The reproduction accuracy for stereolithographic model of the thyroid gland derived from the visible human dataset

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ABSTRACT

الأهداف: من أجل التحقق من دقة إعادة إنتاج تقنية النمط البدائي بواسطة مقارنة نماذج الحاسبات الآلية ذات تصميم الأبعاد الثلاثية (CAD) الوهمية مع التصوير الجرافيكي الصلب لتكرار الغدة الدرقية.

الطريقة: تم استعمال طقم بيانات الإنسان المرئية كبيانات تصويرية مدخله. تم تطبيق حزمة البرامج الحاسوبية لهذه الصور لإعادة بناء الغدة الدرقية كنماذج ملف متغير البيانات ثلاثي الأبعاد (DXF). تم توليد هذه النماذج في برامج السينما (4D) وبرامج (3D–Doctor) لتشكيل اللغة للواقع الوهمي (VRML) واللغة المثلثة المعيارية (STL). تم تصنيع تكرار التصوير الجرافيكي الصلب في آلة النمط البدائي السريع بواسطة استعمال شكل (STL). أجريت هذه الدراسة في الفترة ما بين 30–1 يونيو 2008م بقسم التشريح – جامعة هيسيتيب – أنقرة – تركيا. تبين وجود اتفاق ممتاز في مقارنة الأبعاد القصوى لنموذج (CAD) للغدة الدرقية ونموذج التصوير الجرافيكي الصلب المرسل. سمح الفحص المرئي والحسي لنموذج الغدة الدرقية من تصحيح رسم تشريح الغدة الدرقية. تم الحصول على دقة التصوير الجرافيكي الصلب بواسطة مقارنة تصميم الأبعاد الثلاثية (CAD).

النتائج: أظهر التحليل البعدي أن متوسط الفرق بين القياسات على النماذج الوهمية والصلبة بلغ 0.09 ملمتر (p=0.06) وتراوح ذلك من 0.07 الى 0.92 ملمتر. تم حساب حجم وسطح الدرقية وبلغ 25393.9 ملمتر مكعب و 8242.8 ملمتر مربع بواسطة استعمال برامج (3D–Doctor) والتي كانت متفقة مع تلك التي تم الحصول عليها من صيغة برون.

خاتمة: يعتبر التشكيل الحيوي للتصوير الجرافيكي الصلب كحالة فنية وطريقة معتمدة لرؤية التراكيب التشريحية والشذوذيات (الاختلافات).

Objectives: To investigate reproduction accuracy of the rapid prototyping technique by comparing 3-dimensional computer-aided design (CAD) (virtual) model with stereolithographic (solid) replica of the thyroid gland.

Methods: The Visible Human Dataset was used as the input imaging data. The Surfdriver software package was applied on these images to reconstruct the thyroid gland as 3-dimensional Data Exchange File (DXF) models. These models were post-processed in Cinema 4D and 3D-Doctor software for Virtual Reality Modeling Language (VRML) and Standard Triangulation Language (STL) formats. Stereolithographic replica was manufactured in the rapid prototyping machine using STL format. This study was conducted between June 1-30, 2008 at the Department of Anatomy, Hacettepe University, Ankara, Turkey. An excellent agreement was found in comparing the maximal dimensions of the CAD model of the thyroid gland and the corresponding stereolithographic model. Visual and tactile examination of the thyroid gland model allowed correct depiction of the thyroid gland anatomy. The accuracy of the stereolithographic model was attained by comparing wih the CAD model.

Results: Dimensional analysis showed that an average difference between the measurements on the virtual and the solid model was 0.09 mm (p=0.06), ranging from 0.07-0.92 mm. Thyroid volume and surface area were calculated to be 25393.9 mm^3 and 8242.8 mm^2 using 3D-Doctor software, which were agreement with those obtained from Brunn's formula.

Conclusion: Stereolithographic biomodeling is a state-of-the-art and reliable method of visualizing anatomoclinical structures and abnormalities.

