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Importance of Clinical Applications to Design and Manufacture a Surgical Template through Computer-Aided Design

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Abstract

Surgical software is a computer program that helps surgeons to optimize surgical procedures before they enter the operation room. The surgical planning software lets surgeons manipulate a 3D computer model of the patients body. Through this, the exactness, dependability and safety of the surgery can be improved diverting the preoperative planning into real surgical guide. However, it is quite

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difficult to design and manufacture the surgical guide without proper clinical applications. This study lays the foundation of the importance of various clinical applications and 3D manufacturing technologies to help surgeons design and manufacture surgical templates with high accuracy and high efficiency to save more lives in lesser time.

1 Introduction

In the previous decade, surgical guides or templates in the medical field were used with various surgeries with the high precision technological tools such as oncology [1, 2] nasal prosthesis implant [3] dentistry and computerized tomographic (CT) scans [4]. Nowadays, the medical field is going to be more advanced and growing rapidly in the field of Computer Aided Surgical procedures to get more accurate data in 3-dimensions and manufacture it accordingly with the help of 3D surgical planning software [4]. The early production of the surgical template relied for the most part upon manual structure and assembling techniques, which were not all that precisely standardized. Basically, a surgical template is a guide which direct us to tumor resection, implant placement, bone repositioning, osteotomy and exact position of the implant prosthesis [5]. In light of genuine restorative image information, such as MRI, CBCT and CT scan, 3D recreation and picture preparation are re-built through pre-operative planning software. In view of real 2D picture arrangement and 3D duplicated models, pre-operative arranging is performed including geometrical estimation enhancement and introduction of the clinical methods. Because of the preoperative arrangement, the clinical layout can be organized using reverse engineering and surface reproduction innovation and after that it can be produced using 3D printer and additive manufacturing for performing clinical application toward the end. Furthermore, the surgery can be streamlined in less time spent in Operation Theater. It is therefore effective, lowering the risk to the patients not to mention saving costs for hospitals. Pesun and Gardner [6] clarified the development of a surgical template by using the Qutta-Percha method to be utilized for oral implant placement. In addition, with the advancement in the computer world, the CAD/CAM is extensively used for gathering the modified surgical guides for clinical applications [7]. Moreover, the high speed machining (HSM) or additive manufacturing technology has now become the primary source of the manufacturing process in recent years due to noteworthy headway of the production accuracy and efficiency. The principle endeavors included are preoperative planning, format structure and assembling and image processing.

2 Pre-operative Planning

Preoperative planning with CAD is the fundamental essential for the design and manufacturing of a surgical guide. It has turned into a drifting subject in the field of surgical image computing.

2.1 Image segmentation

Image segmentation is a very important procedure of image processing to extract useful information on blood vessels, nerves and hard and soft tissues. Moreover, its essential limit is to extricate the photos into different areas and generate outcomes estimated to the anatomical structures. Manual division of computed tomography, magnetic resonance imaging and positron discharge tomography are time consuming and barely utilized in some complex circumstances when the distinction in quality between target tissues and encompassing cannot be perceived [8]. Analysts are presently focusing to create self-actuate picture division calculations including local developing technique [9], watershed algorithm [10, 11] and the fuzzy connectedness method [12]. In some cases the precision of segmented outcome may be ignored to fulfill the clinical requirements.

For instance, Pavliha, Mu*šč*, Ser*ša*, et al. [14] obtained three nuclear switch division calculations: area developing, versatile limit and active counters. The outcome showed that the distribution flow for limit based segmentation strategies may remain since explicit organs around the liver have similar power degrees [13, 14]. That explains why a few analysts work on techniques dependent on extraordinary numerical hypotheses, the artificial neural system algorithm dependent on wavelet change, statics fractal hypothesis [15] and scientific morphology [16] is a model objective to enhance the segmentation result.

