Review Article

Rapid prototyping technology in maxillofacial prosthodontics: Basics and applications

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Curiosity is the Mother of 'INNOVATION'. Advent of rapid prototyping technology has opened up new perspectives for design &production in the field of Prosthodontics.Rapid prototyping refers to the automatic construction of mechanical models with 3D printers or stereolithography machines. When attempting to restore a face with a prosthesis, the prosthesis should ideally be customized to restore the anatomy as closely as possible. This process is difficult & time consuming & demands a high level of artistic skill to form a mirror image & achieve a good esthetic match. Rapid prototyping methodologies use an additive process of building an object in layers defined by a computer model that has been virtually sliced. Limitations to use of rapid prototyping technology include the high cost of the equipment, complicated machinery needed, and reliance on special expertise to run the machinery during production .The expense could be justified in light of the many other applications that could benefit from the rapid prototyping which includes construction of surgical stent, fabrication of burn stents ,without subjecting sensitive burn tissues to impression- taking procedures, manufacturing of lead shields to protect healthy tissue during radiotherapy & production of study models prior to surgery for pre-surgical planning. This article reviews the development & current technology available in rapid prototyping & application of this innovative technology in Prosthodontics.

Key words: Maxillofacial models, rapid prototyping, stereolithography

INTRODUCTION

Successful innovation is a feat.........not of intellect, but of will!

- Joseph Schumpeter

People are generally fascinated by innovation, especially if the end result can provide real benefits. Rapid prototyping is extremely beneficial in prosthodontic planning and simulation and represents the technology for today.

The shift from visual to the visual-tactile representation of anatomical objects introduces a new kind of interaction called 'Touch to comprehend.'

This article discusses the birth of a new technology capable of directly generating physical objects from graphical computer data.

'What is rapid prototyping?'

Rapid prototyping refers to automatic construction of mechanical models from graphical computer data.[1] Rapid prototyping is a type of computer-aided manufacturing (CAM) and is one of the components of rapid manufacturing.

Two main methods of rapid prototyping are:
Additive - widely used
Subtractive - less effective

Common additive technologies are:

- Selective laser sintering
- Fused deposition modeling
- Multi-jet modeling
- Stereolithography.

This article mainly focuses on stereolithography as a technology in building maxillofacial models. Stereolithography builds models through layer-by-layer polymerization of a photosensitive resin.

Components of stereolithography device are[2] [Figure 1]

- A container filled with liquid resin (acrylic or epoxy)
- A movable elevator platform inside the container
- An ultraviolet laser with beam focusing optics on the top

This article was presented at the 7th All India PG convention held at Chennai, on 25th-27th August 2005

Figure 1: Stereolithography device

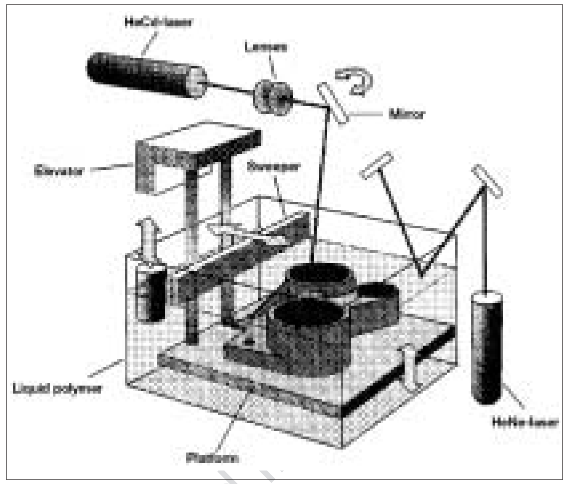

Figure 2: Components of stereolithography device

- A deflecting mirror system to control the laser beam

Basic operation[1]

- CAD model - entire rapid prototyping process begins with a CAD model.
- Translator - CAD file goes from CAD to rapid prototyping translator, so that CAD data is input in the 'tessellated' stereolithography format, which has become standard of rapid prototyping field. In this, boundary surfaces of object are representated as numerous triangles just like 'facets of a cut jewel.'
- Supports - To ensure that the recoater blade will not strike the platform upon which the part is being built and to provide a simple means of removing the part from the platform upon completion supports are provided.
- Slice - Part to be built and supported must be sliced, i.e., the part is mathematically sectioned by the computer into a series of parallel horizontal planes like floors of a tall building.
- Merge - Supports and parts have their computer representations merged.
- Prepare - In this step certain operational parameters are selected such as number of recoater blade sweeps per layer, the sweep period, and the desired Z-wait. Z-wait is the amount in seconds that the system is instructed to pause after recoating.