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Computed tomography (CT) and magnetic resonance imaging (MRI) are useful tools in the definition and evaluation of human anatomy. These contemporary medical imaging technologies provide detailed images of the internal structure of the human body.[1] The images produced from these modalities give physicians accurate and precise information regarding the structures or anatomical sites. These images are limited because they convey only 2-dimensional (2-D) information on a 3-dimensional (3-D) structure that allows the structure to be visualized in different planes and sections. Furthermore, these 2-D images can only be represented on a screen or as a hard copy.[2] Therefore, a solid replica of the anatomy providing tactile views that can be scrutinized from any perspective, a real reality model, was presumed to be helpful when trying to overcome the limits that conventional imaging entails.[3] Stereolithography, reported in 1986,[4] a computer aided design and manufacturing (CAD/CAM) technique of prototype fabrication,[5] utilizes digital image data to produce a physical model. Thus, it offers a unique way of displaying and remodeling both the external and internal anatomical structures of patients individually.[6] It can be used for a quick creation of anatomically correct 3-D epoxy and acrylic resin models from various types of medical data. Multiple imaging modalities such as CT, MRI, and anatomical cryosections can be exploited. That is, stereolithography is used to overcome limitations in previous computer aided manufacturing/milling techniques.[2] This technique is based on the experience gathered in the technical fields, widely applied from the aerospace to automotive industries.[7] Mankovich et al[8] released the first report on the stereolithographic biomodeling for replication of human anatomical structures. Currently, its application covers preoperative planning of orthopedic,[9] maxillofacial surgeries,[10] cardiology,[11] spine surgery[12] and neurosurgery,[13] the fabrication of custom prosthetic devices,[14] and the assessment of the degree of the bony and soft tissue injuries caused by trauma.[2] Despite its increasing use in various medical fields, the application of stereolithography in endocrinology so far has never been encountered. The aim of this study was to investigate reproduction accuracy of the rapid prototyping technique by comparing 3-D virtual model with stereolithographic replica of the thyroid gland.

Methods. This study was conducted between June 1-30, 2008 at the Department of Anatomy, Hacettepe University, Ankara, Turkey. The Local Research Ethics Committee confirmed that ethical approval was not needed for this study.

Data source. The Visible Human Dataset initiated by the National Library of Medicine was employed. This dataset exists in different modalities: CT, MRI, and anatomical cryosections.[15] In this study, anatomical cryosections were used because they were high-resolution cross-sectional colored images and provide better anatomical information than the other modalities (**Figure 1a**). In our study, 69 cryosectional images were used for preparing the CAD models. These cross-sections were between number 1247 and 1315, where the thyroid and its surrounding structures appeared and disappeared.

Development of the CAD model of the thyroid gland. The spatial extents of thyroid gland and surrounding structures were identified to provide their surface models from serial cryosections using the Surfdriver software. Surface models represent the geometric structure that is helpful for fabricating prostheses, inspecting occluded joints, pre-operative simulation, and post-operative analysis.[16] Moreover, these models are necessary for animation and real-time rendering. The model preparation can be divided into registration, segmentation, and surface reconstruction stages. Sections were registered to each other to get an initial ground truth after substantiating their compatibility using both manual and automatic tools as well as visual inspection.[17] Segmentation covers identification and delineation of the organ in the cross-sectional images (**Figure 1a**). To reconstruct an organ surface: a set of points on the surface ("nodes") and information on how these nodes are linked to their neighbors ("facet descriptors") are used to define the organ. Once the organ is interpreted and labeled on the different cross-sections as contours, 3-D reconstruction is achieved by joining the contours of all the pertinent slices using the Surfdriver software to obtain a 3-D surface model (**Figure 1b**).[18] In this study, after generating 3-D surface model of the thyroid gland, the model was converted to the Data Exchange File (DXF) format to process it further for 3D-Doctor and Cinema 4D software.

