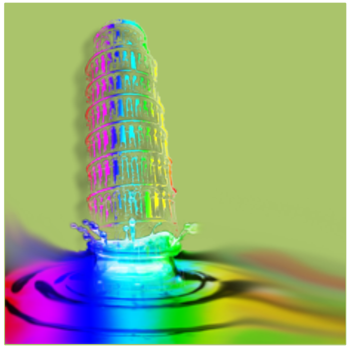
Note sui sistemi di Rapid Prototyping



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NC Machining & Rapid Prototyping

- NC machining requires a skilled operator to set up machine and to specify tools, speeds, and raw materials.
- For this reason, many do not consider NC machining to be a true Rapid Prototyping (RP) technique. True RP should create a part from some model without any assistance.

- NC Machining does have some benefits over "true" RP
- NC Machining allows a wide range of materials for prototypes (true RP techniques often prohibit material for function prototype)
- NC Machining allows better accuracy than most "true" rapid prototyping techniques (may be needed for fit prototypes)
- True RP techniques can produce a prototype of a part that is impossible to manufacture. NC machining often reveals manufacturing limits in a given design.

Additive Fabrication vs Subtractive Fabrication

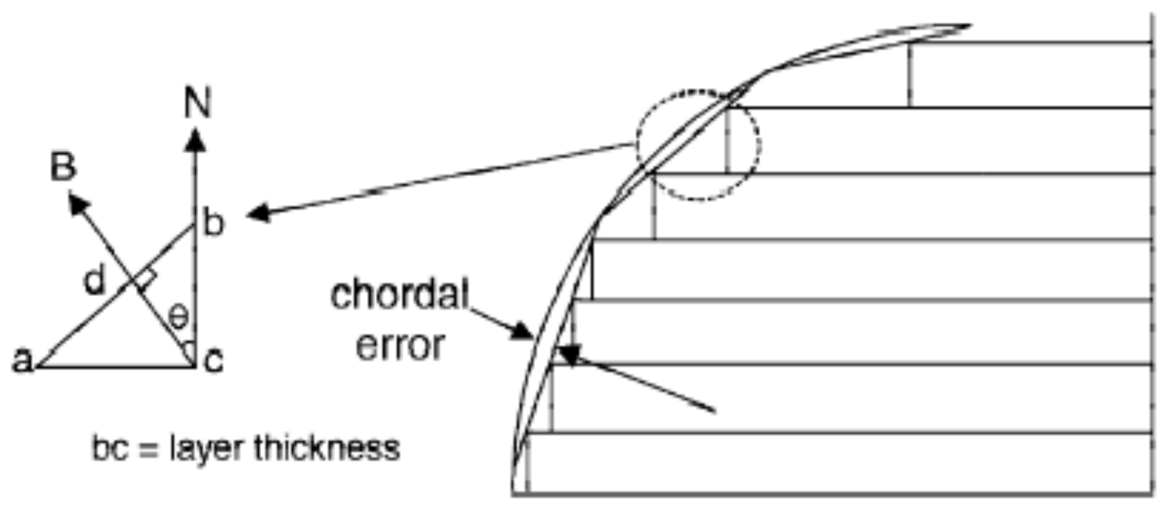
- Additive Fabrication methods (RP) can not become complete replacement for the Subtractive Fabrication methods (Milling, Turning, EDM etc.)
- Subtractive methods:
  - have reached an extraordinary level of development and they continue to evolve.
  - they are fast, versatile, inexpensive, readily available and well-understood by large numbers of practitioners.
  - in many cases they are quite sufficient to make prototypes rapidly,
  - no equal when it's necessary to make very precise parts in final materials.

Additive Fabrication vs Subtractive Fabrication

- Additive technologies are instead complementary to subtractive ones, if the situation calls for:
  - complex or intricate geometric forms,
  - simultaneous fabrication of multiple parts into a single assembly,
  - multiple materials or composite materials in the same part.
- Additive technologies make it possible to completely control the composition of a part at every geometric location.
- Thus, <u>RP is the enabling technology</u> for controlled material composition as well as for geometric control.

Limitations of RP Methods

- ACCURACY
  - Stair Stepping:
    - Since rapid prototyping builds object in layers, there is inevitably a "stairstepping" effect produced because the layers have a finite thickness.

