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Applications of CT/CAD/RPT in the Futuristic Development of Orthopaedics and Fabrication of Plate and Screw Material from Natural Fiber Particle Reinforced Composites for Humerus Bone Fixation – A Future Drift

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Abstract
This research focuses a new method of using data obtained from CT images combined with digital CAD and rapid prototyping model for the surgical planning of difficult corrective and this new application enables the surgeon to choose the proper configuration and location of internal fixation of plate on humerus bone in the field of orthopaedics.This paper presents the procedure for making model of humerus bone using rapid prototyping technologies [RPT]. The present contribution reports the possible future of utilization of Sisal (Agave sisalana), Banana (Musa sepientum) & Roselle (Hibiscus sabdariffa) fibers from renewable resources as particle reinforcing fillers for bio epoxy resin Grade 3554A and Hardener 3554B as matrix for the first time to develop the biocomposite plate and screw materials using RPT and its application in the field of orthopaedics for bone graft substitutes. This paper to help the doctors to diagnose the state of the bone defect illness with the real models manufactured by the rapid prototyping technology.

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Introduction

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), 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 nowadays 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. This paper covers possibilities of using RP technologies as a multi- discipline area in the field of orthopaedics. Using RP in medicine is a quite complex task which implies a multidisciplinary approach and very good knowledge of engineering as well as medicine; it also demands many human resources and tight collaboration between doctors and engineers. After years of development rapid prototyping technologies are now being applied in medicine for manufacturing dimensionally accurate human anatomy models from high resolution medical image data. The procedure for making humerus bone model using RP technologies is also presented in this paper.

Problem Identification

Trauma is a major cause of death and disability in both developed and developing countries. The World Health Organization (WHO) predicts that by the year 2020, trauma will be the leading cause of years of life lost for both developed and developing nations. Now a days Trauma is mainly due to increase in population as well as increase in transportation. Due to that there is an increase in accidents that causes bone fracture of human body. After consulting with Doctors most of the bone fracture in day-today life occurs in the humerus and femur bones. Machining of ORTHOPAEDIC ALLOYS implants, with High Speed Machining, which offers advantages, but also have disadvantages Titanium is also currently used for bone replacements, but the implants are simple geometric approximations of the bone shape. Mismatches can occur between real bone and implants often causing stress concentrations and premature implant failure. More “conventional” machining of Titanium implants, with 5-Axis High Speed Machining, which offers advantages, but also has disadvantages such as, Machining of titanium can be done economically on a routine production basis, if shop procedures are set up to allow for the physical characteristics common to the metal. The factors which must be given consideration are not complex, but they are vital to the successful handling of titanium. Like stainless steel, the low thermal conductivity of titanium inhibits dissipation of heat within the work piece itself, thus requiring proper application of coolants. Milling of titanium is even more difficult than turning, as chips tend to adhere to the cutter, leaving only a part of each revolution for cutting. Cutting failure in titanium normally is a result of chipping. Milling/machining remains a material removal process, wasting both time and material in the manufacturing process, which impacts on the manufacturing costs.

Rapid Prototyping

Rapid prototyping plays a key role in the development of products. This serves as a design visualization tool as well as for fit and function application to speed up the product development. Rapid prototyping works on the basis of adding layers of material to form the desired shape. The majority of commercial rapid prototyping system build object by adding one layer after another. For simplicity, it can be visualized as stacking slices of bread until complete three-dimensional bread loaf is achieved. Rapid prototyping is a highly automated layer manufacturing process. The object is designed in any solid modeling software (CAD) and the data is converted into a standard format widely known as standard triangularisation language (STL) which is understandable by the rapid prototyping machine. Rapid prototyping software receives data in this format and creates a complete set of instructions for fabrication on rapid prototyping machine such as tool path, layer thickness, processing speed, etc. Rapid Prototyping machine then manufactures the object using layer manufacturing method. Upon completion of a three-dimensional model, it is subjected to post-processing treatment for removing support material that was used to support overhang features during fabrication.

Method

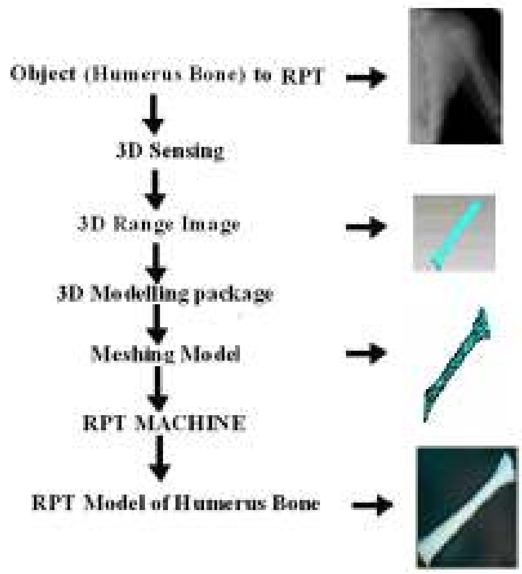

Figure 1 Steps Involved In Rapid Prototyping.

