MODULE – V

APPLICATION OF RAPID PROTOTYPING IN BIOMEDICAL FIELD :

* RP Technologies have been used in a broad spectrum of applications in the field of biomedical engineering.

* A variety of RP systems have been used in the production of scale replicas of human bones and body organs to advance customized drug delivery devices and other areas of medical sciences including anthropology, paleontology and medical forensics.

* Fused Deposition modeling, Selective laser sintering, 3D-printing and stereolithography are most common systems employed in fabrication of tissue engineering scaffolds.

CUSTOMIZED IMPLANTS AND PROSTHESIS :–

* For hip replacements and other similar surgeries, these were previously carried out using standardized replacement parts selected from a set range provided by manufacturers based on available anthropomorphic data and the market needs.

  This works satisfactorily for some types of procedures and patients, but not for all.

* For those patients outside the standard range, in-between sizes, or with special requirements caused by disease or genetics, the surgical procedure may become significantly more complex and expensive.

* For imperfect fits, these implants may even cause poor gait outcomes and further wear or injury to other joints.

* Rp has made it possible to manufacture a custom prosthesis that precisely fits a patient at reasonable cost.

BIOMODELING AS AN AID TO SPINAL INSTRUMENTATION:-

→ Stereotactic Surgery or Stereotaxy is a minimally invasive form of surgical intervention which makes use of a 3D coordinates system to locate small targets inside the body and to perform on them some action such as removal, Biopsy, lesion, injection, Stimulation and implantation.

* In one study, a Novel Stereotactic Technique using Biomodels was developed.

* Bio-modeling was found to be helpful for complex skeletal surgery.

* In a study, 20 patients with complex spinal disorders requiring instrumentation were selected.

* 3D CT scans of their spine were performed and the data was used to generate acrylate biomodels of each spine using RP. The Biomodels were used to simulate surgery.

* Simulation was performed using a standard power drill to place trajectory pins into the spinal biomodel.

* Acrylate drill guides were manufactured using the biomodels and trajectory pins as templates.

* The Biomodels were found to be highly accurate and of great assistance in the planning and execution of the surgery.

* The ability to drill optimum screw trajectories into the Biomodels and then accurately replicate the trajectory was helpful.

* Accurate screw placements were confirmed with post operative CT scanning.
* Approximately 20 minutes were spent before the surgery preparing each biomodel and template.
* Operating time was reduced, as less reliance on intraoperative radiograph was necessary.

DENTAL PRECISION PLANNING:

* Treating an impacted maxillary canine requires identifying its exact position. This can pose a challenge to both orthodontists and oral surgeons.
* By the conventional method of using 2D slices of CT images, it is very difficult to determine the exact location of an impacted tooth.
* A new method of diagnosis and treatment planing of maxillary canine impaction by using CT combined with RP.
* CT image files of a patient with tooth 13 impaction were edited to produce, by means of RP, an anotomic model of the maxillary teeth and a single attachment model that was to be later used to fabricate a metal attachment for bonding to the impacted tooth.
* The dental model was used in the diagnosis and orthodontic treatment planning and for communication.
* The model showed the exact anatomical relationship between the impacted tooth and the other teeth. It was the main aid in the intraoperative navigation during surgery to expose the tooth.

* The metal attachment built from the prototype was bonded to tooth 13 during surgery. Thus RP is also an important tool for fabricating brackets and other precision accessories for specific dental needs.

CONGENITAL MALFORMATION OF FACIAL BONES

→ Restoration of facial anatomy is important in cases of congenital abnormalities, Trauma or post cancer reconstruction.

→ If the patient had a deformed jaw at birth and a surgical operation was necessary to cut out the shorter side of the jaw and alter its position.

→ The difficult part of the operation was the evasion of the nerve canal that ran inside the jaw bone. Such an operation was impossible in the conventional procedure because there was no way of visualizing the inner nerve canal.

→ Using a CAD model reconstructed from the CT images, the position of the canal was identified and a simulation of the amputating process on the workstation was carried out to determine the actual line of the cut.