Development of photorealistic and topological models of the thyroid gland. The CAD model in the DXF file format was transferred into Cinema 4D to be used by the Advanced Render Module. The result can be spectacularly realistic, but incredibly time consuming (**Figures 2a & 2b**).[19]

Topology in our context is defined as a 3-D connectivity graph of anatomical elements for given body parts. Topological information thus provides inter-relationships among elements (**Figure 3a**).[20]

The CAD model in the DXF file format could also be saved in VRML format for displaying on the Internet (**Figure 3b**). The application of the VRML as a portable file format for describing 3-D views of anatomical

structures has enabled researchers, educators, and students to share anatomical models on the web.[21]

Development of Stereolithographic model of the thyroid gland. The first step in rapid prototyping (RP) is to develop a CAD model in DXF file format using the Surfdriver software (**Figure 4a**). The volume of this model is then meshed or broken into small elements. The file containing all information on the mesh elements is known as the Standard Triangulation Language (STL) file.[22] By using a 3D-Doctor software, the CAD model in DXF file format could be converted into STL file format. This file format is readable by most prototyping machines. The STL file is exported to the software that comes with the rapid prototyping machine.[22] Once the STL file has been generated from the original CAD data, the next step is to slice the object horizontally to create a slice file (SLI). Then, they are merged into a final build file. The sliced model is exported to the stereolithography machine. The RP process is additive. That is to builds the parts up in layers of material from the bottom. Each layer is automatically bonded to the layer below and the process is repeated until the part is built (**Figure 4b**).[23]

The measurements on the CAD model were performed using the measuring tool of the 3D-Doctor software, and measurements on stereolithographic model were obtained using digital calipers.

Results. In this study, the CAD model of the thyroid gland and its surrounding structures were reconstructed (**Figures 1b**). Then, the thyroid gland and its surrounding structures were presented in photorealistic and topological models to visualize (**Figures 2a, 2b & 3a**) and converted to VRML format to share on the web (**Figure 3b**). The thyroid gland was also fully automatically fabricated in a solid model form (**Figure 4b**). It took an hour to prepare the CAD model and approximately 10 hours to fabricate the stereolithographic replica. Preparing the CAD model was faster than fabricating the stereolithographic replica. Because thyroid gland had higher contrast than its surrounding structures, differences in contrast facilitated segmentation that made details clearer to view on both the CAD model and its replica. When comparing the CAD model with stereolithographic replica, surface structures on the CAD model were the same as those of the stereolithographic replica. Stereolithographic replica had a very smooth surface. Visual and tactile examination of the thyroid gland model allowed correct depiction of the thyroid gland anatomy.

The measurements made on the right lobe, left lobe, and isthmus of the thyroid gland from the CAD and stereolithographic models were similar (**Table 1**). Average difference in dimension of the virtual and the

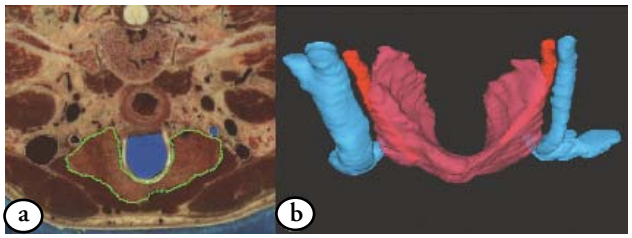

Figure 1 - Photographic cross-section of the **a)** thyroid gland and its surrounding tissues from the Visible Human Male and surface modeling first involves identifying the region of a desired tissue in the volume and **b)** then constructing a description of this region as a surface.

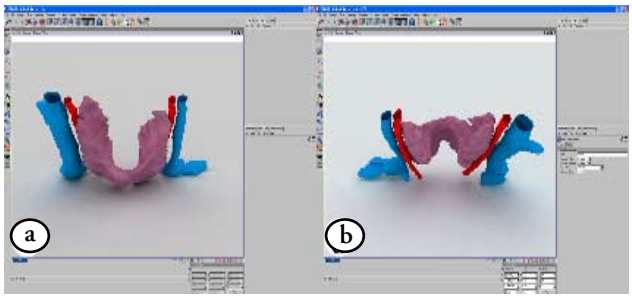

Figure 2 - The photorealistic **a)** anterior and **b)** posterior view of the thyroid gland and its surrounding tissues rendered in Cinema 4D. All the anatomical details belonging to the thyroid gland and its surrounding tissues can be seen with a high sensitivity.

