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Anaplastology - A new era in Maxillofacial Rehabilitation

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Abstract

Rehabilitation of maxillofacial defects will be necessary to restore their lost function. Maxillofacial prosthodontist should have a wide range of knowledge about the recent trends and the future insights to give their best to rehabilitate the lost structures of the body. The loss of facial structures caused due to various reasons such as trauma, congenital deformity, tumours, gunshot injuries, accidents etc., can cause psychological as well as physiological impact and can affect the individual's quality of life by hampering their day-to-day functions such as mastication, phonetics and aesthetics. Prosthodontic intervention can help reduce hospitalizations, speeds recovery and reduces expenses. But it requires utmost care while fabricating the desired prosthesis so that it will not cause any discomfort for the patient. Anaplastology, as a new approach, can bring changes in the field of medicine, dentistry, research and development. A thorough knowledge in the field of Anaplastology would help the expert health professionals to understand and recognise the pathology, its prognosis, rehabilitation and finally to design his treatment plan which uplifts the quality of life of the patient which is at most important.

The main aim of the Anaplastological team would be to prevent postoperative complications, to maintain and improve balance, general mobility, educate and finally to provide functional independence. Psychological reassurance and encouragement play a very important role in the recovery of the patient.

Keywords: Anaplastology, Nasal prosthesis, Retinal prosthesis, Auricular prosthesis, Hand prosthesis, Leg prosthesis, Craniofacial reconstruction, Burn masks, 4 D printing and 5 D printing.

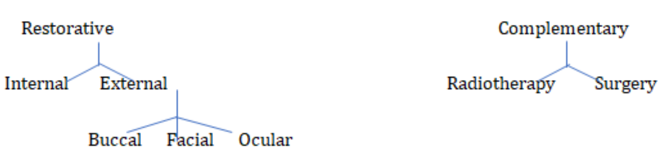
Introduction

Face is the individuals contact with the world and it forms the physical basis for personal recognition. Facial attractiveness not only impacts social interactions, but also exerts a significant influence on self-concept, psychological well-being and social welfare. In this modern competitive society, our present generation is giving importance to a pleasing appearance which often means difference between success and failure.

Physical attractiveness is regarded as an important ingredient to success. Thus, patients suffering from severely disfigured facial structures which can be due to various etiological factors such as acid attacks, chemical burn, fire attacks undergo severe emotional trauma leading them to depression and also to an extent of committing suicide. Prosthesis will offer the advantage of medically uncomplicated rehabilitation of defects and also, they can be readily removed to allow evaluation of the health of underlying tissues. Prosthetic reconstruction of maxillofacial defects has become easy with the help of Anaplastological team. Anaplastology in Greek means Ana-again, a new, upon. Plastos-something made, formed or molded. Logy-the study of. It is a branch of medicine dealing with the prosthetic rehabilitation of an absent, disfigured, developmental and acquired defects. The term Anaplastology was coined by Sir. Walter G Spohn and is used world – wide.

Classification of maxillofacial Prostheses

In general, maxillofacial prostheses can be classified as restorative or complementary. Restorative prostheses substitute for bone loss or repair deformities of facial contour. Complementary prostheses help during plastic surgery, in the pre-, trans-, or postoperative period and in radiotherapy sessions



Maxillo facial prosthesis Nasal prosthesis

Facial defects resulting from neoplasm, congenital malformation or trauma can be restored with facial prosthesis using different materials and retention methods to achieve life-like look and function. The nose is relatively immobile structure which can be re-established by nasal prosthesis. Lot of factors such as harmony, texture, color matching and blending of tissue interface with the prosthesis are important for successful results [1].Materials commonly used for fabrication of facial prostheses are acrylic resins, acrylic copolymers, vinyl polymers, polyurethane elastomers and silicone elastomers, but none has fulfilled all requirements of a satisfactory prosthesis.[2] Thermally activated acrylic resin and heat cured silicone at room temperature are the most commonly used materials for manufacturing facial prostheses. Greater preference is given to silicone material in consideration that acrylic resin has no flexibility. The acrylic resin has advantages of color stability and useful for upto 2 years. However, silicone remains the most widely used materials for facial restorations because of their surface texture and good hardness.[3] In recent years, with the development of computer technology in modern medicine, new technologies of computer-aided design and manufacturing (CAD-CAM) for nose prostheses have increased.