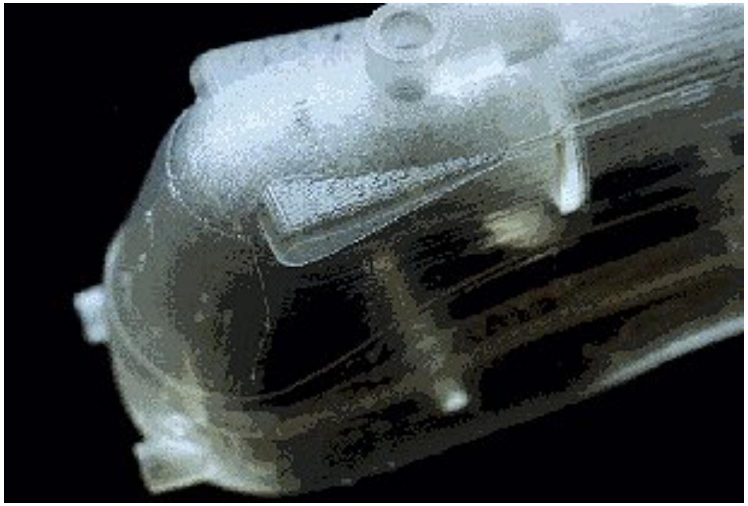


Limitations of RP Methods

- ACCURACY
  - Precision:
    - tolerances are still not quite at the level of CNC,
    - Because of intervening energy exchanges and/or complex chemistry one cannot say with any certainty that one method of RP is always more accurate than another, or that a particular method always produces a certain tolerance.

Limitations of RP Methods

- FINISH
  - The finish and appearance of a part are related to accuracy, but also depend on the method of RP employed.
  - Technologies based on powders have a sandy or diffuse appearance, sheet-based methods might be considered poorer in finish because the stairstepping is more pronounced.



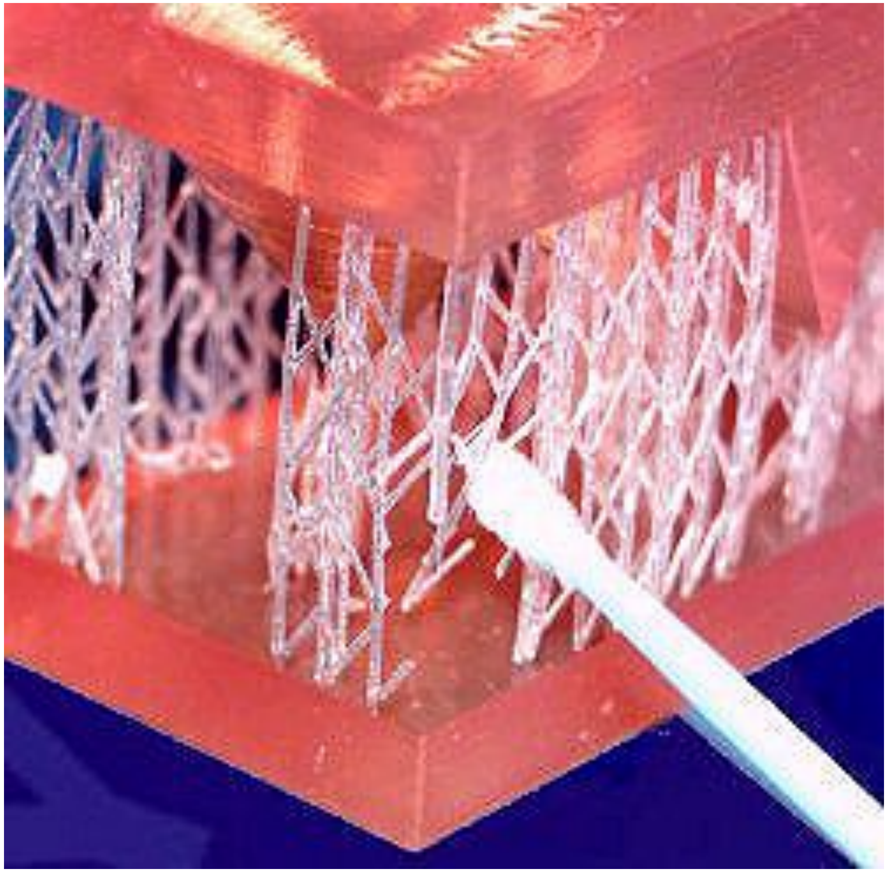
Limitations of RP Methods

- Secondary Operations
  - Parts made by stereolithography are frequently not completely cured when removed from the machine. Final cure is effected in a box called a post-cure apparatus (PCA)
  - Parts made by three dimensional printing (3DP) and MultiJet Modeling (MJM) can be very fragile and might not be able to take normal handling or shipping stresses. These parts are often infiltrated with cyanoacrylate adhesive or wax as a secondary operation to make them more durable.
  - Metal parts will almost certainly require final machining and must usually undergo a thermal baking cycle to sinter and infiltrate them with a material to make them fully-dense.
  - Other than powder-based methods all other methods require a support structure to be removed in a secondary operation which may require considerable effort and time.