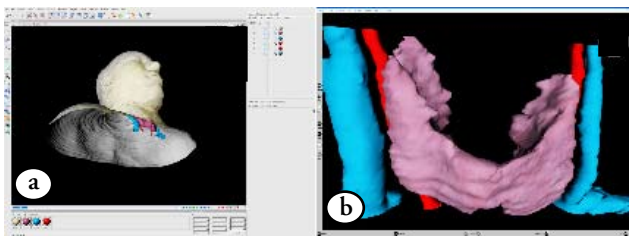

Figure 3 - The topographical position of the **a)** thyroid gland and its surrounding tissues in the cranium **b)** and a view of the thyroid gland and its surrounding tissues using Virtual Reality Modeling Language model.

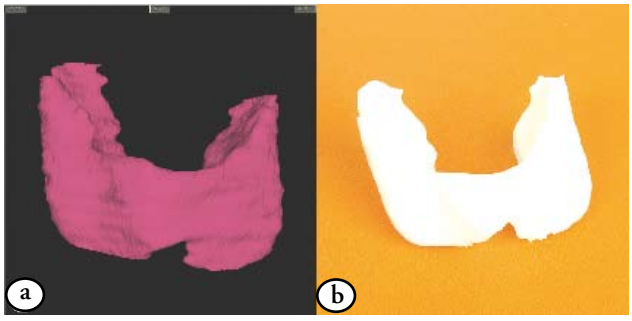

Figure 4 - An image of a 3-dimensional virtual biomodel of the **a)** thyroid gland created by computer-aided design modeling and **b)** an image of a 3-dimensional solid biomodel of the thyroid gland created by stereolithographic technique.

Table 1- Results comparing the measurements between different landmarks.

Thyroid/parameters	Models*	
	Virtual model (mm)	Physical model (mm)
Right lobe		
Longitudinal diameter (length)	57.82	56.90
Antero-posterior diameter (depth)	25.98	25.84
Lateral diameter (width)	17.19	17.11
Left lobe		
Longitudinal diameter (length)	51.18	51.11
Antero-posterior diameter (depth)	24.47	24.40
Lateral diameter (width)	14.76	14.68
The isthmus		
Longitudinal diameter (length)	28.49	28.40
Antero-posterior diameter (depth)	7.22	7.13
Lateral diameter (width)	30.32	30.05

*Virtual model refers to the CAD model developed from serial cryosections using the Surfdriver software (Figure 4a). Physical model refers to stereolithographic model developed using further processing of the CAD model (Figure 4b). CAD - computer aided design

solid model was 0.09 mm, ranging from 0.07 mm to 0.92 mm (p=0.06). Moreover, linear regression revealed that the CAD model precisely and accurately described the stereolithographic model (Y=0.99X + 0.12, R^2 = 1.00, with slope being not different from one and intercept being not different from 0). Finally thyroid volume and surface area were calculated on the CAD model. Thyroid volume was calculated 25393.9 mm^3 and surface area was calculated 8242.8 mm^2 using a 3D-Doctor software.