Recently, there are new protocols for constructions of an eye glasses supported nasal prosthesis and an implant-supported prosthesis for a nose defect using CAD-CAM techniques.

CAD – CAM

A protocol based on 3-D reconstruction, computer-aided design and rapid prototyping technologies is followed together with conventional silicone processing to construct the nasal prosthesis [4] (Fig: 1).

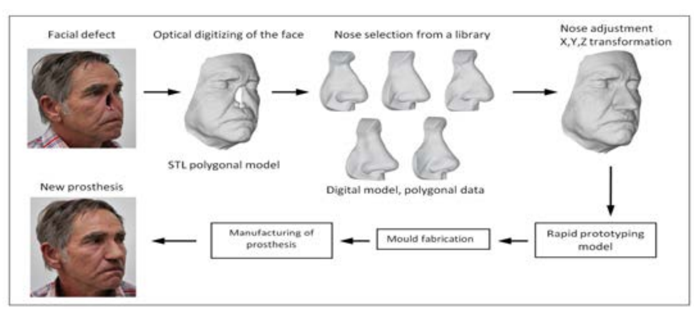


Fig. 1: Design process and the methodology of the Nasal Prosthesis manufacturing.

Implant-Retained Nasal Prosthesis

The placement of implants and associated reconstructive surgical procedures aim at the retention of the prosthetic device. They also seek to facilitate the design and provision of a prosthesis that can restore the tissue defect and provide for the maximum improvement in long-term function, comfort and esthetics.[5]

Nose Prosthetics–Alloplastic Nasal Reconstruction

Fig. 2: Real Life Skin™ Nasal Prosthesis Technologes Diagram

Nose Prosthesis Retention

Retention of RealLifeSkin™ nose prostheses is accomplished by use of patented Intra-Anatomy™ (also called Internal Fixation Retention- IFR), osseointegration, medical adhesive, use of eye glasses, or a combination of these methods. The above diagram depicts the use of osseointegration and the Intra-Anatomy™ retention methods. These methods may or may not be used together. During the first Prosthetic Clinic visit, each nose prosthesis patient is evaluated individually to best determine which prosthetic retention method or combination of methods is best for them (Fig: 2).

Retinal prosthesis

Facial deformities due to inborn or acquired facial defects has a crippling effect on the psychology of a patient leading to significant physical and emotional problems. Eye being a vital organ in terms of vision and an important component of facial expression [6]. Due to retinal degeneration (e.g., retinitis pigmentosa) or Age-related macular degeneration (AMD) millions of people worldwide lose their photoreceptors [7]. In situations like irreparable trauma, malignant orbital tumours, infections, painful blind eye and sympathetic ophthalmia, surgical removal of an eye is inevitable. Peyman, Saunders and Goldberg (1987) classified the surgical procedures adopted for the removal of an eye into three general categories such as enucleation, evisceration and exenteration. An ocular prosthesis is a maxillofacial prosthesis that artificially replaces an eye missing as a result of trauma, surgery or congenital absence.

Retinal implants

Retinal prostheses for restoration of sight to patients blinded by retinal degeneration are being developed by a number of private companies and research institutions worldwide. The system is meant to partially restore useful vision to people who have lost their photoreceptors due to retinal diseases such as retinitis pigmentosa (RP) or age-related macular degeneration (AMD) [8].

Epiretinal (on the retina), subretinal (behind the retina) and suprachoroidal (between the choroid and the sclera): are the three types of retinal implants currently in clinical trials.

Retinal implants introduce visual information into the retina by electrically stimulating the surviving retinal neurons. Elicited perception had a low resolution and may be suitable for light perception and recognition of simple objects so far [9] (Fig: 3).