2.2 Image Registration

To get more detailed information about the patients history, it is required to obtain medical images from different sensors for treatment verification. Among these, anatomical body structure is recorded by MRI and Ultrasound or Computed tomography (CT) and metabolic body activities. Currently, there are two major registration methods used: the feature based algorithms

[17] and intensity based algorithms [18]. Recently, many new advanced methods for image registration have been introduced; for example, fast Fourier transform based method [19], maximum likelihood approach [20], iterative principal axes method [21] and local frequency representation algorithm [22]. Hu et al. proposed a new algorithm, deformable enrollment technique, that empowered self-arrangement (with the help of infrared sensors) of MR and 3D transracial ultrasound images of the prostate organ [23]. Additionally, many software packages have been designed for easy image enrollment activity utilizing different methodologies dependent on previously mentioned techniques. For instance, the function of 2D enrollment, 2D non-rigid enrollment, 3D surface enrollment and 3D voxel enrollment are present in the software of Analyze (Analyze Direct, 3D Medical Image analysis software for research, Overland Park, KS, 66085, United States, (www.analyzedirect.com). Most image registration algorithms in the literature and those used in practice were based on variations on these basic elements and their combination [24]. Assuredly, a reader familiar with the basic principles and their various combinations can easily gain a good understanding of a new image registration technique or system [24].

2.3 3D visualization

With visualization, doctors do not need to refer 2D images from numerous modes (i.e. CT/MRI or radiograph), this method provides 3D or even 4D image data. Recently, the 3D reconstruction algorithm further classified two classic functions, surface rendering, and volume rendering [25]. The principal surface rendering strategy separates the surface layers in the display group of polygonal surfaces, the layer is essentially built with the help of the marching cubes (MC) method [26] which is the most widely used method. Volume rendering is an innovation of processing rays to deliver projection picture through the volumes. This technique is usually considered to be most convenient visualization technique [25]. Nowadays, the volume rendering method further includes splitting algorithm [27], ray casting algorithm [28] and shear warp algorithm [29]. The real rendering procedure comprises of three essential advances: projection, shrouded part expulsion and shading. These means are expected to grant a feeling of three dimensionalities to the rendering picture that is made. Extra signals for three-dimensionality might be given by procedures such as stereoscopic display, motion parallax by turn of the items, shadowing and surface mapping [30].

Even with PCs persistently getting quicker, the introduced volume visualization algorithms (VVA) still face difficulties in enhancing the rendering performance of large data log files (megabytes or gigabytes) and the pixels of their reproduced pictures [31]. Since the GPU can give huge computational processing energy compared to CPU on a for each dollar premise, the Graphics Processing Unit based volume rendering system was intended to deliver clear pictures and viably passing on visual data over the ongoing years [32]. For example, Schlegel et al. and Chen et el. displayed a novel methodology in direct volume rendering dependent on Graphics Processing Unit ray casting for getting quick, plausible volume brightening and shading effect [7,33]. Other authors introduced a novel methodology for GPU-based great efficiency volume rendering of tremendous volume information, which can easily lessen the rendering time over traditional algorithms [7,34]; they proposed an intelligent GPU-based illustrative volume rendering structure to get proper interaction and prompt parametrization of illustrative styles [35]. The rendering step can be hypothetically part of the image generation and the presentation step. In the presentation step a large number of pictures can be obtained and looked at in quick arrangement in this manner showing up as a consistently enlivened portrayal of the chosen substance.

3 Materials and Methods

3.1 Surgical Planning Software

Medical planning is a procedure of utilizing PC innovation to configure, reproduce and advance careful plan (3D geometrical estimations, therapeutic picture examination, 3D anthropometric investigation, virtual careful direction of tumor resection, careful recreation, embed/format structure by means of CAD programming, reenactment of embed or prosthesis arrangement). Recently, numerous CAD preoperative planning software packages have been created and generally utilized; for instance, MIMICS (3D medical image processing software Materialize N. V., Leuven, Belgium) (https://www.materialise.com/en/medical/software/mimics), Analyze, 3D-DOCTOR (3D modeling, measurement and image processing software for Computed tomography, MRI, PET and other industrial imaging applications developed by Able Software Corp., Lexington, KY, USA, https://www.ablesw.com/3d-doctor/), SimPlant Pro/OMS (Materialize Dental N.V.), 3dMD Vultus (3dMD Inc), and likewise some open source program;, for example, 3D Slicer, Gimias (work process situated condition concentrated on biomedical simulation, created by GIMIAS is developed by

CISTIB at Sheffield University, UK). Picture preparation incorporates recovery of the CT scan information, division of anatomical parts (for instance, skull, mandible, delicate tissue, and nerve) and foundation of the composite model that blends all vital data by means of registration. The vital favorable position of the assembling composite model is that ancient rarities of metals (i.e. braces) in CT scan can be wiped out during the 3D displaying stage [35].