Limitations of RP Methods

Support structure (red material), water-soluble, fused deposition modeling (FDM).

Support structure, stereolithography.



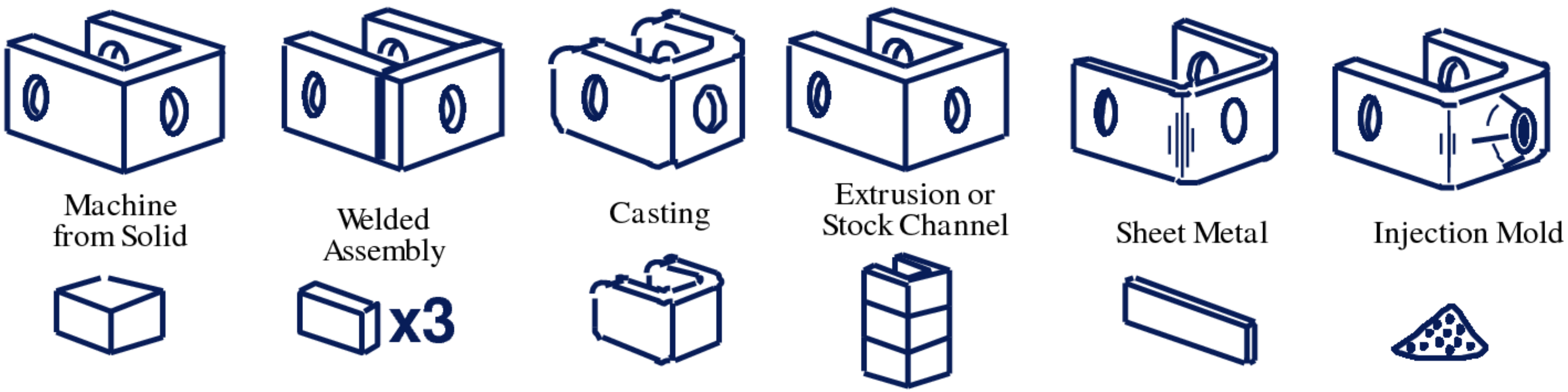
Limitations of RP Methods

- SYSTEM COSTS
  - RP systems cost from $30,000 to $800,000 when purchased new. The least expensive are 3D Printer and FDM systems; the most expensive are specialized stereolithography machines.
  - In addition, there are appreciable costs associated with training, housing and maintenance. For example it can cost more than $20,000 to replace a laser in a stereolithography system.
- Material
  - High cost. Available choices are limited.

MARKET, ALCUNE CLASSIFICAZIONI, TABELLE E LINK UTILI

Design for manufacture

A simple fork end for Pneumatic Piston



$95	$75	$55	$25	$1.20	$0.30

Piece-part costs

$10	$100	$400	$8	$5,000	$60,000

Tooling costs

Production Volume: Recurring Costs versus Non-Recurring Costs

Ottenere un preventivo...

- http://www.xpress3d.com

Rapid Prototyping (RP)

- Features of RP Systems

  The features of some commercially available RP systems can be summarised into:

  - Process type - Stereo lithography, Laminating, Fused deposition modelling, Sintering of powder, Solid ground curing, etc.
  - Work space(mm) - depends on the models
  - Material - photopolymer resin, coated paper, ABS, wax, metal alloy, etc.