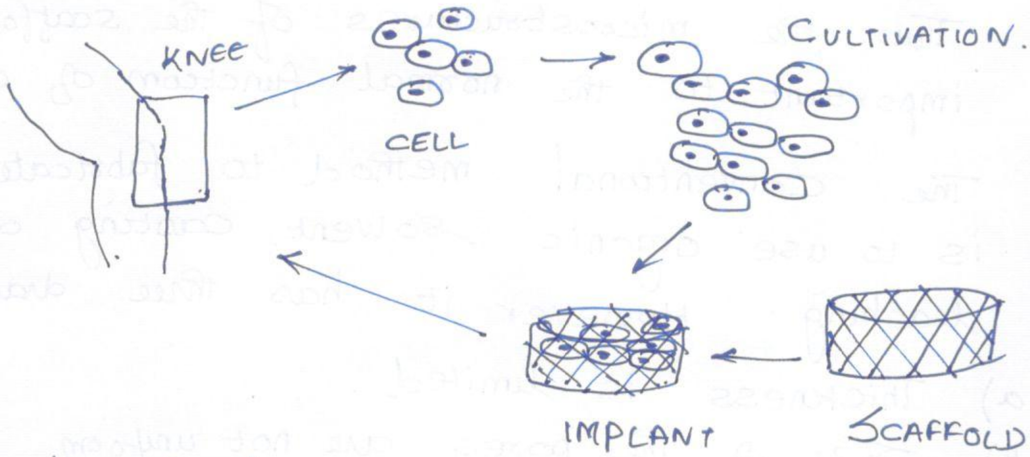
→ Furthermore, the use of a semi-transparent resin prototype of the jaw bone allowed the visualization of the internal nerve canal and facilitated the determination of the amputation line prior to the surgery. The end result was a more efficient surgery and improved post-surgery results.

TISSUE ENGINEERING SCAFFOLDS :-

* Tissue Engineering involves a combination of cells, scaffolds and suitable biochemical factors to improve or replace damaged or malfunctioning organs such as skin, liver, pancreas, heart valve leaflet, ligaments, cartilage and bone.

* A scaffold is a polymeric porous structure made of Biodegradable materials such as PLA [Poly lactic acid] and PGA [poly glycolide or poly (Glycolic Acid]. They serve as supports to hold cells.

* A Typical process in Tissue Engineering is illustrated.



a) Examine the defects and determine if scaffold is necessary.
b) Isolate functional (undamaged) cells from donor tissue to be cultured.
c) Select suitable materials to be prototyped.
d) The patent is introduced to CT or MRI scanning to obtain the geometric data of the defects.
e) Reconstruct CT data into a Virtual model.
f) Design a scaffold with suitable porous Networks to fit the virtual model.
g) Convert CAD model of scaffold to STL file

h) Create the scaffold using RP machine.

i) Transplant cells to the scaffold.

j) Implant the scaffold to the defected receiver site with growth factors.

i) Scaffold degrades gradually while cells grow and multiply.

→ One challenge in Tissue engineering is to improve the Vitality of cells during transplantation

→ When transplanted to the scaffold, a high cell density means that the inner cells lack nutritional input from the exterior environment, causing some of them to die of malnutrition.

→ Thus the microstructures of the scaffold are very important to the normal function of cells.

* The conventional method to fabricate a scaffold is to use organic solvent casting or particulate leaching. However it has three drawbacks.

a) Thickness is limited.

b) Size of the pores are not uniform

c) Interconnectivity or distribution of pores is irregular.

* This certainly will affect the number and quality of the cells that are seeding on the scaffold. To solve these problems, RP was explored.

* Based on cell type, interconnected networks of the scaffold can be predetermined in a computer CAD model. After conversion to a STL file, a fine structure can be built layer by layer using RP machines.

* PCL/HA {Polycaprolactone & Hydroxyapatite} biocomposite is a favourable material for the process.

