technology in surgery may indeed become standard in every operating room.

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