The main function of a planning software is that it enables the specialists to lead the client characterized 3D anthropometric examination, which gives evaluated data on the disfigurement as well as intelligent with a careful reproduction process and give anticipated measures in a similar manner. They are proficient to reenact a careful process; for example, the osteotomies of the skeletal structures, repositioning of sections, and assessment of occlusion, 3D photograph mapping and even recreation of delicate tissues reaction to the skeletal remaking. Moreover, it should be noticed that the delicate tissue reenactment work is still in its beginning period and as such has not yet been incorporated into the clinical convention [36]. Furthermore, the virtual surgical planning program can be played remotely at both the clinic and the operating room via center a Wi-Fi network. This permits the surgical arrangement to be directed in a group with the participation of master specialists, orthodontist and other specialized staff in the facility destinations. Likewise, the framework allows the virtual careful arrangement to be clarified in the operating room by means of an extensive LED screen.

3.2 Template design

When the virtual careful arrangement is endorsed by specialists, the implant and intraoperative surgical guides/layout (i.e. braces for orthognathic medical procedure) are structured and altered utilizing CAD programming to enhance careful precision and dependability.

Various commercial 3D design software packages are used to design surgical templates and are used in various clinical cases for human and animal experiments. In addition, there are various 3D designing software packages that are available to design surgical templates and convert them into STL file for 3D printing. Some examples of clinical tools include Geomagic studio, solid works, etc. Geomagic is usually used for complex shapes on built-in model, curved shape on CT scan data like template design on human mandible where solid work is used to create a new design from scratch.

3.3 Template manufacturing

When the structure method is concluded by specialists, a surgical template can be created utilizing AM innovation (also called 3D printing or RP innovation) by manufacturers. RP is basically a methodology of using fine particles of ceramic or metal materials to 3D manufacture a layer by layer object to arranged model [37]. Compared with conventional CAD/CAM innovations, RP permits the formation of exceptionally typical design structures and has the benefits of patient-explicit plan, minimal effort and high precision [38]. It also saves time. It might take many days to deliver a layout for iliosacral screw inclusion through the conventional machines while the entire procedure just needs 6 to 20 hours on RP technology. There are various ways to print the layers in order to shape the complete item. Some techniques liquefy or simply soften the material to make the layers whereas others use powerful UV laser to fix photo-reactive resin and "print" the object. Table 1 shows some 3D printing technologies along with accuracy and surface finish.

Table 1: The classification of additive manufacturing technology [39]

Technology	Accuracy	Finish Options
Stereo lithography	Most accurate printing	Excellent surface finish
Fused deposition modelling	Accurate and reliable	Standard Finish
Selective Laser Sintering	Not very accurate	Standard Finish
Laminated object manufacturing	Slight accuracy	Wood like characteristics
Digital Light Processing	High Accuracy	Good finish. High resolution
Direct Metal Laser Sintering	Normal Accuracy	Standard Finish
Selective Laser Melting	Not very accurate	Standard Finish

The most commonly used 3D printing technologies are illustrated in Figure 1, which shows the total percentage of popularity of all technologies and Figure 2 shows the applications of 3D printing.

Finally, after successful design, discussion and manufacturing of template, it is delivered to the operation room. The discussion/communication among surgeons, designers and manufacturers can be conducted online or in a laboratory.

