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Rapid prototyping as a Tool for Designing and Manufacturing of Customised Anatomical Implants.

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ABSTRACT

Rapid prototyping (RP) technologies are mostly related with applications in the product development and the design process as well as with small batch manufacturing. Due to their comparatively high rapidity and flexibility, however, they have also been engaged in various non-manufacturing applications. A field that attracts increasingly more attention by the scientific community is related to the application of technologies in medicine and health care. The associated research is focused both on the development of specifically customized or new methods and systems based on principles, as well as on the applications of existing systems assisting health care services. In this paper, representative case studies and research efforts from the field of medical applications are presented and discussed in detail. The case studies included cover applications like the fabrication of custom implants and scaffolds for rehabilitation, models for pre-operating surgical planning, anatomical models for the mechanical testing and investigation of human bones or of new medical techniques, drug delivery devices fabrication, as well as the development of new techniques specifically designed for medical applications.

INTRODUCTION

Rapid prototyping models have found applications for planning treatment for complex surgery procedures, training, surgical simulation, diagnosis, design and manufacturing of implants as well as medical tools.

Rapid prototyping technologies are finding remarkable applications in medical field for manufacturing dimensionally accurate human anatomy models from high resolution medical image data. Recent advancements in the areas of Rapid Prototyping, Reverse Engineering and Image Processing, lead to the emergence of the field of Medical Applications of Rapid Prototyping. Soon ter the introduction of Rapid Prototyping to industry, the advantages of this new technique were realized and researchers started to look at the medical community to implement new applications. With improvements in the medical imaging, it is now feasible more than ever to produce a physical model "directly" from Computed Tomography (CT) scan or Magnetic Resonance Image (MRI) with great accuracy. RP requires that CAD files be provided in layers. Since medical data resulting from CT/MRI is usually provided in a slice format, it seemed natural to be able to produce physical models directly by the new layered- manufacturing technique. By combining RP, RE and Image processing, the medical applications took off and have been under constant development ever since. While the technology is still in its developing stage, compared to other improvements in the medical environment, the technical. Challenges and the pace by which such technology is advancing prove very promising.

Literature Review

As it is well known, the term "rapid prototyping" refers to a number of different but related technologies that can be used for building very complex physical models and prototype parts directly from 3D CAD model. Among these technologies are stereolithography (SLA), selective laser sintering (SLS), Direct metal laser Sintering (DMLS), fused deposition modeling (FDM), laminated object manufacturing (LOM), inkjet-based systems and three dimensional printing (3DP). RP technologies can use wide range of materials (from paper, plastic to metal and now a days biomaterials) which gives possibility for their application in different fields. RP (including Rapid Tooling) has primary been developed for manufacturing industry in order to speed up the development of new products. They have showed a great impact in this area (prototypes, concept models, form, fit, and function testing, tooling patterns, final products - direct parts). Preliminary research results show significant potential in application of RP technologies in many different fields including medicine.[1]

The technologies of reverse engineering and rapid prototyping are emerging as useful new tools in medicine. Orthopedic, dental and reconstructive surgery. it involves the imaging, modeling and replication (as a physical model) of a patient's bone structure. The models can be viewed and physically handled before surgery, which is of great benefit in evaluation of the procedure and implant fit in difficult cases. the technology promises lessened risk to the patient and reduced cost through saving in theatre time. Joint replacements for patients who had experienced severe bone loss through osteoporosis using RP technique is achieved. Such applications are a further step towards the development of a new generation of customized bone implants.[2,3]

Rapid prototyping is the automatic construction of physical objects using solid freeform fabrication. The first technique for rapid prototyping became available in the late 1980s and was used to produce models and prototype parts. Rapid prototyping takes virtual designs from Computer Aided Design (CAD) or animation modeling software, transforms them into thin, virtual, horizontal cross-sections and then creates each crosssection in physical space, one ter the next until the model is finished. However, each rapid prototyping platform uses the same principles of slicing, layering and bonding to build parts. Several research institutions and commercial organizations have integrated Computer-aided Design (CAD) and Rapid Prototyping (RP) systems with medical imaging systems to fabricate medical devices or generate 3D hard copy of these objects for use in surgical rehearsal, custom implant design and casting. In manufacturing, models are planned and conceived entirely on the computer screen, then converted to physical reality. In bio-medical applications, the objects normally already exist physically. Prior to building, this highly complex data needs extensive pre-processing to provide a format that a CAD program can utilize, before transferring to an RP system.[6].