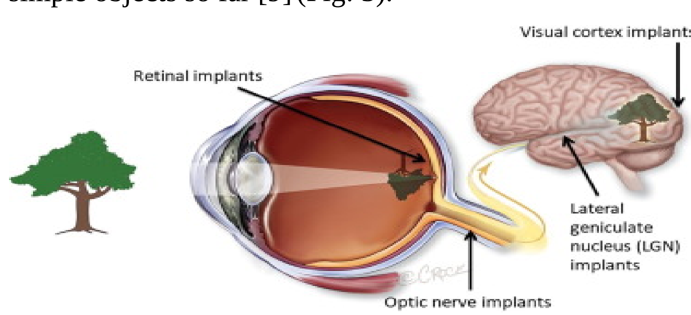
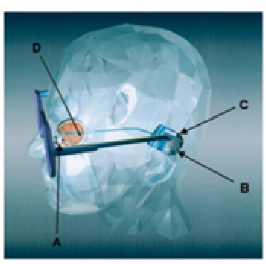


Fig.3: Schematic representation of Retinal implants

Design principles

Epiretinal implants are placed on top of the retinal surface, above the nerve fiber layer, directly stimulating ganglion cells and bypassing all other retinal layers. Array of electrodes is stabilized on the retina using micro tacks which penetrate into the sclera. Typically, external video camera onto eyeglasses acquires images and transmits processed video information to the stimulating electrodes via wireless telemetry. An external transmitter is also required to provide power to the implant via radio-frequency induction coils or infrared lasers. The real-time image processing involves reducing the resolution, enhancing contrast, detecting the edges in the image and converting it into a spatiotemporal pattern of stimulation delivered to the electrode array on the retina [10]. The majority of electronics can be incorporated into the associated external components, allowing for a smaller implant and simpler upgrades without additional surgery. The external electronics provides full control over the image processing for each patient (Fig: 4).



A. Camera in the glass frame

B. wireless transmitter

C. Extraocular electronic case (receiver)

D. Intraocular implant (electrodes array)

Fig. 4: Schematic showing the concept of the retinal prosthesis.

Advantages

Epiretinal implants directly stimulate the retinal ganglion cells, thereby bypassing all other retinal layers. Therefore, in principle, epiretinal implants could provide visual perception to individuals even if all other retinal layers have been damaged.

Disadvantages

Since the nerve fiber layer has similar stimulation threshold to that of the retinal ganglion cells, axons passing under the epiretinal electrodes are stimulated, creating arcuate percepts and thereby distorting the retinotopic map. So far, none of the epiretinal implants had light-sensitive pixels and hence they rely on external camera for capturing the visual information.

Therefore, unlike natural vision, eye movements do not shift the transmitted image on the retina, which creates a perception of the moving object when person with such an implant changes the direction of gaze. Therefore, patients with such implants are asked to not move their eyes, but rather scan the visual field with their head.

Additionally, encoding visual information at the ganglion cell layer requires very sophisticated image processing techniques in order to account for various types of the retinal ganglion cells encoding different features of the image.

Subretinal implants (Fig: 5**)**

1. Optobionics was the first company to develop a subretinal implant.
2. Initial reports indicated that the implantation procedure was safe and all subjects reported some perception of light and mild improvement in visual function.
3. The Retina Implant AG device developed by Germany contains 1500 microphotodiodes, allowing for increased spatial resolution, but requires an external power source.
4. Patients receiving subretinal implants report perception of phosphenes, with some gaining the ability to perform basic visual tasks, such as shape recognition and motion detection.

Design principles

Subretinal implants sit on the outer surface of the retina, between the photoreceptor layer and the retinal pigment epithelium, directly stimulating retinal cells and relying on the normal processing of the inner and middle retinal layers.

Adhering a subretinal implant in place is relatively simple, as the implant is mechanically constrained by the minimal distance between the outer retina and the retinal pigment epithelium.

A subretinal implant consists of a silicon wafer containing light sensitive microphotodiodes, which generate signals directly from the incoming light. Incident light passing through the retina generates currents within the microphotodiodes, which directly inject the resultant current into the underlying retinal cells via arrays of microelectrodes.

The pattern of microphotodiodes activated by incident light therefore stimulates a pattern of bipolar, horizontal, amacrine and ganglion cells, leading to a visual perception representative of the original incident image. In principle, subretinal implants do not require any external hardware beyond the implanted microphotodiodes array [9].

However, some subretinal implants require power from external circuitry to enhance the image signal.

