Restoring form, function and aesthetics - A comprehensive review of maxillofacial prosthetics.

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ABSTRACT:

Background: The goal of maxillofacial prosthetics is to provide patients with custom-designed prostheses that mimic natural facial structures, allowing them to regain vital functions like speech, mastication, swallowing, and facial expressions. It will take a multidisciplinary team with experience in prosthodontics, oral and maxillofacial surgery, otolaryngology, and facial plastic surgery to advance this field.

Material and Methods: A comprehensive examination of pertinent research and publications in the field of maxillofacial prosthetics was carried out. Using preset keywords pertaining to maxillofacial prosthetics, prosthesis materials, fabrication methods, and patient outcomes, searches were conducted across electronic databases, such as PubMed, Scopus, and Google Scholar. Selected articles addressing developments, challenges, and prospects in maxillofacial prosthetics went through screening and eligibility criteria.

Results: Significant advances in materials and fabrication methods, such as the use of silicone elastomers, CAD/CAM technology, and 3D printing, were found in the literature analysis. Two other essential components of maxillofacial prosthetic care that have emerged are interdisciplinary collaboration and patient-reported outcomes. On the other hand, difficulties with prosthesis stability, upkeep, and biointegration were noted, highlighting the need for more study and advancement in the area.

Conclusion: The review emphasizes the significant advancements in patient-centered care, interdisciplinary collaboration, fabrication techniques, and materials that have led to significant progress in maxillofacial prosthetics. In order to improve patient care and quality of life, this review advocates for ongoing advancements in maxillofacial prosthetics and offers insightful information to clinicians, researchers, and educators.

Keywords: 3d printing, adhesives, maxillofacial prosthetics, maxillofacial rapid prototyping, retentive aids.

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Introduction

Maxillofacial prosthetics is a subfield of prosthodontics that deals with restoring and replacing the missing stomatognathic and craniofacial structures with prostheses that may or may not be removed on a regular or elective basis.[1] These craniofacial deformities are congenital and acquired due to developmental disturbances, trauma, onco-surgeries, and necrotizing diseases.[2] So, these maxillofacial Prostheses help in restoring form, function, and aesthetics as well as provide a positive impact on the patient's psychology and hence help them regain their confidence and self-esteem.[3-5] The first maxillofacial prosthesis was documented by a French surgeon, Ambrose Pare long back in the 16th century.[6] The maxillofacial prostheses are classified into intraoral, extraoral, and combination types.[7,8] Modern maxillofacial prostheses not only replace missing craniomaxillofacial structures, but

they also help with function, form restoration, surgical assistance, and the reduction of postoperative morbidity.[9] The successful clinical outcome of maxillofacial prosthetics depends on the retention and the aesthetics of the prostheses.[10]

This comprehensive article starts with discussing the historical background and classification of maxillofacial prostheses and later briefing about the properties along with advantages and disadvantages of the impression and fabricating materials and retentive anchorage used for the fabrication and retention of the craniofacial prostheses along with understanding how 3D printing helps to fabricate exact fit prostheses in the intricate anatomical structural areas so that it helps the clinician in achieving a successful treatment result.

Historical background:

Ambroise Pare (1510-1590) a French surgeon proposed a lusitanus' obturator where he uses to put obturator that utilized a small metal plate attached to a curved sheet of gold and left into patients' palatal defect and engaged with a plier and locked in place. He also constructed artificial eyes with eyelids which were with metallic strips encircled around the head and he also constructed an artificial nose which was held with the help of spectacles. Pare also gave tongue prostheses made of wood which helped people utter intelligible speech.[6]

Later many changes were made to the proposed obturator by many inventors:

Pierre Fauchard (1678-1761), the father of dentistry proposed a modified obturator where the obturator had pair of wings which could be folded and placed by the patient into the defect and screwed in the inferior portion so that the wings spread and engages into the palatal defect.[11]

Christophe Delabarre, the Parisian dentist gave an obturator that that had velum and uvula that was made of flexible gum-like material and later got modified by James Snell, in the year 1828 he gave the first true functional velar appliance. [12]

In 1863, Norman W. Kingsley (1829–1913) won a gold medal at the American Dental Conventional Meeting for his invention of a functional obturator.[13]

In the 19th century, William Morton created an obturator prosthesis using a gold plate. Morton made a porcelain prosthetic nose that was fastened to the patient's spectacles.[14]

By the end of 19th century, a fabricating material vulcanite was put to service for fabricating prostheses.

Present: At present some of the fabricating material used are Polymethyl methacrylate (PMMA), Polyurethanes, Silicone Polymers and vinyl plastisol.[15,16] The recurrently applied materials for the contriving of craniofacial prostheses among the materials are silicone and acrylic resins.[16-18] The retentive aids used to hold these prostheses are classified as adhesion, anatomical, mechanical, or surgical.[19] Osseo-integrated implants are also retentive aids in maxillofacial prosthetics. With the recent advancements and introduction of 3D printing, the exact fit prostheses are fabricated these days in enigmatic anatomical structures.

The material, retentive aids, and Implant-supported maxillofacial prosthetics are discussed in detail below sections.