BUILDING OF MODEL [FIGURE 2]

The laser beam draws onto the surface of the resin stimulating the local polymerization of liquid. The laser solidifies at first the object borders, then the internal parts. When the layer is polymerized, the elevator platform goes down a defined distance, typically a layer thickness of 0.1-0.5 mm, submerging the model in the liquid resin bath. A sweeper smoothes out the surface and the resin levels out. Thus, the hardened layer is covered with a new liquid layer and drawing continues. In this way the model is built layer by layer.

To prevent sagging of isolated and overhanging parts during the building process, supporting structures (supports) must be provided in the production process. Completed objects are finished by draining unnecessary liquid resin, stripping off supports and curing the object surfaces under ultraviolet floodlights. Depending on complexity of the model, the number of slices and resolution of data set, production of a model may last up to 24 hours.

Two sides of coin

Advantages	Disadvantages
· High geometrical accuracy (0.1 mm)	· Complex and time-consuming post-processing, especially support removal
· Transparency of used material which allows to look into the model	· Costly cleaning process.

Applications in maxillofacial prosthodontics[3]

- Production of auricular and nasal prosthesis
- Obturators
- Duplication of existing maxillary/mandibular prosthesis especially crucial when an accurate fit to natural teeth or an osseointegrated implant is needed
- Manufacturing of surgical stents for patients with large tumors scheduled for excision
- Manufacturing of lead shields to protect healthy tissue during radiotherapy treatment
- Fabrications of burn stents, where burned area can be scanned rather than subjecting delicate, sensitive burn tissue to impression - taking procedures.

Fabrication of model wax ear using stereolithography[4]

3-D data are obtained from a patient using a MRI scanner employing a dual echo steady state 2-D sequence. The patients head is stabilized, but without compression of normal ear.

Over a period of approximately 7 minutes, a zone is scanned from above the supra-orbital ridge to below the columella anteriorly and posteriorly from the level above and below the ear. About 1 mm contiguous axial slices (approximately 70-75 slices) are recorded and downloaded on an optical disk. Data is then transferred to 8-mm magnetic tape. Sliced data on tape are processed into 3-D format using a customized software program, e.g., Breuckmann optoTop system.

3-D VISUALIZATION OF FACE AND EAR[4]

Initially all of the soft tissue features of the face are displayed. This image is rotated so that the surface contour detail of both the unaffected normal ear and the affected side of face are viewed.

The image of normal ear is extracted, mirrored, and then placed on the deficient side. The software allows the mirrored image to be moved anteroposteriorly and supero-inferiorly and projected from skull to provide the appropriate prominence of ear.

Fabrication of obturator[5]

Any patient who undergoes maxillectomy needs an obturator as the prosthesis of choice. The prosthodontist makes an impression of the defect to be restored. There is a limit to the accuracy of the impression, as one cannot get all the undercuts of the defect in the impression. These undercuts play an important role in the retention of the prosthesis. Another way to get a model of the defect is by stereolithography.

When after surgical resection of the tumor the tissues have healed a CT scan is made. This is the base for the stereolithographic soft-tissue model. Once we have the model we block out the undercuts, which we do not need for the retention of the obturator and pour silicone in the model. In this way we get an accurate obturator, which fills out the defect. This obturator is fitted in the patient; the only adjustment we have to do is correcting the support of the cheek because when making the CT scan the patient does not wear his prosthesis so the cheek collapses. This adjusted silicone obturator is transferred into a definite one.

The advantages of the stereolithographic soft-tissue model are:

- That is less aggravating for the patient,
- The treatment of patients having a trismus is much easier, and
- It is more accurate than making an impression.

DISCUSSION

The goal of providing the best patient care is contrasted with rising cost.

Rapid prototyping can be generated so quickly that it becomes simple to verify that the design does not indeed contain the features desired and conversely does not contain any features that are not desired.

The saying ‘a picture is worth a thousand words’ has been updated by stereolithography users to suggest that ‘one real prototype is worth a thousand pictures.’

Limitations to use of rapid prototyping technology include high cost of equipment, complicated machinery needed, and reliance on special expertise to run the machinery during production.

How to overcome these limitations?

1. Setting up a pilot lab at one of the established dental laboratories.
   a. business case with projected return on investment and other benefits to be prepared.
   b. funding to be solicited from the industry, professional associations, and multi-lateral aid organizations like world bank.
2. If results are encouraging, regional service centers could be set-up

CONCLUSION

The Greek sculptor Phidias - fourth century BC is known for the technical and artistic quality of his representation of the human being, full of dignity and nobility. His conserved masterpiece, the Friese of Parthenon, is still today a great symbol of European culture. The maxillofacial models resulting from stereolithography should contribute to make disabled, injured, or ill persons resembling again to the ideal human beings of Phidias. Keeping this as our motto we can say that; we have only scratched the surface of rapid prototyping technologies full potential, but the goal is to encourage the application of rapid prototyping in the field of maxillofacial prosthodontics.

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Source of Support: Nil, **Conflict of Interest:** None declared.

Announcement

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