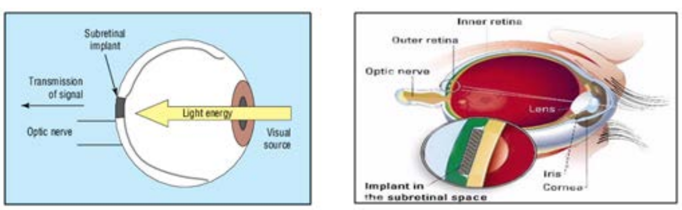


Fig. 5: Schematic representation of subretinal implants

Auricular Prosthesis

An auricular prosthesis is an artificial substitute for malformed or removed parts of the pinna. Prosthetic ears are needed when the natural ones are lost. They are indicated when surgical procedures cannot produce satisfactory functional or aesthetic results and when the physical condition of the patient does not permit all of the necessary surgical protocols. Repair by flaps may cover the recurrence of malignancy in any area previously treated either by surgery or radiotherapy [1].

Methods of Retention for Auricular Prostheses

In the mastoid region, prostheses may be retained either by

1. Medical adhesives
2. Osseo-integrated titanium implants.

Retention by Implants

The advent of percutaneous titanium implants has revolutionized the fixation of auricular prostheses, because this method guarantees secure and reliable retention. Bone anchorage has significant advantages over the other methods of retention [11].

Advantages	**Disadvantages**
Well suited for complex anatomical structures such as the auricle	Not ideal for replacement of mobile parts of face (in the auricular region, jaw movements with mouth opening have to be considered)
Optimal camouflage	“Foreign body”/have to be taken off at night
No donor site morbidity	Color mismatch with changing complexion/discoloring by cigarette smoke
Predictable cosmetic result	Cost
Method is simple and fast.	Renewal every 2–3 years
Early detection of tumor recurrence	
Secure retention	
Edges can be made extremely thin to become transparent and blend into the face.	

Implant Systems

The first system was the Branemark system, which is a solitary screw-type implant made out of commercially pure titanium with a minimally rough surface. Most osteosynthesis plates are produced according to American Society for Testing and Materials various titanium alloys, such as the very popular alloy titanium 6-aluminium 4-vanadium (Ti6Al4V) are used in orthopedic titanium implants that have to bear more strain.

While there is a great diversity of implant systems and manufacturers for dental implants, there are only few systems available for craniofacial prostheses [12].

Hand Prosthesis

The loss of one or both hands is a devastating experience which requires significant psychological support and physical rehabilitation. The hand is an integral component of the human body with an incredible spectrum of functionality. The majority of hand amputations occur in working-age males, most commonly as a result of work-related trauma or as casualties. Congenital deficiencies, cancers and vascular disease are also major causes of amputations.

Recent Advances

1. Three-dimensional printing
2. Bio-inspired dexterous robotics hands
   a. Hand bio-mimetic compliance control structures of finger.
   b. Development of bio-mimetic robot hand using parallel mechanism
   c. Zurich–Tokyo hand: Inspired by the muscletendon system of the human hand
   d. Squse life-like robot hand
3. Bionic and prosthetic hands
   a. iLIMB hand
4. Sensory motor systems of artificial and natural hands
5. Fda approved ‘‘luke’’ prosthetic arm
6. prosthesis re-creates sensation of touch

Squse life-like robot hand

A Japanese based company, known as Squse, Kyoto, has built a crude robotic hand resembling a real-life hand (Fig: 6). It is known as the Robot Hand H-Type. The hand is powered by a series of actuators and has multiple joints and moveable polycarbonate bones. The robotic hand is covered with silicone rubber to give a skin like look.

The robotic hand has the ability to lift and move small objects. The hand was built from a polycarbonate skeleton.

The hand skeleton, weighing 220g, is covered by a skin which is made of soft silicone weighing 120g. The hand is designed to lift up to 1.5kg load.

Fig.6: Squse life-like robot hand

It is available in two variations. One is more human resembling and is known as the H-Type Squse Hand. The other is known as the G-Type Squse Hand, is mounted on a base and resembles industrial robots. The entire arm has 16^0 of freedom, thereby permitting the hand to move in a human-like manner.

It can perform a full-hand squeeze to a delicate two finger pinch used to move delicate and soft objects. The hand can also handle delicate grips as it is designed to pack, handle and even harvest fruits and vegetables without bruising them or to handle fragile goods or factory parts being processed. The entire hand weight is 340g. This also allows the hand to be used as a prosthetic limb [13].