Discussion. Since 1970, there have been striking advancements in medical imaging capabilities to enhance organ morphology. These advancements provided a variety of new diagnostic methodologies for health status. The 3-D imaging and visualization continuously develops to achieve accurate non-invasive clinical diagnosis and treatment. Moreover, this method seems imperative for quantitative biological investigations and scientific explorations.[24] To visualize a 3-D structure, successive 2-D slices are generally stacked to create a 3-D volume, which can then be displayed on an appropriate computer terminal. Numerous rendering techniques have been implemented to improve the quality of images, eventually leading to virtual reality models.[25] The creation of life-sized anatomical replicas through stereolithographic biomodeling is another method of visualizing anatomoclinical structures and abnormalities. Stereolithographic biomodeling is a new technology that allows 3-D imaging data to be used for manufacturing accurate solid plastic replicas of anatomical structures.[3]

One of the major advantages of stereolithographic biomodeling is the ability to create highly complex structures elaborating external surfaces as well as internal cavities[1] and to obtain an overview of complex anatomy from any perspective by using a haptic biomodel during surgical planning (real reality model). The models enhanced the surgeon's comprehension of the 3-D pathological anatomy preoperatively, particularly when the findings of conventional images were ambiguous.[3] An additional advantage results from the surgeon being able to exercise on the model with the usual surgical tools as this enables him to discuss and rehearse different surgical techniques realistically. Because of this, surgery can be simulated in a way, which is not possible even with the latest visualization technologies. Such an intensive planning of surgical procedures allows the selection of the best technical approach. Additionally, using a model clearly improves the communication between surgeon and patient before a complicated surgical intervention. Furthermore, it is possible to use medical models to build individual implants, which fit more precisely,[26] suggesting that stereolithographic biomodeling seems to be beneficial for the treatment planning, as a reference during surgery, for the education of less experienced colleagues and for obtaining patients' informed consent.[3]

One drawback of stereolithographic modeling is minimum 10 hours of manufacturing and delivering time.[3] The advancements in the hardware, software and manufacturing technologies can reduce time needed to develop the products. Also, both imaging and manufacturing systems can be established in the same unit of the hospital. Another drawback is that the synthetic material of the biomodel is too rigid to use in dissecting exercises. The synthetic resin is also too brittle to simulate the anatomical structure. The solid model is thus less suitable for training than for planning because

its tactile quality still does not correspond to reality.[3] Also, the cost of the stereolithographic model should be considered.[27]

In the literature there are several studies concerning dimensional accuracy. Swaelens and Kruth[28] reported an average deviation of 0.25 mm for the modeling of a dry human tibia. Such a low deviation can be resulted from the absence of surrounding soft tissue and the simplicity of the tibia anatomy. Another study with a fresh vertebra has shown a maximum difference of ±0.5 mm. Wolf[29] made a stereolithographic model of a dry skull and obtained 0.25 mm accuracy. With another type of data processing, Barker et al[30] obtained an average dimensional deviation of 0.85 mm for a human skull; Klimek et al[31] reported an accuracy of between 0.2-0.5 mm for posterior fossa cranioplasty, and Mole et al[32] an overall distortion <3.2%. In addition, Bouyssié et al[1] reported an average difference of 0.12 mm with an accuracy of 97.9% for mandible. Our results for dimensional analysis for the thyroid gland showed no difference in the measurements on the virtual and the solid model. The accuracy of stereolithographic models is influenced by factors in each step of the process: data acquisition, 3-D data rendering, data transfer, model fabrication, post fabrication changes, and handling.[33] One of the most important reasons of our choosing the thyroid gland for the volume measurement is that the thyroid volume is the determining factor in calculating the radioactive iodine dose. In the literature, there are many conflicting data for the thyroid volume. Clinically, the thyroid volume is calculated according to Brunn's formula:[34] Volume = 0.52 x (length x width x depth), where the value of 0.52 represents pi/6, length is longitudinal diameter, width is measured as the transverse or lateral diameter, and depth is the anteroposterior diameter. The final volume is calculated by adding the volumes of the 2 lobes together. The thyroid volume measured with volumetric measuring tool of the software is consistent with its volume calculated with Brunn's formula using dimensions of the model, suggesting that the volumetric measuring tool of the software is a sufficiently reliable technique for volume calculations.