The advantage of RPT is complete visual appreciation of bony anatomy hitherto unavailable. The modeling process is very accurate reproducing CT data to a tolerance of 0.1 mm. The major source of error is the CT scanning process itself, where inaccuracies of up to 1 mm can occur. Thus, medical imaging is the limiting factor when producing RP bone models But now a days the rapid advances in computer technology, often driven by the demands of industry, have created new possibilities in surgery which previous generations of surgeons could only have imagined. Improved imaging with computerized tomography (CT) has been followed by magnetic resonance imaging (MRI) and, more recently, it has become possible to reformat the data as three-dimensional images.(4) The most commonly used techniques for capturing internal medical data are the Computed Tomography (CT) and the Magnetic Resonance Imaging (MRI). Either of the techniques provides cross sectional images of a scanned part of the human body. The main difference is that the CT scanner uses radiation in the process while MRI does not. The quality of the finished model totally depends on the accuracy of the scanning machine and the resolution of the data. Decreasing the scan distance, which produces more slices along the scanned region, can increase resolution. The longer scanning period required for a high-resolution scan, however, must be weighed against increasing the patient's exposure to radiation, scan time and cost, and patient discomfort. The new spiral CT-scan technology allows faster acquisition of smaller scan distances compared to traditional scanners that must translate the patient for each transverse section. [2]. In either of the techniques, the output of the scanning process is a set of cross-sectional data images. CT-data is most suitable for modeling bone structures and MRI-data is best suited for modeling of soft tissues. ter saving CT or MRI image data, they should be transferred to RP or RE laboratory.[1]

The next step is processing these data, which is a very complex and important step, that the quality of the final medical model depends on. For this step engineers need software package (Mimics,Invesalius,3D Doctor) in which they can make segmentation of this anatomy image, achieve high resolution 3D rendering in different colors, make 3D virtual model and finally make possible to convert CT or MRI scanned image data from DICOM to .STL (Stereolithography) file format, which is universally accepted RP file format. These software packages allow making segmentation by threshold technique, considering the tissue density. In this way, at the end of image segmentation, there are only pixels with a value equal or higher than the threshold value. Using this STL file format the required 3D model can be constructed using various RP techniques. These implants are to be properly customized as per the requirement of patient. With the availability of solid model customization of implant can be achieved using different design tools and patient data. However, the data used is dependent on the implant being designed, Typical data may include patient age, weight, activity, and others. Coupled with the natural bone design and the patient bone density special formulas and certain designs are selected to achieve near optimal fit while minimizing bone removal. Traditional and nontraditional design formulas are used in shaping up the final design.[1]

Customized implants are far superior than "standard" implants. In addition to the robustness in the design, there are usually less natural bone removal that may result.[2]

Further ter final optimization of the design the implant is either directly manufactured by Rapid prototyping using bioactive materials or the required patterns are produced & the implants are casted using investment casting.

Finally, the product created in this way i.e. modeled from one massive piece of biomaterial, will match exactly (3D shape) patient's anatomical region to be cured (changed or replaced). For each patient the customized 3D models of anatomical regions to be surgically treated and replaced will be manufactured. This approach exhibits a huge benefit for surgery practice, because it ensures properly postoperative functioning of patient's anatomical/organic system, which by this means, becomes in fact almost the same to its original natural model.[5]

In nineties the Rapid prototyping technology was in initial stage this paper Provides an overview of how RP technology is developing, and concludes with an upbeat view of the potential for growth in the medical applications. Terry Wohlers et.al suggests that orthopedics appears to be an attractive market for rapid prototyping systems manufacturers & Compares the development and manufacture of a surgical tool manufactured by rapid prototyping with conventional cast and machining methods [1]. The rapid prototyping has a part to play in reducing time and cost, particularly in the development phase. [2].

The best direction of formation of an object by layered manufacturing process that allows the use of support structures. In the orientation determined by the best direction of formation, the object is constructible with a minimal support structure, is stable, and rests on a planar base. Implementation results are also included. [3].