Data acquisition
The morphological data of the humerus bone was collected using the above mentioned CT scanner. A 3D data set was acquired producing 119 sagittal slices with a slice thickness of 1 mm. The reconstructed CT data was transferred to a CD and loaded into the MIMICS software.

Software
The humerus scanning data and model STL manipulation were processed using MIMICS and MAGICS RP Software .The modeling software is a general purpose segmentation programme for grey value images. This software can generate both the frontal and lateral view from the CT scans (Fig. 2). From CT data 3D model of humerus bone has been created. RP made a real copy of the bone (Fig. 2). The real copy was used for planning of orthopedic surgery (Fig. 3) especially choice of implant type, implant position and application procedure.

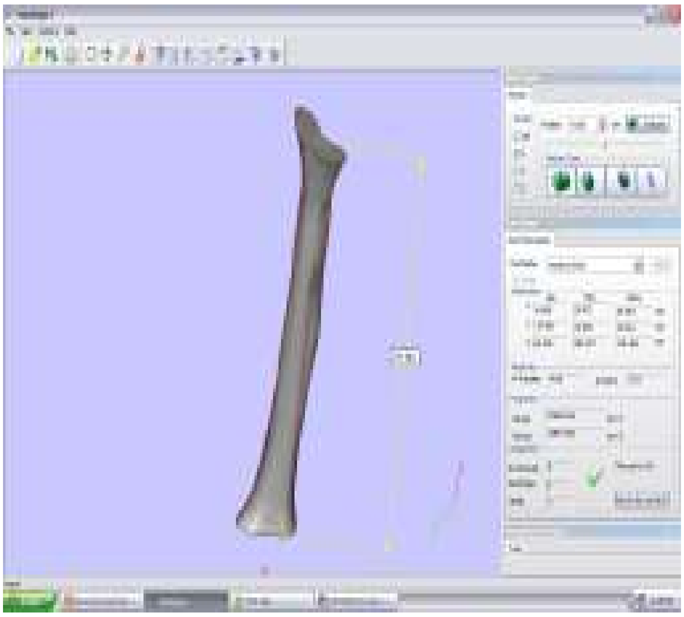

Figure 2 Humerus bone in MAGICS software.

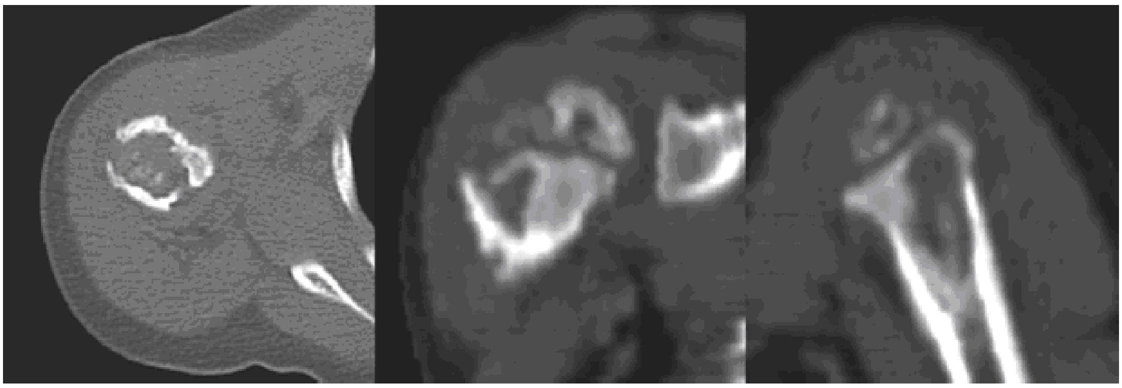

Figure 3 CT scans of humerus bone

Fused deposition modeling (FDM)

The FDM process works as follows; first, a 3D solid model exported to the FDM QuicksliceTM software using the (STL) format. The software generated the process plan that controls the FDM machine's hardware. The hardware for the FDM machine is represented in Fig. 1. The concept is that an ABS filament (A) is fed through a heating element, which heats it to a semi-molten state. The filament is then fed through a nozzle (B) and deposited onto the partially constructed part. Since the material is extruded in a semi-molten state, the newly deposited material fuses with adjacent material that has already been deposited. The head (C) then moves around in the x–y plane and deposits material according to the part geometry. The platform holding the part then moves vertically downwards in the z-plane to begin depositing a new layer on top of the previous one. After a period of time, the head will have deposited a full physical representation of the original CAD file of the humerus bone.