Rapid Prototyping (RP)

- Features of RP Systems

	Layer thickness(mm)	Accuracy (mm)
SLA	0.05 - 0.3	0.01 - 0.2
LOM	0.1 - 1	0.1 - 0.2
FDM	≈0.05	0.130 - 0.260
SLS	≈0.08	0.03 - 0.4
SGC	0.01 - 0.15	0.05 - 0.5

Rapid Prototyping

Machine	Cost	Material	Application
Fused Deposition Modeler 1600 (FDM)	$10/hr	ABS or Casting Wax	Strong Parts Casting Patterns
Laminated Object Manufacturing (LOM)	$18/hr	Paper (wood-like)	Larger Parts Concept Models
Sanders Model Maker 2 (Jet)	$3.30/hr	Wax	Casting Pattern
Selective Laser Sintering 2000 (SLS)	$44/hr	Polycarbonate TrueForm SandForm	light: 100%; margin: 0">Casting Patterns Concept Models
Stereolithography 250 (SLA)	$33/hr	Epoxy Resin (Translucent)	Thin walls Durable Models
Z402 3-D Modeller (Jet)	$27.50/hr	Starch/Wax	Concept Models

Comparison chart

Technology	SLA	SLS	FDM	Wax Inkjet	3D printer	LOM
Max Part Size (cm)	30x30x50	34x34x60	30x30x50	30x15x21	30x30x40	65x55x40
Speed	Average	Average to fair	Poor	Poor	Excellent	Good
Accuracy	Very good	Good	Fair	Excellent	Fair	Fair
Surface finish	Very good	Fair	Fair	Excellent	Fair	Fair to poor
Strenghts	Market leader, large part size, accuragy, wide product	Market leader, accuracy, materials, large part size	Lab on desktop, price, materials	Accuracy, finish, lab on desktop	Speed, lab on desktop, price, color	Large part size, good for large castings, material cost
Weaknesses	Post processing, messy liquids	Size and weight, system price, surface finish	Speed	Speed limited, materials, part size	Limited materials, fragile parts, finsh	Part stability, smoke, finish and accuracy

Which Process Should You Pick?

- Do you need a prototype (not just a model)?
  - SLS, FDM (for robustness, strength).
- Do you need a mold for a small batch?
  - SLA (for smooth, hard surface).
- Does part need multiple colors?
  - 3D Color-Printing.
- Does part have convoluted internal spaces?
  - 3D-Print, SLS, SLA (easy support removal).

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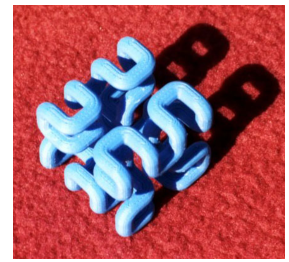
Informal Process Ratings Matrix



	Holoow Sphere	Hollow sphere with drain/vent	2 Nested, perforated shperes	3D hilbert pipe	Preassembled gear mechanism
LOM	★	★	★	★★★	★
SLA	★	★★★	★★★★	★★★★★	★★★
FDM	★	★	★★★★	★★★★	★★★
3D-P	★	★★★★★★	★★★★★★	★★★★	★★★★★
SLS	★	★★★★★★	★★★★★★	★★★★★	

Another Classification

- Photopolymers
- Deposition (filament and inkjet)
- Lamination
- Powders (layered and sprayed)

Vendors (1/4)

- Photopolymers
  - 3D Systems (formerly DTM, US)
    - http://www.3dsystems.com
  - EOS (Germany)
    - http://www.eos.info/en
  - CMET (Japan)
    - http://www.cmet.co.jp/eng/
  - Envisiontec Perfactory (Germany)
    - http://www.envisiontec.de

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Vendors (2/4)

- Deposition
  - Stratasys (US) (filament)
    - http://www.stratasys.com
  - Solidscape (US and the Netherlands) (inkjet)
    - http://www.solid-scape.com
    - Now it is a Stratasys company
  - 3D Systems (formerly DTM, US)
    - http://www.3dsystems.com
    - ThermoJet™
  - Soligen (US; casting cores/patterns)
    - http://www.soligen.com

Vendors (3/4)

- Lamination
  - Solidica (US)
    - http://www.solidica.com
  - Cubic Technologies (formerly Helisys, US)
    - http://www.cubictechnologies.com

Vendors (4/4)

- Powder
- Selective Laser Sintering
  - 3D Systems
  - EOS

MEDICAL APPLICATION OF RAPID PROTOTYPING

RP in Medical Applications

- Modelling in Medical Applications:
- Models are created using medical imaging data obtained from
  - a standard Computed Tomography (CT) or
  - Magnetic Resonance Imaging (MRI).
- Bone structures such as skull or pelvis are all imaged using CT.
- Soft tissue structures such as brain and organs are best imaged by MRI.
- The “slice” data from CT or MRI are processed into 3D images by using dedicated software.

Invisalign Orthodontic Aligners

- An aligner for orthodontic use manufactured using a combination of rapid tooling and thermoforming.