The Tooling and Casting subgroup of the European Action on Rapid Prototyping (EARP) has undertaken a project to investigate the problems associated with using rapid prototype models as sacrificial patterns for investment casting. The accuracy and surface finish of the models and the castings were also assessed so that a comparison could be made. Models from each process were manufactured by different members of EARP and then three foundries were each given a set of models to convert to castings. Observes that one of the oldest metal manufacturing techniques, which dates back to 4000-6000 BC, is being used with one of the most modern – rapid prototyping [4].

Also the further developments in systems werw focused on two distinct market sectors. Machines are being used as design office support facilities or "desktop" manufacturing units. One way of achieving this may be to inte- grate industrial robotics with the technology in the form of flexible manufacturing (or rapid prototyping] cells. [5].

The mechanical properties of a new mould- making material, proposed for producing rapidly proto- typed injection mould inserts for plastics by selective laser sintering. Explains that, although the strength of this material is far below that of the tool steel usually used to fabricate moulds, design calculations indicate that it can still be used for mould insert production.Points out that the thermal conductivity of this material is lower than that for steel but higher than that for plastic melts. Indicates, from the calculations, that proper choices of conduction length and cycle time can minimize differences, relative to steel moulds, in the operational behaviour of moulds made of the new material. Discusses the longevity of example moulds[6].

In post nineties the CAD systems brings revolution in design sectors.The computer controls a laser beam or a print head, or any process that leads to the formation of a slice of a part using resins, powders, paper, wax or other materials. The original CAD representation is translated into commands to drive the process, and accuracy issues will make or break these emerging technologies. It is therefore important to understand where the errors stem from, what are the issues associated with the software representation formats, and how to minimize or eliminate these errors. Presents a summary of CAD to RP software formats, and explains the accuracy issues associated with the selected representation. Discusses improvements that can be obtained by process modifications. [7].

The main focus on the fused deposition process and examines the rationale behind the cooling process model. Outlines the complexity of the problems and characteristics of fused deposition .It Presents a general formulation for road cooling followed by results and their implications. [8]. The fused deposition modelling is a rapid prototyping technology by which physical objects are created directly from a CAD model using layer by layer deposition of extruded material. The technology offers the potential of producing parts accurately in a wide range of materials safely and quickly. In using this technology, the designer is often confront with a host of conflicting options including achieving desired accuracy, optimizing building time and cost and fulfilling functionality necessities. Presents a methodology for resolving these problems through the development of an intelligent rapid prototyping system integrating distributed blackboard technologies with different knowledge based systems and feature based design technologies [9].

Also it has been already started the use of RP technology in medical applications.The results of an investigation into the feasibility of producing models of human anatomy by linking MRI and stereolithography. Begins by describing the require- ments for developing a link between the two technologies together with the major problems that this involves. Describes the processes undertaken to enable the creation of a model of a human brain. The model showed excellent anatomical details and demonstrated that the technique of linking MRI and stereolithography is entirely feasible. [11].

An adaptive slicing procedure for improving the geometric accuracy of layered manufacturing techniques which, unlike previous procedures, uses layers with sloping boundary surfaces that closely match the shape of the required surface. This greatly reduces the stair case effect which is characteristic of layered components with square edges. Considers two measures of error, and outlines a method of predicting these measures for sloping layer surfaces. To cater for different manufacturing requirements, presents a method to produce parts with either an inside or outside tolerance, or a combination of both. Finally, considers some problems associated with surface joins, vertices, and infection points and proposes some solutions. 12].

The analysis of the market for rapid prototyping equipment and reports on the rapid growth that this market has experienced over the last ten years. Highlights the companies that are winning business and the technologies that are influencing growth. Describes applications of rapid prototyping for automotive parts, pharmaceutical pill, bottles and jewellery design.

On new technology used by recently introduced low-cost 3D printing machines for concept modelling and outlines new materials that have been developed to improve the performance and functionality of prototypes [13]. A taxonomy is suggested, along with a preliminary guide to process selection based on the end use of the prototype.1998 Elsevier Science Ltd. All rights reserved. [14].