It is essential to find out a material with properties similar to those of human tissue, so that the dissecting exercises on the model of segmented structures and their environment may become possible. Our future aims to obtain models in which the quality is equivalent to the plastic that is molded for use in cadaver studies. The ability to practice dissection and surgery of an individual patient's situation without disruption of the anatomy should then provide additional quality, preoperative, noninvasive information, which cannot be reached by other means.[3]

In conclusion, stereolithographic biomodeling is a state-of-the-art and reliable method of visualizing anatomo-clinical structures and abnormalities. It provides anatomical models in VRML format to be used for both education and clinical application on the internet. This study showed the stages of building stereolithographic model of the thyroid gland. A lack of difference in dimensional comparison of the virtual and the solid model ascertained the accuracy. Moreover, volume measurements from CAD model and Brunn's model were in agreement. These confirm a creation of a life-sized anatomical replica of the thyroid gland. Future studies should deal with improving durability and functionality as well as cost effective and rapid production of stereolithographic model of organs.

References

1. Bouyssié JF, Bouyssié S, Sharrock P, Duran D. Stereolithographic models derived from x-ray computed tomography. Reproduction accuracy. ***Surg Radiol Anat*** 1997; 19: 193-199.
2. Dolz MS, Cina SJ, Smith R. Stereolithography: a potential new tool in forensic medicine. ***Am J Forensic Med Pathol*** 2000; 21: 119-123.
3. Wurm G, Tomancok B, Pogady P, Holl K, Trenkler J. Cerebrovascular stereolithographic biomodeling for aneurysm surgery. Technical note. ***J Neurosurg*** 2004; 100: 139-145.
4. Park GC, Wiseman JB, Clark WD. Correction of congenital microtia using stereolithography for surgical planning. ***Plast Reconstr Surg*** 2000; 105: 1444-1447.
5. Webb PA. A review of rapid prototyping (RP) techniques in the medical and biomedical sector. ***J Med Eng Technol*** 2000; 24: 149-153.
6. Wurm G, Tomancok B, Holl K, Trenkler J. Prospective study on cranioplasty with individual carbon fiber reinforced polymer (CFRP) implants produced by means of stereolithography. ***Surg Neurol*** 2004; 62: 510-521.
7. Stoker NG, Mankovich NJ, Valentino D. Stereolithographic models for surgical planning: preliminary report. ***J Oral Maxillofac Surg*** 1992; 50: 466-471.
8. Mankovich NJ, Cheeseman AM, Stoker NG. The display of three-dimensional anatomy with stereolithographic models. ***J Digit Imaging*** 1990; 3: 200-203.
9. Gittard SD, Narayan RJ, Lusk J, Morel P, Stockmans F, Ramsey M, et al. Rapid prototyping of scaphoid and lunate bones. ***Biotechnol J*** 2009; 4: 129-134.
10. Mainenti P, Oliveira GS, Valério JB, Daroda LS, Daroda RF, Brandão G, et al. Ameloblastic fibro-odontosarcoma: a case report. ***Int J Oral Maxillofac Surg*** 2009; 38: 289-292.
11. Vranicar M, Gregory W, Douglas WI, Di Sessa P, Di Sessa TG. The use of stereolithographic hand held models for evaluation of congenital anomalies of the great arteries. ***Stud Health Technol Inform*** 2008; 132: 538-543.
12. Paiva WS, Amorim R, Bezerra DA, Masini M. Aplication of the stereolithography technique in complex spine surgery. ***Arq Neuropsiquiatr*** 2007; 65: 443-445.
13. 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: 133-139.