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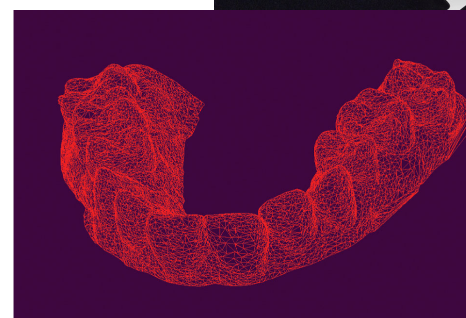
Invisalign Orthodontic Aligners



- The manufacturing sequence for Invisalign orthodontic aligners.
  a. Creation of a polymer impression of the patient's teeth.
  b. Computer modeling to produce CAD representations of desired tooth profiles.
  c. Production of incremental models of desired tooth movement.
  d. An aligner is produced by thermoforming a transparent plastic sheet against this model.

Source: Courtesy of Align Technologies, Inc.

Manufacturing, Engineering & Technology, Fifth Edition, by Serope Kalpakjian and Steven R. Schmid.
ISBN 0-13-148965-8.

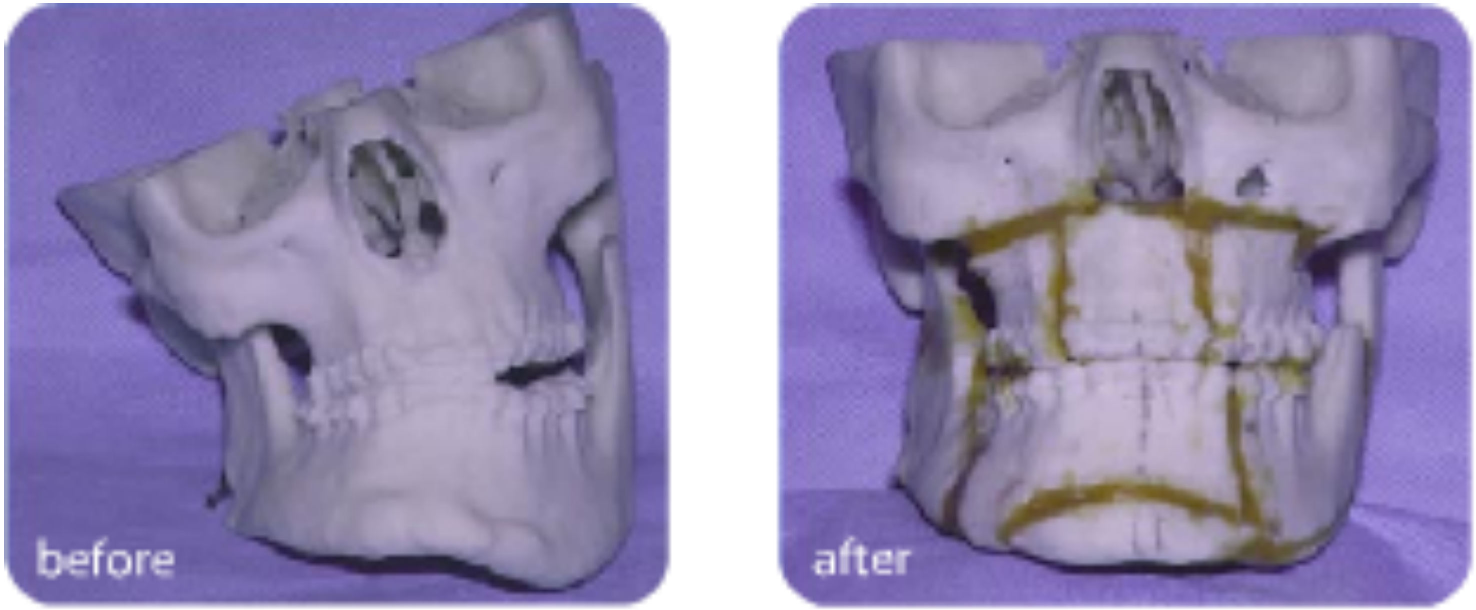
RP in Medical Applications

- Oral Surgery




RP in Medical Applications

- Oral Surgery



RP in Medical Applications

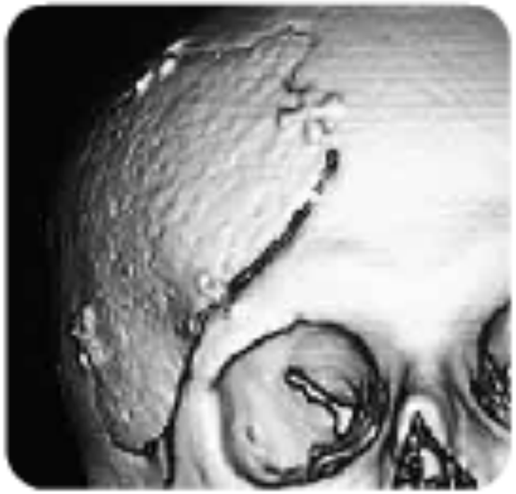
- Oral Surgery




RP in Medical Applications

- Oral Surgery






RP in Medical Applications

- Prosthesis Applications
  - A bone structure which was produced from ceramic powder embedded paper material in LOM.

RP in Medical Applications

Photograph of Twins showing Ahmed on the left and Mohamed on the right.

Illustration of the Twins showing their external soft tissue with Mohamed on the left and Ahmed on the right.

RP in Medical Applications

Photograph of Twins showing Ahmed on the left and Mohamed on the right.

Illustration of the Twins showing their external soft tissue and cranial bones in the area of conjunction.