The work done by Paul Alexander on concepts of build orientation problem was con- sidered for processes that required an external support structure. The influence of part accuracy, hollow parts and processes that do not need support are now considered for orientation. Also, cost calculations are incorporated, extending the analysis further. [15].

Anna Kochan Analyses the market for rapid prototyping equipment and reports on the rapid growth that this market has experi- enced over the last ten years. Highlights the companies that are winning business and the technologies that are influencing growth.Describes applications of rapid prototyping for automotive parts, pharmaceutical pill bottles and jewellery design. Reports on new technology used by recently introduced low-cost 3D printing machines for concept modelling and outlines new materials that have been developed to improve the performance and functionality of prototypes. [16].

Justin Tyberg presents a new approach to adaptive slicing that significantly reduces fabrication times. The new approach first identifies the individual parts and features that comprise each layer in a given build, and then slices each independently of one another. This technique improves upon existing adaptive slicing algorithms by eliminating most of the slices that do not effectively enhance the overall part surface quality. [17].

A study was done by Raymond N. Chuk of rapid prototyping technologies and their ability to make components for wind tunnel models in a timely and cost effective manner. Components and corresponding fabrication technologies were put into three categories: non-structurally loaded, lightly loaded and highly loaded according to the stress endured during wind tunnel tests. Rapid prototyping technologies were found capable for non-structurally loaded parts, but numerically controlled machining was still best for any part enduring significant loads [18].

According to Karapatis Rapid prototyping technologies are now evolving toward rapid tooling. The reasons for this extension are found in the need to further reduce the time-to-market by shorten- ing not only the development phase, but also the industrialization phase of the manufacturing process. The present state of rapid tooling is reviewed and the direct rapid tooling concept, aimed at developing direct and rapid tool manufacturing processes, is presented, along with three promising methods. Their intrinsic properties are outlined and compared. Necessary research and development are described in terms of direct rapid tooling requirements. [19].

Jack G. Zhou has suggested some polymer materials for new rapid tooling technique named Rapid Pattern Based Powder Sintering (RPBPS).The new technique has the advantages of using a variety of materials, rapidity, making complex geometry parts and low cost, compared with several existing rapid tooling techniques. Many key technical problems in RPBPS are related to the binder. In order to select a suitable binder, the heat deformation resistance and heat stabilization of some polymer materials are discussed in depth.

Rapid tooling (RT) technology is defined as a process that allows a tool for injection mold- ing or die casting operations to be manufactured quickly and efficiently, so the resultant part will be representative of production material (Jacobs, 1996). Up to now, over ten RT techniques have been proposed, in which only three techniques are relative to the RPBPS technique. The following is a brief introduction to the three techniques. [20].

Loh has discusses the selection of building direction for four RP processes, namely stereolith- ography (SL), selective laser sintering (SLS), fusion deposition modelling (FDM) and laminated object manufacturing (LOM). Main differences in the four processes are first examined with emphasis on the effects of these differences with regard to the building inaccuracy, the surface finish, the manufacturing time and cost. An optimal orientation algorithm is demonstrated on a part considered for processing with one of the four RP processes. The influence of the process characteristics on the selection of appropriate orientation with different RP processes is illustrated in the example. [21].

Eric Radstok said Rapid tooling can be seen as the second wave in rapid prototyping because, with rapid tooling, the production process can be prototyped instead of the final product and compares several existing processes available for rapid tooling. For each process,the product size and the number of shots is estimated. [22].

RP laboratory safety issues were discussed by Stephen M. Deak et.al. It considers health and safety awareness, a health and safety plan of action and a health and safety follow-up. A conference discussion summary is featured at the end of the article. [23]. RP requires potential content of standards for the RP industry. [24].

F. Xu H.T. Loh et al. discusses the selection of building direction for four RP processes, namely stereolith- ography (SL), selective laser sintering (SLS), fusion deposi- tion modelling (FDM) and laminated object manufacturing (LOM). Main differences in the four processes are first examined with emphasis on the effects of these differences with regard to the building inaccuracy, the surface finish, the manufacturing time and cost. An optimal orientation algorithm is demonstrated on a part consid- ered for processing with one of the four RP processes. The influence of the process characteristics on the selection of appropriate orientation with different RP processes is illustrated in the example. [25].