14. Staffa G, Nataloni A, Compagnone C, Servadei F. Custom made cranioplasty prostheses in porous hydroxy-apatite using 3D design techniques: 7 years experience in 25 patients. ***Acta Neurochir (Wien)*** 2007; 149: 161-170.
15. Ackerman MJ, Banvard RA. Imaging outcomes from the National Library of Medicine's Visible Human Project. ***Comput Med Imaging Graph*** 2000; 24: 125-126.
16. Robb RA, Hanson DP. A software system for interactive and quantitative visualization of multidimensional biomedical images. ***Australas Phys Eng Sci Med*** 1991; 14: 9-30.
17. Bro-Nielsen M. Rigid registration of CT, MR and Cryosection images using a GLCM framework. In: CVRMed/MRCAS'97. 1st Joint Conf, Comp Vision, VR and Robotics in Medicine and Medical Robotics and Comp-Assisted Surgery. Heidelberg: Springer-Verlag; 1997. p. 171-180.
18. Decraemer WF, Dirckx JJ, Funnell WR. Three-dimensional modelling of the middle-ear ossicular chain using a commercial high-resolution X-ray CT scanner. ***J Assoc Res Otolaryngol*** 2003; 4: 250-263.
19. Hastings-Trew J. Cinema 4D Global Illumination. [accessed 2008 June 1]; Available from: http://planetpixelemporium.com/
20. Magnenat-Thalmann N, Cordier F. Construction of a human topological model from medical data. ***IEEE Trans Inf Technol Biomed*** 2000; 4: 137-143.
21. Warrick PA, Funnell WR. A VRML-based anatomical visualization tool for medical education. ***IEEE Trans Inf Technol Biomed*** 1998; 2: 55-61.
22. Alan M, Mavroidis C, Langrana N, Bidaud P. Mechanism design using rapid prototyping. Proceedings of the Tenth World Congress on the theory of machines and mechanisms; 1999 June 20-24; Oulu, Finland (this is the place of the proceedings). Oulu (Finland): Oulu University Press; 1999. p. 930-938.
23. Jacobs PF. Stereolithography and other RP & M Technologies. New York: ASME Press; 1996. p. 5-10.
24. Robb RA. Three-Dimensional Visualization in Medicine and Biology. In: Bankman IN, editor. Handbook of Medical Imaging: Processing and Analysis. San Diego (CA): Academic Press; 2000. p. 685-712.
25. Koyama T, Okudera H, Kobayashi S. Computer-assisted surgical design of a basilar aneurysm in open microneurosurgery. ***Journal of Computer Aided Surgery*** 1995; 1: 78-82.
26. Robb RA, Hanson DP. A software system for interactive and quantitative visualization of multidimensional biomedical images. ***Australas Phys Eng Sci Med*** 1991; 14: 9-30.
27. Yau YY, Arvier JF, Barker TM. Technical note: maxillofacial biomodelling--preliminary result. ***Br J Radiol*** 1995; 68: 519-523.
28. Swaelens B, Kruth JP. Medical applications of rapid prototyping techniques. Proceedings of the Fourth International Conference on rapid prototyping; 14-17 June 1993; Dayton (OH): The University of Dayton; 1993. p. 107-120.
29. Wolf HP, Lindner A, Millesi W, Knabl J, Watzke I. [Technique and applications of stereolithographic cranial models]. ***Fortschr Kiefer Gesichtschir*** 1994; 39: 19-22. German.
30. Barker TM, Earwaker WJ, Lisle DA. Accuracy of stereolithographic models of human anatomy. ***Australas Radiol*** 1994; 38: 106-111.
31. Klimek L, Klein HM, Schneider W, Mösges R, Schmelzer B, Voy ED. Stereolithographic modelling for reconstructive head surgery. ***Acta Otorhinolaryngol Belg*** 1993; 47: 329-334.
32. Mole C, Gérard H, Della Malva R, Mallet JL, Corbe S, Miller N, et al. Imagerie médicale, exploitation et perspectives: modélisation 3D et reconstruction plastique stéréolithographique. ***Act Odont Stomatol*** 1993; 181: 127-141.
33. Chang PS, Parker TH, Patrick CW Jr, Miller MJ. The accuracy of stereolithography in planning craniofacial bone replacement. ***J Craniofac Surg*** 2003; 14: 164-170.
34. Brunn J, Block U, Ruf G, Bos I, Kunze WP, Scriba PC. [Volumetric analysis of thyroid lobes by real-time ultrasound (author's transl)]. ***Dtsch Med Wochenschr*** 1981; 106: 1338-1340. German

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