3.4 Accuracy

After the successful design and manufacturing of surgical templates using clinical tools and 3D designing software packages, specialists can perform the

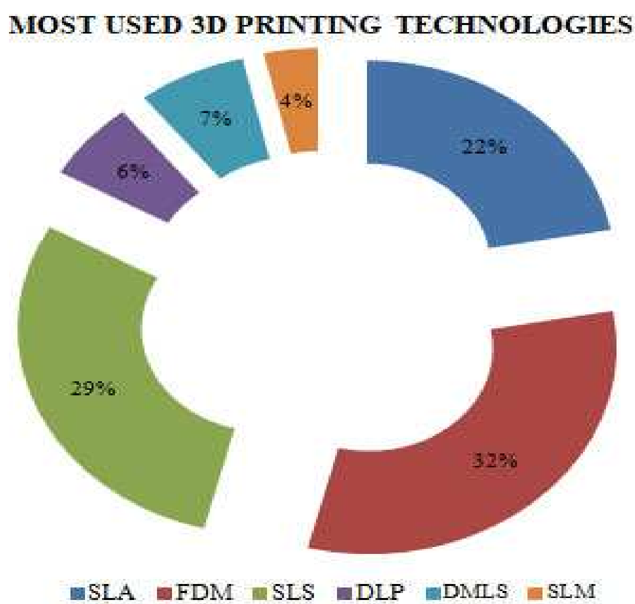

Figure 1

medical procedure through the utilization of surgical format. The accuracy and completion of guided implant surgery has been studied in recent years to show the precision of these methods. Cassetta and his associates published two works that respected the exactness of PC structured careful guide contrasting and 3-dimensional positions of planned and placed implants.

The researchers reasoned that implants position utilizing CAD/CAM surgical guides yielded better precision a sidelong way than traditional guides. Also, CAD/CAM guides indicated less fluctuations of deviation esteems from implant arranged areas than traditional guides.

All perception in this survey showed a sensible mean exactness with anyway generally high deviations. This inconstancy appeared to depend essentially on the guided surgical system picked and particularly on the sort of template adjustment. CAD/CAM surgical guides have a preferred level of precision over traditional guides. Meta-investigation of the precision uncovered a mean error of around 1 mm at the passage point and 1.3 mm toward the end purpose of apex.

From the literature, we can state information that PC-GIS has great precision levels due to the still critical deviations in the urgent decision of the most proper careful guided convention and its circumspect execution.

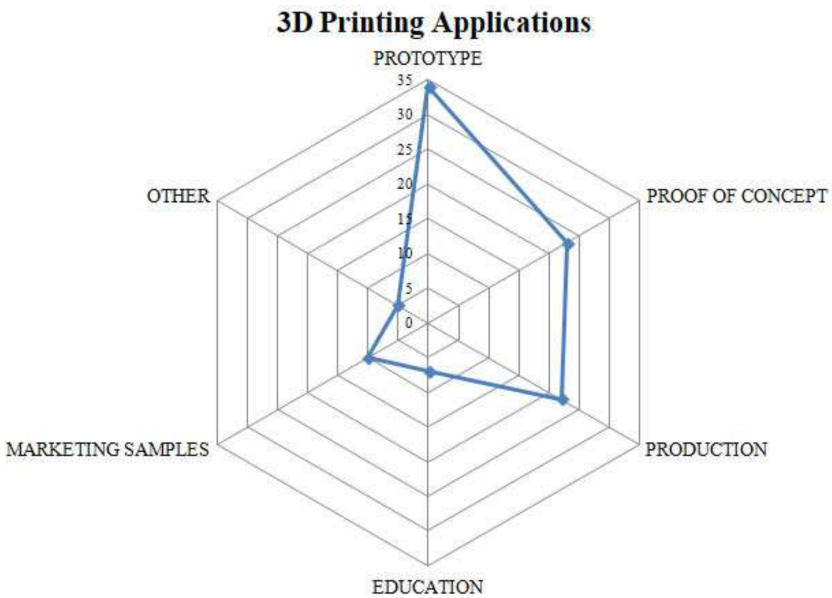

Figure 2

4 Conclusion

Guided surgery requires special knowledge and high standardized care. It is very important to have better communication between the surgeon and the template designer for better understanding and accuracy. However, when performed in accordance with the patients specific needs it may represent a faster and safer procedure. By playing out the medical procedure for all intents and purposes, the specialist can think about and improve the different surgical choices and the patient has a chance to envision the multifaceted nature of accomplishing the coveted outcome. Various surgical planning software packages exist with varying capabilities and features that allow for the design and manufacturing of proprietary computerized guided surgical template (GST). This study found that, CAD/CAM surgical guides and surgical planning software can improve the efficiency and accuracy and surgeons can save more lives in lesser time with the help of clinical tools and planning software packages.

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