Leg prosthesis

A prosthetic limb is an artificial replacement for a biological limb that may have been lost due to disease, injury or deformation.

The two primary sources could be the causes of lower limb amputations. The first cause of amputations is diabetes and its related ailments. Traumatic injury or a wound resulting from an external source is the second leading reason for amputation [1]. Diabetes can damage the nerves of the foot and blood vessels. It also leads to secondary illnesses such as peripheral arterial disease.

Some of the symptoms of the peripheral arterial disease include cramping in the calf or buttocks muscles which worsens during walking and also hardens the patient's veins, restricting blood flow to limbs and eventually leading to amputations. Many sufferers of diabetes do not realize their foot has been injured, has ulcers or is infected due to the nerve damage. The second leading cause of amputations is a traumatic injury, the causes of amputations from traumatic injury are car accidents and injuries by machines.Parts of a prosthetic limb (Fig: 7)

Fig. 7: A prosthetic device for a transfemoral device.

Physical Therapy

It is necessary for the patient to become comfortable with the device and learn to use it in order to meet the challenges of everyday life once the prosthetic limb has been fitted. The patients must learn special exercises that strengthen the muscles used to move the prosthetic device at the same time Some new amputees are trained to wash the devices including the socks daily and to practise getting them on and off.

Some patients fitted with an artificial leg undergo physical therapy. It typically takes 18-20 weeks for a new amputee to learn how to walk again.

The Future

According to many experts, there is vast room for improvement in the future of prosthetic limbs. A prosthetic limb is preferably simple in design, yet it is a sophisticated device. The ideal prosthetic device should be easy for the patient to learn how to use, be comfortable and easy to put on and take off, require little repair or replacement, be easily adjustable, be strong yet lightweight, look natural and be easy to clean.

Carbon fibre is a strong, lightweight material that is now being used as the basis of endoskeletal parts (the pylons). In the past, it was used primarily for reinforcement of exoskeletal prostheses, but some experts claim that carbon fibre is a superior material that will eventually replace metals in pylons.

One researcher has developed software that superimposes a grid on a CAD scan of the stump to indicate the amount of pressure the soft tissue can handle with a minimum amount of pain. By viewing the computer model, the prosthetist can design a socket that minimizes the amount of soft tissue that is displaced.

An experimental pressure-sensitive foot is also in the works. Pressure transducers located in the feet send signals to electrodes set in the stump. The nerves can then receive and interpret the signals accordingly. Amputees can walk and also do dynamic functions such as dancing as normally on the new device because they can feel the ground and adjust their gait appropriately.

Another revolutionary development in the area of prosthetic legs is the introduction of an above-knee prosthesis that has a built-in computer that can be programmed to match the patient's gait, thereby making walking more automatic and natural.

Craniofacial Reconstruction

Trauma, decompressive craniotomies and bone flap loss due to infection contribute to the cause of cranial vault defects which compromises the patient's esthetics and also expose a significant area of the brain. Cranioplasty will be required to compensate for the defect and alleviate various signs and symptoms.

Various types of materials are now available for reconstruction of cranial defects: -

1. Autogenous bone - It is the first documented bone autograft which was described by Walther in 1821 where he replaced the bone plug after trephination and noted partial healing.
2. Poly Methyl methacrylate - It is an acrylic-based resin which is widely used in craniofacial reconstruction.

- Advantage of PMMA: - As it is a poor conductor of heat and is highly resistant to compressive and torsional forces, it is the most commonly used alloplastic material for cosmetic and reconstructive surgeries. PMMA is also radiolucent and noncarcinogenic. Goyal and Goyal demonstrated the posttraumatic restoration of the large cranial defect with alloplastic heat-cure PMMA resin material in the Indian subcontinent albeit without the use of titanium mesh in recent literature.
- Demerits of PMMA include:
  - Rate of infection is higher than autogenous bone.
  - Composite tensile displacement profile is low.
  - Smooth surface characteristics prevents tissues that are in growth.
  - It is contraindicated in children as they do not accompany the growth of cranial skeleton.