Acrylonitrile Butadiene Styrene (ABS):

Acrylonitrile Butadiene Styrene, chemical formula: (($C_8H_8 \cdot C_4H_6 \cdot C_3H_3N$) n) is a common thermoplastic used to make light, rigid, molded products. ABS plastic ground down to an average diameter of less than 1 micrometer is used as the colorant in some tattoo inks. It is a copolymer made by polymerizing styrene and Acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% Acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of polybutadiene criss-crossed with shorter chains of poly (styrene-co-Acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The most important mechanical properties of ABS are resistance and toughness.

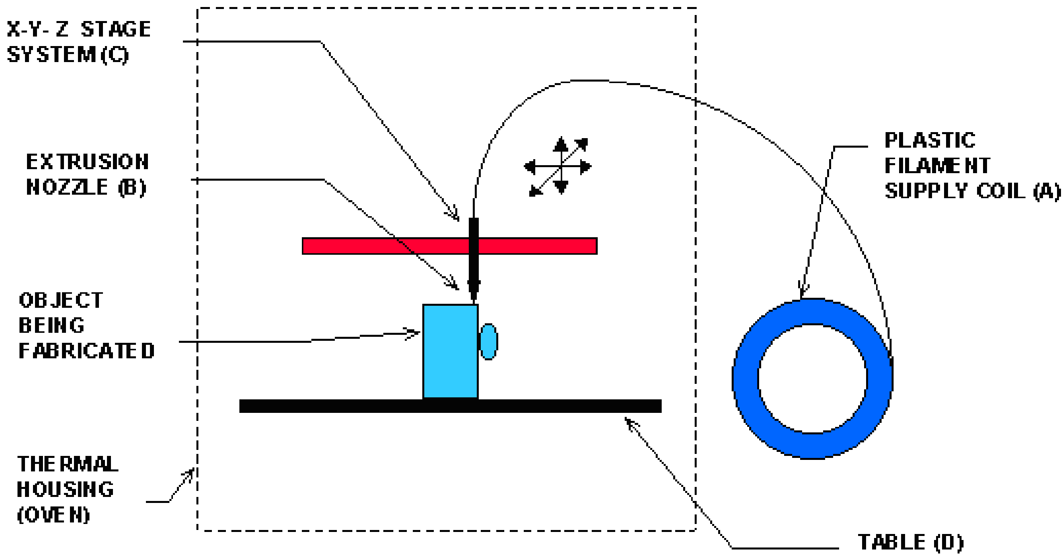

Figure 4 FDM Process representation diagram

Figure 5 RPT Model of Humerus Bone Using ABS material

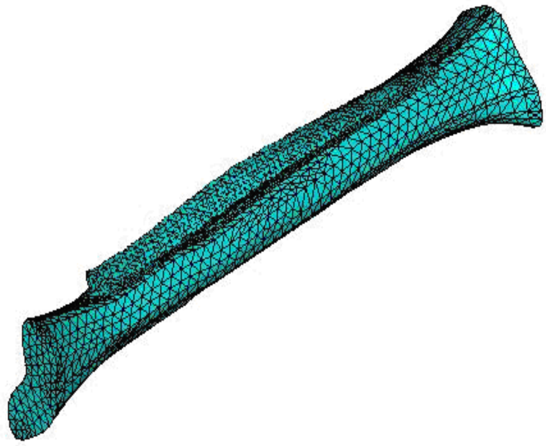

Figure 6 Model of Humerus Bone with plate for planning of orthopedic surgery

Planning and explaining complex surgical operations

This is very important role of RP technologies in medicine which enable pre-surgery planning. The use of 3D model of humerus bone helps the surgeon to plan and perform complex surgical procedures and simulations and gives him an opportunity to study the bony structures of the patient before the surgery, to increase surgical precision, to reduce time of procedures and risk during surgery as well as costs (thus making surgery more efficient). The possibility to mark different structures in different colors (due to segmentation technique) in a 3D physical model can be very useful for surgery planning and better understanding of the problem as well as for teaching purpose.