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Jonathan Colton et.al investigates the degree of cure achieved in the UV chamber and the degree of cure achieved by heating in a thermal oven. It is hypothesized that a more fully cured mold is harder and hence will produce more parts before failure. Also investigates various post-cure processes and suggests a post- cure strategy to achieve this end. [27].

Jeng-YwanJeng et.al presented a new flexible layer fabrication method to separate the fabrication processes of the profile and the interior, respectively, in order to maintain model accuracy and thinner slice thickness, and to accelerate the fabrication speed. [28].

M.A. Jafari et.al has presenedt the system developed for the solid free form fabrication of multiple ceramic actuators and sensors .With solid free form fabrication, a part is built layer by layer, with each layer composed of roads of material forming the boundary and the interior of the layer. With our system, up to four different types of materials can be deposited in a given layer with any geometry. This system is intended for fabrication of functional parts; therefore the accuracy and precision of the fabrication process are of extreme importance. A mathematical model to predict the layered process error and an optimization algorithm to define the fabricating orientation based on the minimum process error for layered manufacturing fabrication has been developed by Feng Lin et.al. Case studies to determine the preferred orientation candidates for fabricating spherical objects, cube objects and objects with irregular geometrical shapes have been conducted by him and the results were validated. Different orientation candidates determined by minimum processing error and by minimum processing time were also compared. The developed model and the optimization algorithm can be used, in conjunction with other processing parameters such as processing time and support structure, to define an optimal processing planning for layered manufacturing fabrication. [30].

C.W. Ziemian et.al has developed a multi-objective decision support system to aid the user in setting FDM process variables in order to best achieve specific build goals and desired part characteristics. The method uses experimentation to quantify the effects of FDM process variables on part build goals, and to predict build outcomes and expected part quality. The system offers the user the ability to quantify the trade-offs among conflicting goals while striving towards the best compromise solution. [31]. Also he described an algorithm to determine the build orientation. It considers the deposition process attributes and the machining process attributes simultaneously. [32].

P. Ng presented the development of a prosthetics Computer-Aided- Manufacturing (CAM) system that utilizes Rapid Prototyping (RP) technology. The system reduces the socket making time from days to less than 4h. Clinical and biomechanical studies are conducted to evaluate the comfort and fit of the new socket during gait. Preliminary investigation of the new socket shows that its functional characteristics are very similar to that of a traditional socket. [33].

Ian Gibson describes work carried out to investigate potential applications for architectural modeling, as well as an attempt to explore the limits of the technology. It will go on to discuss how the technology may be developed to better serve the requirements of architects. [35].

S.H. Masood et.al. presents a generic mathematical algorithm to determine the best part orientation for building a part in a layer-by-layer rapid prototyping (RP) system. The algorithm works on the principle of computing the volumetric error (VE) in a part at different orientations and then determining the best orientation based on the minimum VE in the part. [38].

Alan J. Dutson advances in the empirical similitude technique. Sources of coupling between material properties and geometric shape that produce distortions in the current empirical similitude technique are outlined. A modified approach that corrects such distortions is presented. Numerical examples are used to illustrate both the current and the advanced empirical similitude methods. [39].

L.C. Hieu et.al design methods for medical rapid prototyping (RP) of personalized cranioplasty implants are presented in this paper. These methods are applicable to model cranioplasty implants for all types of the skull defects including beyond- midline and multiple defects. The methods are based on two types of anatomical data, solid bone models (STereoLithography files – STL) and bone slice contours (Initial Graphics Exchange Specification – IGES and Strata Sys Layer files – SSL). [40].

By RE, the customized bone substitute is designed according to the CT sectional pictures, and the customized localizer is designed to locate the customized bone substitute in the patient's body at the right position. A customized mandible substitute designed and fabricated by RE and RP has been put into clinical use and is discussed in detail. The results confirm that the advantage of RP in the field of bone restoration is that it can fabricate the customized bone substitute rapidly and accurately. [41].

Design methods for medical rapid prototyping (RP) of Personalized cranioplasty implants are presented by Heiu. [42].Bellini presented a methodology of the mechanical characterization of products fabricated using fused deposition modeling. [43]. In 2004 Wang Guangchun proposes a rapid design and manufacturing system of the product. There are two ways to develop a new product in this system. One is beginning with a design concept, and another is from a sample as are ference. The reverse engineering technology, transmission processing software or modules of the input data, structure analysis and optimization means and manufacturing process analysis tools were integrated in the system. [44].