3. Hard Tissue Replacement - It is another polymeric composite consisting of a poly methyl methacrylate substrate sintered with polyhydroxyethyl and a calcium hydroxide coating which shields the poylmethylmethacrylate from the external surface.
4. Hydroxyapatite – It is the primary mineral component of teeth and bone. It is more common forms of calcium phosphate in clinical use. It has a hexagonal structure and can be produced synthetically as a ceramic by a process called sintering. It has excellent tissue compatibility and the advantage of being osteoactive, radiolucent and readily available.
5. Porous polyethylene – It is commonly used for facial augmentation and to restore continuity to craniofacial skeletal defects. Polyethylene resins are straight-chain aliphatic hydrocarbons that are inert and promote little tissue reactivity.
6. Bioactive glass particulate (Nova Bone) - Bioactive materials are defined as those that elicit a specific biological response at the interface of the material that results in the formation of a bond between the tissue and the material. This minimizes the formation of a fibrous capsule around the implant.
7. Demineralized bone – It is another alternative for reconstruction of the craniofacial skeleton. Recently, demineralized bone paste has become commercially available. An advantage of this biomaterial is that it is porous and is easily molded to fit the defect. The

material does not harden but remains as a paste intended to serve as a matrix for bone ingrowth [14].

Additive manufacturing

Additive manufacturing (AM) or rapid prototyping (RP) is a fabrication technique using the additive method, based on the successive addition of fine layers of material. The process starts with a 3D computer model of the part, which is electronically sliced. These slices are used to provide 2D contour lines which will define, in each layer, exactly where material is going to be added. These layers are sequentially processed, generating the physical part through stacking and adhesion of them, beginning at the bottom and working up to the top part [15].

Creation of a bio model and customized implant

The bio model was constructed by 3D virtual model from computed tomography with the help of a software and materials such as powder gypsum, binder and resin. It also facilitates communication between professionals and patients. Bio models allow for the simulation of osteotomies and of resection techniques, the measurement of structures (Fig 8). The materials that can be used are Titanium (Ti64) because it fulfills the mechanical and chemical requirements for surgical implant applications and is inert. The implant surface was finished then by polishing and sterilization of the biomodel [16].

Fig:8. Biomodel and customized implant for craniofacial reconstruction surgery.

Burn Mask

In this competitive society our modern generation is giving importance to the pleasing appearance which is regarded as an ingredient to success. Attractive individuals are said to be more successful as they possess a tremendous self confidence in them. So, patients suffering from severely disfigured facial structures which can be due to various etiological factors such as acid attacks, chemical burn, fire attacks undergo severe emotional trauma leading them to depression and also to an extent of committing suicide.

Today, with the recent advances, we as a Prosthodontist can assure these patients to rehabilitate their facial appearance to face the social embarrassment with confidence using a new approach which makes use of BURN MASKS.

Custom burn masks / hanger burn mask is a clear plastic prosthesis used to apply pressure to minimize the formation of hypertrophic scars or to flatten those already present by using material called Silon-STS. By applying direct pressure over the wound site it prevents the excess formation of collagen fibers and realigns them in a normal pattern, while protecting the wound site from unwanted external forces that may impair wound healing [17]

Application and Removal

1. Apply the mask by placing it on the chin and pushing it up and into the face. If the Burn Mask is not positioned properly, it will allow scars to rise. Take care in proper positioning.
2. Affix the bottom strap first, middle and then top strap last.
3. To remove, the straps can be unfastened in any order. Slowly pull the Burn Mask off of the face to ensure the skin does not stick to the mask.

Wearing Schedule

An individual should start to wear the mask for ½ to 1 hour three times a day. Increase the wearing time each day until wearing it all day. When wearing a mask for the first time, it is recommended to slowly increase the tension on the straps as well.

Cleaning and Maintenance

The Burn Mask should be cleaned every time it is removed. It is recommended to use a mild, hypoallergenic soap. Soaps with deodorants or lotions should be avoided. Thoroughly rinse and dry the Burn Mask before putting back on.

Tips and Problem Solving

- Care should be taken to avoid prolonged exposure of the mask to sunlight or heat. Heat can cause the mask to deform.
- Store the mask in a safe place when not wearing. The material of the mask is brittle and can easily crack.
- If the Velcro tabs of the mask fall off, clean off any Velcro residue first and then apply a new piece. Do not use crazy glue or similar products to attach the Velcro.