Teaching purposes

RP models can be used as teaching aids for students in the classroom as well as for researchers. These models can be made in many colors and provide a better illustration of anatomy, allow viewing of internal structures and much better understanding of some problems or procedures which should be taken in concrete case. They are also used as teaching simulators.

Future Augmentation

When a bone is severely crushed, physicians usually cannot set it and bone grafts, or amputation – until now – has remained a primary option. The same is true for bones damaged by disease, such as cancer If, for instance, the humerus bone in the arm is injured and damaged CT scan or MRI image can be made of the good arm bone, and converted to a "growth code" – a 3-D virtual image – of the replacement bone segment needed . As a replacement for of orthopaedics alloys such as titanium, cobalt chrome, stainless steel and Zirconium this project aims to fabricate natural fiber reinforced Polymer composite [NFRPC] plate material with bio epoxy resin Grade 3554A and Hardner 3554B will be coated by calcium phosphate and hydroxy apataite then it can be used for inside fixation on human body for fractured bone.

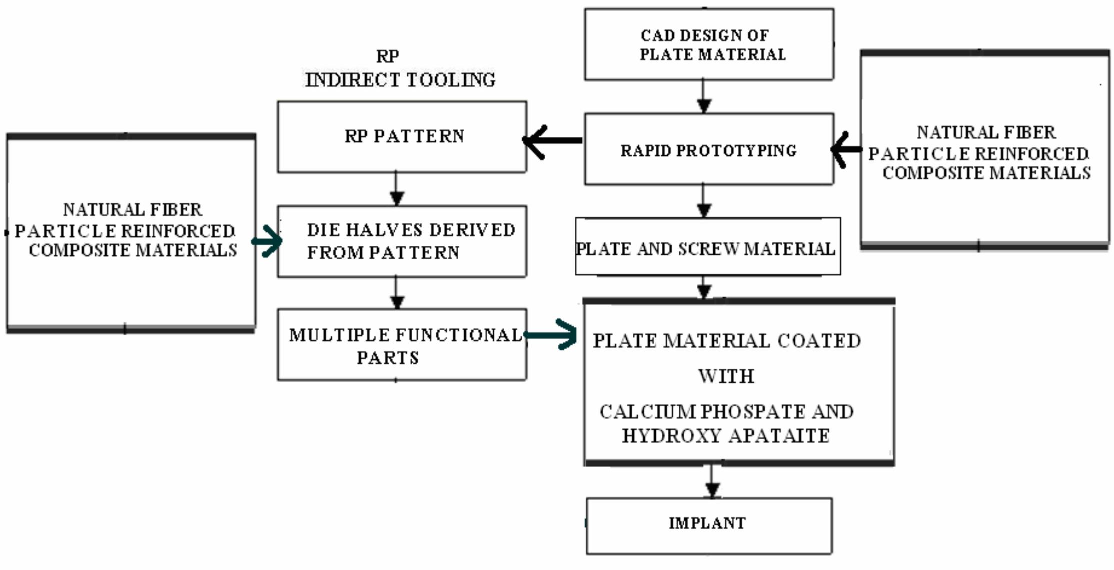

Figure 7 Procedural steps followed to make a NFRPC plate and screw material using RP