Zhao Jibin establishes optimizing model based on the considerations of staircase effect, support area and production time. The general satisfactory degree function is constructed employing the multi-objective optimization theory based on the general satisfactory degree principle. The best part-building orientation is obtained by solving the function employing generic algorithm. Experiment shows that the method cans effective resolve the part-building orientation in RP [45].

D. Dimitrov's research was undertaken to characterize the three dimensional printing (3DP) process in term of the achievable dimensional and geometric accuracy.[46].

L.K. Cheung presented the intimate aim to illustrate a number of instances where RP and associated technology has been successfully used for specially medical applications. [47].

Jiankang He presented a custom design and fabrication method for a novel hemi-knee joint substitute composed of titanium alloy and porous bio ceramics based on rapid prototyping (RP) and rapid tooling (RT) techniques. [48].

SekouSingar describes computer-aided design (CAD) and rapid prototyping (RP) systems especially for the fabrication of maxillofacial implant.[50].

The interegreated approach for how the various CAD/CAM/RP technologies applied to support a medical team from the GrootteSchuur and Vincent Palotti hospitals in Cape Town, to save limbs – as a last resort at a stage where conventional medical techniques or practices may not apply any longer. [51].

The purpose of this paper is to describe how the Integrated Product Development research group of the Central University of Technology, Free State, South Africa is applying various CAD/CAM/RP technologies to support a medical team from the GrootteSchuur and Vincent Palotti hospitals in Cape Town, to save limbs – as a last resort at a stage where conventional medical techniques or practices may not apply any longer.[52].

Kun Tong's research is to extend the previous approach to software error compensation to fused deposition modeling (FDM) machines and explores the approach to apply compensation by correcting slice files [53].

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Ben Vandenbroucke et.al investigated the possibility of producing medical or dental parts by selective laser melting (SLM). Rapid Manufacturing could be very suitable for these applications due to their complex geometry, low volume and strong individualization. [54].

YH Chen presented, seven factors affecting build orientation are formulated based on the STL file of an object and represented as fuzzy variables. A fuzzy multi-criteria decision method is used to rank candidate build orientations. Experiment with two examples shows satisfactory results. [55].

Jibin Zhao et al established optimizing model based on the considerations of staircase effect, support area and production time. And then, through analyzing the hatching characteristic of polygonal contours, approximately optimization model of direction of scanning vectors is established. The best part-building orientation is obtained by solving the general satisfactory degree function employing genetic algorithm and the optimal scanning direction is also solved by genetic algorithm. Two cases of experiment show that GA can effectively solve not only the determination problem of part-building orientation but also the optimization problem of scanning direction in RP. [56].

DiethardBergers et. al generated facsimiled rapid prototyping (RP) models for medical analysis that demands an answer about the accuracy of medical models.

Applying decision methods to select rapid Sprototyping technologies Anderson Borille et. al.suggested the use of rapid prototyping (RP) technologies is becoming increasingly popular due to the reduction of machinery prices. Consequently more and more industries now have the opportunity to apply such processes to improve their product development cycles. Also Presented the different decision-making approaches to choose an adequate RP process[57].

Nikhil Padhye et.al described a systematic multi-objective problem solving approach, simultaneously minimizing two conflicting goals - average surface roughness ‘Ra’ and build time ‘T’, for object manufacturing in FDM process by usage of evolutionary algorithms [59].

Richard Bibb et.al again takes the focus on the computer-aided design (CAD) and manufacture of custom-fitting surgical guides have been shown to provide an accurate means of transferring computer-aided planning to surgery. To date guides have been produced using fragile materials via rapid prototyping techniques such as stereolithography (SLA), which typically require metal reinforcement to prevent damage from drill bits. The purpose of this paper is to report case studies which explore the application of selective laser melting (SLM) to the direct manufacture of stainless steel surgical guides. The aim is to ascertain whether the potential benefits of enhanced rigidity, increased wear resistance (negating reinforcement) and easier sterilisation by autoclave can be realised in practice[60].