APPLICATION IN AEROSPACE SECTORS :

* Prototyping Air inlet housing for Gas Turbine Engine.

→ Manufacturer of auxillay engines for Military and Commercial aircraft, needed prototypes of an air inlet housing for a new gas Turbine engine.

→ It first needed mock-ups of the complex design and also several fully functional prototypes to test on the development engines.

→ The part which measures about 250 mm in height and 300 mm in diameter, has a wall thickness as thin as 1.5 mm.

→ To realize the part, Sundstrand used the SLS system at a service bureau to build the evaluation models of the housing and then generate the necessary patterns for investment casting, ultimately the method used for the manufacture

→ As the designs were finalized, new SLS versions of the part were created as Tooling for investment Casting.

Polycarbonate patterns were created, sealed with wax and sent for casting. The patterns were first Coated with a thin layer of polyurethane to fill any remaining Surface pores and provide the necessary surface finish.

→ Then the patterns were used to cast the part in Inconel 718 steel. and finally sent for testing.

APPLICATION OF RPT IN AUTOMOBILE SECTORS

Creating Cast metal Engine Block with RP Process:

→ prototyping of a 4-cylinder engine block was taken for the project under study.

→ The aim was to cast the engine block directly from a Stereolithography Quick cast pattern.

→ The engine block was designed based on ~~be~~ data tranfered to 3D systems where one-piece pattern of the block was built on SLA machine.

→ The pattern was then sent for shell investment casting, resulting in the 300 x 330 x 457 mm engine block being cast in A356-T6 aluminium.

→ The completed engine block incorporated cast-in water jacket, core passage ways and exhibited Grade B radiographic quality in all areas evaluated.

→ The entire prototyping process using RP technology took only few weeks (six weeks) compared to 15-18 weeks using traditional methods and the cost savings is less compared to other process.

→ These two factors are more significant especially in the need for short time to market requirement.

GEOMETRIC INFORMATION SYSTEM APPLICATIONS:

RP has been applied to create physical models of 3D Geographic information sysrem (GIS) objects to replace 2D representation of Geographical information.

a) 3D PHYSICAL MAP :-

* The sensual capability creates a possibility to provide maps for blind and visually impaired persons.
* The haptic experience could be utilized as an additional stimulus for transmitting a cartographic message and to induce insight.

b) 3D REPRESENTATION OF LAND PRICES :-

* A 3D map visualizing the average cost of land in a country or city could be plotted.
* The height of the prisms would be proportional to the average prise of the land.
* In contrast to a 2D choropleth map depicting value classes, the absolute differences in height could be perceived immediately.

c) 3D REPRESENTATION OF POPULATION DATA

* The volume of the prisms could be proportional to the number of inhabitants in each unit area.
* The height of the prisms would then be proportional to the population density.

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RAPID PROTOTYPING CLASSIFICATION :

SUPPLY PHASE	PROCESS	LAYER CREATION TECHNIQUE	PHASE CHANGE TYPE	MATERIALS .
1) LIQUID .	a) Stereolithography	Liquid layer curing	Photopolymerization	photopolymers [Acrylates, Epoxies, colorable resins, filled resins)
	b) Fused Deposition Modeling	Extrusion of melted polymer	Solidification by cooling	Polymers [ABS, polyacrylate, wax, metals, ceramics with binder]
	c) Ballistic - particle manufacturing	Droplet deposition	Solidification by cooling	polymers, wax.
	d) Solid Ground curing	Liquid layer curing and milling	photopolymerization	photopolymers.
2) POWDER	a) Three - Dimensional Printing	Layer of powder and binder droplet deposition	No phase change	Ceramics, polymer and metal powders with binders.
	b) Selective - Laser Sintering .	Layer of powder	Laser driven sintering Melting and solidification	Polymers, metals with binders, metals, ceramics, sand with binder.
3) SOLID .	Laminated object Manufacturing	Deposition of sheet material	No phase change	papers, Polymers.