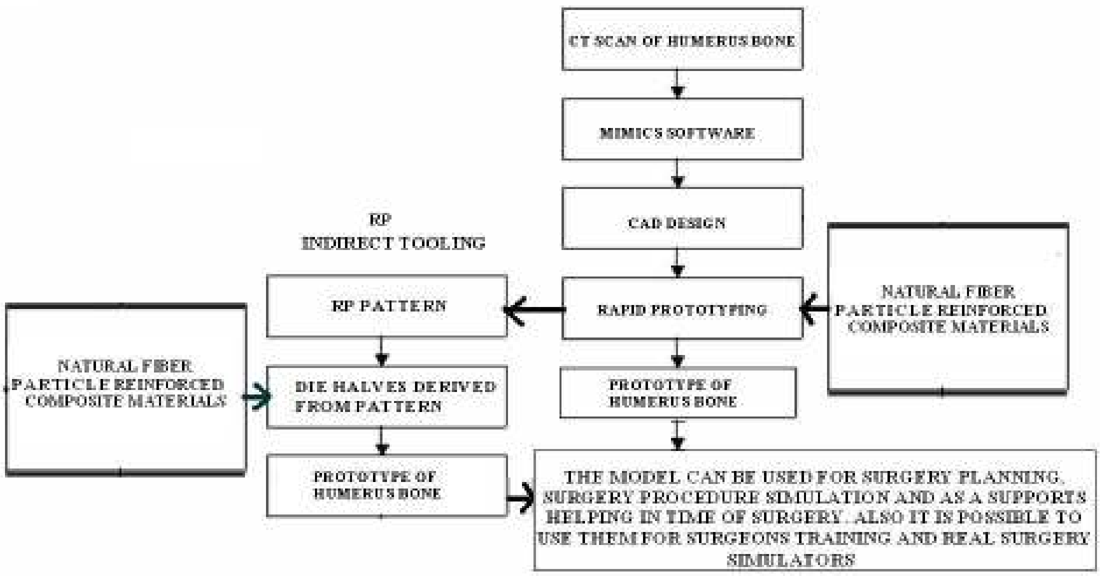

Figure 8 Procedural steps followed to make a NFRPC material of humerus bone using RP

Natural fibers

Natural fibers present important advantages such as low density, appropriate stiffness and mechanical properties and high disposability and renewability. Moreover, they are recyclable and biodegradable. Over the last decade, composites of polymers reinforced by natural fibers have received increased attention. Natural fibers such as sisal and roselle possess good reinforcing capability when properly compounded with polymers.

Uses of Sisal (Agave sisalana)
Products made from sisal are being developed rapidly, such as furniture and wall tiles made of resonated sisal. A recent development expanded the range even to car parts for cabin interiors. Other products developed from sisal fiber include spa products, cat scratching posts, lumbar support belts, rugs, slippers, cloths and disc buffers. Sisal wall covering meets the abrasion and tearing resistance standards of the American society for testing and materials and of the national fire protection association. Products made from sisal fiber are purchased throughout the world and for use by the military, universities, churches and hospitals.

Uses of Roselle (Hibiscus sabdariffa)
The seeds are considered excellent feed for chickens. The residue after oil extraction is valued as cattle feed when available in quantity. Nutritionists have found Roselle calyces as sold in Central American markets to be high in calcium, niacin, riboflavin and iron.

Uses of Banana (Musa sepientum) and Plantain: Culinary uses
Banana leaves, pseudo stems, fruit stalks and peels can all be used for various culinary purposes. Bananas are primarily eaten as a fruit, either on its own or as a part of a salad. All parts of the banana have medicinal applications as well.

Materials
The matrix material used in this investigation was bio epoxy resin Grade 3554A and Hardner 3554B. Supplied by Lab chemicals, Chennai. From last decade, the roselle , banana and sisal fibers were used traditionally in age-old applications in the form of high strength ropes in India especially in South India regions

Manufacturing process

Chemical Treatment
First make fibers in to powdered (particles) material**.** Then the powdered material of fibers should be cleaned normally in clean running water and dried. Take A glass beaker, add 6% NaOH is and 80% of distilled water and made a solution. After adequate drying of the fibers in normal shading for 2 to 3 hours the fibers are taken and soaked in the prepared NaOH solution. Soaking must be carried out for different time intervals depending upon the strength of fiber required. After completion of the soaking process the fibers should be washed in running water and dried for another 2 hours. Then the fibers are taken for the next fabrication process namely the pro-casting process.

Advantages of chemical treatment
First and foremost chemical treatment with NaOH will remove moisture content from the fibers thereby increasing its strength. Secondly the chemical treatment also enhances the flexural rigidity of the fibers. Thirdly this treatment clears all the impurities that are adjoining with the fiber material and also stabilizes the molecular orientation.

Conclusion
An artificial bone model was fabricated using ABS (Acrylonitrile Butadyine Styrene) by Rapid Prototyping Technology. This technique helps to analyze the actual bone structure and plate fixation can be done more accurately. Due to RP technologies doctors and especially surgeons are privileged to do some things which previous generations could only have imagined. However this is just a little step ahead. There are many unsolved medical problems and many expectations from RP in this field. Development in speed, cost, accuracy, materials (especially biomaterials) and tight collaboration between surgeons and engineers is necessary and so are constant improvements from RP vendors. This will help RP technologies to give their maximum in such an important field like medicine. Using the Natural Fiber particle Reinforced Composite material it is possible to fabricate plate and screw for internal fixation on humerus

bone [plate and screw must be externally coated by calcium phosphate and hydroxyl apataite] and prototype model of humerus bone can be used for surgery planning, surgery procedure simulation and as a supports helping in time of surgery. Also it is possible to use them for surgeons training and real surgery simulators. Surgeries supported by the models could be more accurate, with lover risk of possible complications and shorter. Generally it helps to made health care better and cheaper.

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