In tissue engineering P.S. Maher et.al focused on hydrogels with low viscosities tend to be difficult to use in constructing tissue engineering (TE) scaffolds used to replace or restore damaged tissue, due to the length of time it takes for final gelation to take place resulting in the scaffolds collapsing due to their mechanical instability. However, recent advances in rapid prototyping have allowed for a new technology called bioplotting to be developed, which aims to circumvent these inherent problems. This paper aims to present details of the process [61].

Lin Lu et.al worked on Musculoskeletal conditions are a major health concern in the USA because of a large aging population and increased occurrence of sport related injuries. Bone tissue engineering may offer a less painful alternative to traditional bone grafts with lower risk of infection. The purpose of this paper is to present a novel porogen-based fabrication system for tissue engineering scaffolds using sucrose ($C_{12}H_{22}O_{11}$) as the porogen buildingmaterial [62].

P.S. Maher et.al described a comparison between two different RP 3D printing methods of fabrication and investigates the merits of each technology for direct cell culture applications using micro-assays, while also examining the dispensing accuracy of both techniques [62].

Ihab El-Katatny et.al recent advancement in fused deposition modelling (FDM) rapid prototyping technology has made it a viable technology for application in reconstructive surgery. Also investigated the errors generated during the fabrication stage of complex anatomical replicas derived from computed tomography coupled with the technique of FDM [64].

Richard Bibb has studied the case which explores the application of selective laser melting (SLM) to the direct manufacture of stainless steel surgical guides. The aim is to ascertain whether the potential benefits of enhanced rigidity, increased wear resistance (negating reinforcement) and easier sterilization by autoclave can be realized in practice. [65].

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In recent years the pre –operative practices are dramatically increased Timon Mallepree generated facsimiled rapid prototyping (RP) models for medical preoperative analysis that demands an answer about the accuracy of medical models. [67].

Manak Jain et.al developed club foot is a historical foot deformity where the foot is turned in and pointing down causing the subject to walk on the outside edges of foot. The non-surgical correction of this deformity is an uncertain challenging problem in the medical domain and it becomes interesting due to the increasing number of such patients. The purpose of this paper is to build a biomodel of this historical foot deformity in newborn babies and hence an attempt to develop a corrective procedure using rapid prototyping technology (RP) [68].

Elena Bassoli used Rapid prototyping technology for optimization the mechanical performances of parts produced by the Direct Metal Casting process varying the thermal treatment parameters. Adopting the optimized settings, a specific dimensional evaluation is planned to calculate the international tolerance (IT) grade ensured by the process.[69].

P.S. Maher et.al has greatly enhanced the area of microfluidic systems invitro field of tissue engineering. Microfluidic systems such as micro channeled assays are now widely used for mimicking ivivo cell behaviour and studies into basic biological research. In certain cases engineered tissue cell design use 3D ordered geometrical configurations i n v i t r o (such as microchannel assays) to reproduce native invio functions. The most common approach for manufacturing micro-assays is now rapid prototyping (RP) technology. The choice of assay material is dependent on the proposed cell type and ultimately the tissue application. However, many RP technologies can be unsuitable for cell growth applications because of the construction methods and materials they employ. The purpose of this paper is to describe a comparison between two different RP 3D printing methods of fabrication and investigates the merits of each technology for direct cell culture applications using micro-assays, while also examining the dispensing accuracy of both techniques [70].

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Prof.D.S. Ingole et.al highlighted the efforts made to improve the application potential of the fused deposition modelling (FDM) process by producing the rapid prototyping parts at minimum cost .Also focused on Build orientation analysis for prismatic, curved boundary, and complex-shaped machine ,biomedical parts is carried out. The mathematical model is formulated to estimate the total cost of part preparation in fused deposition modelling(FDM).

CONCLUSION

The study has revealed that rapid prototyping,has great potential in the manufacturing of customized anatomical implants.Pre-operative models are quiet useful in complicated surgeries that leads to life saving activity also operation time may be reduced & accuracy is increased. Ability to simulate surgical interventions on patient data. This allows you to derive best possible surgical plans by evaluating outcomes of various approaches, validate custom implants and make changes to the surgical plan.

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