RP in Medical Applications

Photograph of Twins showing Ahmed on the left and Mohamed on the right.

Illustration of the Twins showing their external soft tissue, bone structure and cranial vasculature at the area of conjunction.

RP in Medical Applications

Photograph of Twins showing Ahmed on the left and Mohamed on the right.

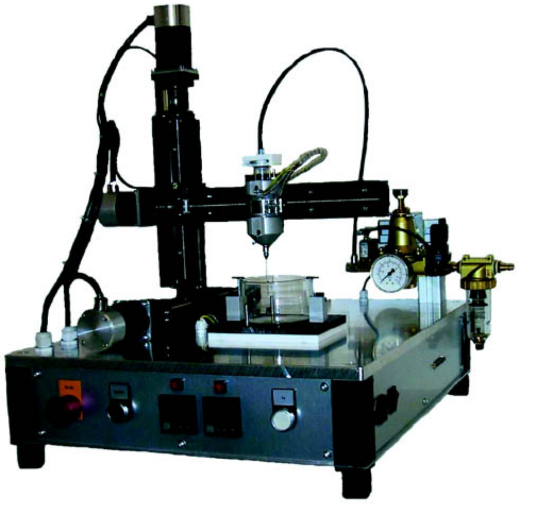
Illustration of the Twins' bone structure.

RP in Medical Applications

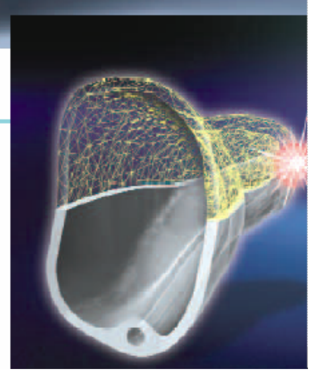
- Bone Structure with the cranial vasculature highlighted in red.
- The model was made using SLS with a special material called Stereocol. (Coloured when exposed to high power laser)

RP in Medical Applications

- TISSUE ENGINEERING
  - Actual living tissue cells are extracted from the patient and seeded onto a carrier which accomodates and guides the growth of new cells in 3D within laboratory environment.

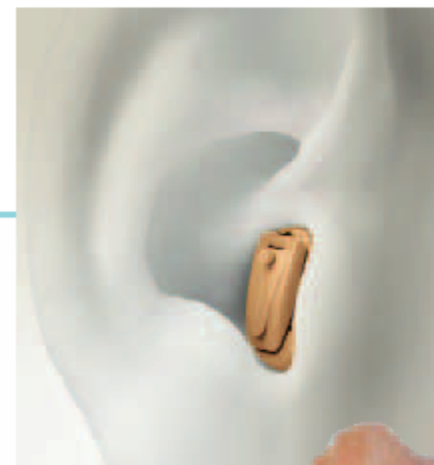


RP in Medical Applications



The Human Ear and Auditory Canal

- Unique like a fingerprint
- Dynamic during head and yaw movements
- Soft in the cartilageous area
- Sensitive tissue in the bony part



laser-sintered in-the-ear hearing devices

Earmold Key Criteria

- Acoustical seal
- Comfortable seat
- Retention in the canal

Bone Structure

- STL Data produced from Micro-CT scan data
- Multiple specimens of identical structure can be made, reducing samples variations.