In order to get the most benefit from the mask, monthly adjustments with an Orthotist should be made. The mask will need to be remolded to accommodate changes of the face

Recent Trends

4D Printing: In dentistry, 4D printing would have an excellent impact as this technology can produce dynamic and adaptable materials to be functional in the oral environment under the continuously changing thermal and humidity conditions.

4D printing is based on adding a fourth dimension to the standard 3D printing, that is, motion over time. The aim of 4D printing is to produce functional objects rather than static ones. The printed models transform into a predetermined shape and function after fabrication.

Skylar Tibbits and his co-workers converted the stable 3D- printing materials into actively moving objects by the use 4D-printing approach. They designed self-folding structures that reshape overtime under certain environmental conditions and converted the stable 3D-printing materials into actively moving objects.

Based on the concept of motion over time, 4D scanning could allow the modelling of complex anatomical structures which can improve the preoperative planning. 4D printing is the process of self-folding overtime under thermal and humidity changes. 4D printing relies on 3D printing of multi-materials followed by selective photo-curing to give the 4D-printed objects the nature of motility.

Steps for fabrication:

1. Processing: The model is firstly processed into an original shape then it is intermediately temporized into another shape
2. Programming: following the processing, the model is programmed to convert to another shape when exposed to certain stimuli in a self-folding pattern. the outcome of the recently introduced 4D printing technology is called self-folding materials.

In removable prosthetic dentistry

- The technology can produce materials with similar properties of the natural hard and soft tissues.
- 4D-printed materials can adapt to the types and directions of forces in the oral cavity.
- 4D-printed prosthetic materials can have reliable fitting and retention characteristics and optimal dynamic properties according to their self-folding nature.

- The denture base can be fabricated that encompass elasticity and thermal changes similar to the periodontal ligaments or overlying mucosa.
- A variety of designing options can be provided for patients with individual demands. For example, patients with areas of residual ridge resorption can be managed by installing additional materials that compensate for bone loss.

In Implant dentistry

- 4D-printed structures can be fused to the currently available dental implants by modifying their apical portion to act as soft base under implants.
- Avoids injury of vital structures around implant site such as maxillary sinus or inferior alveolar nerve. Thus, the technique can overcome sophisticated surgeries such as sinus augmentation when done for implant cases. (Fig: 9)

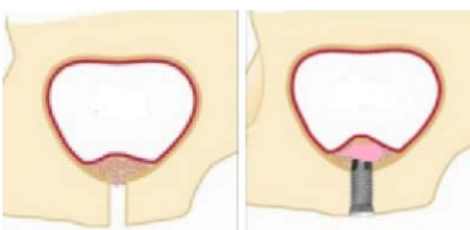


Fig. 9: 4D-printed membrane is placed between a dental implant and a vital to act as a soft cushion to prevent injury

5 D Printing

Five-dimensional printing can easily take over different challenges. This technology will be applicable for complex shape manufacturing, planning, education and making reliable operation.

The dental implants, dentures and other devices are not flat and have a curved shape. 5-D technology could manufacture a complex curved shape with higher strength. These can improve patient outcomes and reliability of implant after surgery. They provide dental surgical guides with a high degree of precision. The concept of 5D printing originated from American University by Mitsubishi Electric Research Laboratories by William Yerazunis.

Functioning of 5 D Printers

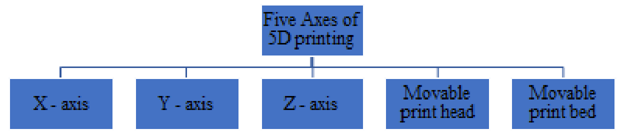


Fig.10: Five Axes of 5D printing

In 5D printing, during the printing process, the print plate also moves along with the print head. In 3D printing technologies, printing is done in three axes, i.e., X, Y and Z axes. In addition to these three axes, 5D printing adds two more axes, i.e., moving of the printing head and moving of the print bed at defined angles (Fig: 10).

This technology is a new version of 3D printing which allows curved layers; therefore, it prints stronger complex design parts. One of the benefits of 5D printing is the 25% less usage of material than 3D printing. Limitations are the extra cost for two more axes, for the movable print head and bed. There is also a requirement of highly skilled human resources in developing and maintaining the 5D printer [18].

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