Stereolithography

Stereolithography is a constructive process for the manufacture layer-by-layer of plastic models using an ultraviolet laser to catalyze the polymerization of a liquid plastic solution [1) 2)].

Computer-aided design (CAD) and computer-aided manufacturing (CAM) by stereolithography are already being widely used in industry for the design and manufacture of new parts and have already shown accuracy in reproducing the desired model. The only shortcoming of this technique is that it can only make one model at a time, a “prototype.” It cannot be used for mass production. It is precisely this property, namely making a prototype, that makes it so attractive in reconstructive surgery and implantation of prostheses, where each “part” has to be adapted to the unique anatomy of the patient. It was not until the early nineties that reports of the application of stereolithography to reconstructive surgery appeared in the literature [3)].

Indications

Surgical simulation

3D imaging does not allow image manipulation and surgical simulation on screen before surgery. The potential for generating 3D structural models from CT scans was conceived as early as 1980 [4)].

Many techniques have been proposed for surgical training as a learning process for young surgeons or for the simulation of complex procedures. Stereolithograpfy, , has been presented as an option for these purposes.

It is easier for the surgeon to understand the complexity of a case and plan the approach before any surgical procedure [5) 6)].

Skull base surgery

Optimal craniotomy or craniectomy for maximal visualization of operative fields can be determined in individually tailored skull models using actual surgical tools. Anatomical configurations and relationships in cranial base bony structures, such as the jugular tubercle, occipitalcondyle, and jugular foramen, vary among individuals. It is important to estimate the extent of drilling of these bony structures before actual surgery. Anatomical variations must be accurately modeled for operative procedures to be realistically simulated. In addition, the presence of extradural tumors such as chordomas and chondromas, which are often associated with bone destruction, makes intraoperative orientation under a microscope much more difficult. Simulations provide the surgeon with accurate mental images of the anatomy that will be en countered [7)].

Three-dimensional models used in neurosurgical simulation to teach skull base anatomy through a transsphenoidal approach showed objective and subjective improvement in testing scores in neurosurgery residents. This study confirms that 3-D models are a useful educational tool [8)]

Neurovascular surgery

Prototyping of cerebral vasculature models through stereolithographic methods have the ability to accurately depict the 3D structures of complicated aneurysms with high accuracy.

With improving and more widespread printing options, these models have the potential to become an important part of research and training modalities [9) 10)].

Complex spine surgery

Cranioplasty

The approach combining computer-aided design, stereolithography and surgical navigation could help managing the complex lesions in the skull base and craniofacial area requiring rigid reconstruction [11)]

Custom made implant [12) 13) 14)].

Disadvantages

The disadvantages of using skull models include the time and cost of making the models. Further more, hand-made models of the tumors, major vessels and nerves placed inside the skull models may not provide exact reproductions.

Current 3D MR imaging of intracranial structures with 3D computed imaging of the skull may be superior to hand-made models inside the skull model if used only for observation. For surgical simulation, however, skull models are considered superior to currently available computer-generated screen images; once skull models are made, they provide a more realistic tool that is easier to handle than computer graphics. Use of these models may be a transitional stage until the capabilities of computers are significantly expanded. Advances in computer hardware and software could lead to new surgical simulation techniques that are even more similar to the actual surgical procedure [15)].

1)
Korves B, Klimek L, Klein HM, Mcesges R: Image and model-based surgical planning in otolaryngology. J Otolaryngol 24: 265-270, 1995
2)
Stoker NG, Mankovich NJ, Valentino D: Stereolitho graphic models for surgical planning: Preliminary report. J Oral Maxillofac Surg 50: 466-471, 1992
3)
Foroutan M, Fallahi B, Mottavalli S, Dujovny M. Stereolithography: application to neurosurgery. Crit Rev Neurosurg. 1998 Jul 20;8(4):203-8. PubMed PMID: 9683679.
4)
Alberti C: Three-dimentional CT and structure models. Br J Radio] 53: 261-262, 1980
5)
Paiva WS, Amorim R, Bezerra DA, Masini M. Aplication of the stereolithography technique in complex spine surgery. Arq Neuropsiquiatr. 2007 Jun;65(2B):443-5. PubMed PMID: 17665012.
6)
van Nunen DP, Janssen LE, Stubenitsky BM, Han KS, Muradin MS. Stereolithographic skull models in the surgical planning of fronto-supraorbital bar advancement for non-syndromic trigonocephaly. J Craniomaxillofac Surg. 2014 Jan 14. pii: S1010-5182(14)00018-3. doi: 10.1016/j.jcms.2014.01.017.

[Epub ahead of print] PubMed PMID: 24530077.
7) 15)
,
Abe M, Tabuchi K, Goto M, Uchino A. Model-based surgical planning and simulation of cranial base surgery. Neurol Med Chir (Tokyo). 1998 Nov;38(11):746-50; discussion 750-1. PubMed PMID: 9919909.
8)
Three-Dimensional Printed Model Used to Teach Skull Base Anatomy Through a Transsphenoidal Approach for Neurosurgery Residents Kushal J.Shah - Jeremy C.Peterson - D. DavidBeahm - Paul J.Camarata - Roukoz B.Chamoun - Operative Neurosurgery - 2016
9)
Khan IS, Kelly PD, Singer RJ. Prototyping of cerebral vasculature physical models. Surg Neurol Int. 2014 Jan 27;5:11. doi: 10.4103/2152-7806.125858. eCollection 2014. PubMed PMID: 24678427.
10)
Wurm G, Lehner M, Tomancok B, Kleiser R, Nussbaumer K. Cerebrovascular biomodeling for aneurysm surgery: simulation-based training by means of rapid prototyping technologies. Surg Innov. 2011 Sep;18(3):294-306. doi: 10.1177/1553350610395031. Epub 2011 Feb 8. PubMed PMID: 21307017.
11)
Wu CT, Lee ST, Chen JF, Lin KL, Yen SH. Computer-aided design for three-dimensional titanium mesh used for repairing skull base bone defect in pediatric neurofibromatosis type 1. A novel approach combining biomodeling and neuronavigation. Pediatr Neurosurg. 2008;44(2):133-9. doi: 10.1159/000113116. Epub 2008 Jan 24. PubMed PMID: 18230928.
12)
Solaro P, Pierangeli E, Pizzoni C, Boffi P, Scalese G. From computerized tomography data processing to rapid manufacturing of custom-made prostheses for cranioplasty. Case report. J Neurosurg Sci. 2008 Dec;52(4):113-6; discussion 116. PubMed PMID: 18981986.
13)
Della Puppa A, Mottaran R, Scienza R. Image-guided cranial osteoma resection and bioceramic porous hydroxyapatite custom-made reconstruction in a one-step surgical procedure. Technical notes and illustrative case. Acta Neurochir (Wien). 2010 Jan;152(1):155-9. doi: 10.1007/s00701-009-0374-6. Epub 2009 May 9. PubMed PMID: 19430722.
14)
Brie J, Chartier T, Chaput C, Delage C, Pradeau B, Caire F, Boncoeur MP, Moreau JJ. A new custom made bioceramic implant for the repair of large and complex craniofacial bone defects. J Craniomaxillofac Surg. 2013 Jul;41(5):403-7. doi: 10.1016/j.jcms.2012.11.005. Epub 2012 Dec 6. PubMed PMID: 23218977.