Future: According to Ferreira[20] in future the use of CAD/CAM and surgical guide would be commonly used for fabricating of prostheses. These would help in eliminating the facial impression and wax pattern sculpting[21] along with reducing the treatment time and better fitting prostheses.[22]

Classification:

Maxillofacial prostheses are classified into restorative and complementary (Fig. 1). Restorative prostheses are basically used to mask the maxillofacial deformity. The Restorative prostheses are further classified as

Intraoral or Extraoral whereas the complementary prostheses are use in plastic surgery during pre, trans and postoperative phase or in radiotherapy sessions.[8]

Materials:

The material used for fabricating the protheses are impression taking materials and fabricating materials. The properties, advantages and disadvantages of the materials are discussed in details so that it helps us in understanding the use of these materials in different defective anatomical structures.

Impression materials and techniques:

A precise impression and pertinent technique are required to achieve close tissue adaptation of the prosthesis. Different impression materials and techniques required for extraoral prostheses are Reversible hydrocolloid, Irreversible hydrocolloid and Plaster of Paris.

Impression technique for auricular prosthesis:

Reversible hydrocolloid was used by Kenneth E. Brown in 1970, while the patient was instructed to lie supine with their defect in a horizontal plane. In order to box the defect and fill it with reversible hydrocolloid, an indelible pen is used to mark the patient's skin in the vertical and horizontal coordinate axes. An impression is then taken, and a diagnostic cast is retrieved.[23]

Irreversible hydrocolloid was employed by Mathew MF (2000) to take an impression. Using a facebow or an orientation caliper with a special design, the unaffected ear's vertical and horizontal axes will first be transferred to the replacing site with a skin marker. After applying lubricant to the affected area, the 60 ML syringe is filled up with an impression, which is then loaded into the helix of ear and finished by taking the internal ear contours. After setting, boxing, and pouring the working cast, the impression is removed with a small twist force.[24]

A functional impression for a prosthesis was made by Jain A (2016). Using this method, a diagnostic cast is poured after an alginate impression is taken. Subsequently, a clip-retained acrylic substructure with an orientation groove is fabricated and adapted over the diagnostic cast, and a custom tray is made using auto polymerizing resin. Polyvinylsiloxane light body elastomeric is used as the impression material, and the patient is asked to do all the movements, such as depressing their mandible and moving left and right, while the Polymer substructure is placed over the bar. After accuracy checking, the impression is poured.[25]

Philip John F. Wolfaardt (1996) Using impression copings, the procedure entails creating an impression, after which a resin substructure that is held in place by bars and clips and spaced 1-3 mm from the skin is fabricated. The retentive bar is then clearly visible through a window in the resin substructure thanks to a specially designed tray made of auto polymerizing resin that is indexed to it. By measuring the movement of the mandible's condyle under ear skin and head movement, the point of maximum skin depression is determined, and impressions are taken in these areas. Using a syringe, uncatalyzed silicone putty is injected around the edge of the acrylic resin substructure to create a seal and continuous skin contact after marking the intended location of the prosthesis on the skin. To activate the indices, the tray is filled with polyether impression material, placed on the substructure, and seated after an adhesive coat has been applied. It is possible to verify the relationship of the retentive bar by peering through the tray's cutout and seeing the acrylic resin substructure. Soft tissue regions free of tissue contact are identified and excised using a bur after the impression has been recovered. A stainless steel wire with the same diameter as the retentive bar is inserted

into the clips in the resin substructure. The imprint is poured into a box. [26]

Impression for Orbital prosthesis:

Brown (1969) The patient is asked to lie down for this technique. The face is covered with a wax box, and reversible hydrocolloid is used as the impression material. Once the impression is taken, Plaster of Paris is poured onto it, allowing the cast to be removed and revealing the patient's facial moulage.[23]

According to Levy et al. (1980), this method involves having the patient sit up straight while an alginate impression of their face is made. Plaster of Paris is then applied over the impression, and a gauge pad is positioned in between the plaster of Paris and the impression to act as a retentive aid.[27]

The polysulphide used in Beumer's (1979) technique serves as the impression material. An imprint is made on the defect, covered with a gauge pad prior to polymerization, a thin layer of Plaster of Paris is applied, the imprint is verified for accuracy, and then it is poured. [28]

Impression for ocular Prosthesis fabrication:

In this technique, developed by Allen L et al. (1969), the patient is asked to perform all movements in all directions while the stock tray is used to take the impression, overextension is checked, and the impression is taken using alginate.[29]

According to Taylor (2000), the patient is instructed to look straight ahead while alginate is injected into the defect using a syringe. A stock tray with perforations in it is then loaded, and an impression is once more taken, retrieved from the defect, and poured into a cast.[30]

Miller, in 1996 Using this method, a solid suction rod is fastened to the patient's pre-existing prosthesis shell to create an alginate mold. Once the alginate has had time to solidify, the prosthesis, conformer, or wax is removed and replaced with clear acrylic resin. A tunnel that is cut through the tray is perforated, and an injection of alginate impression material is made.[31]

Hughes and Le Grand (1990) This technique uses a wax shell and an aluminum iris button to measure the anterior portion of the eye. Once the correct shape is oriented, the button is removed and a pre-made plastic tube is fastened. You can use sticky wax to secure the tube firmly for added strength. The tube's connection to a syringe will then allow alginate to flow into the tray or socket. When the alginate has solidified, a two-piece stone mold is made around the impression and shell. Using this method has two advantages: efficiency and speed.[32]

Impression for nasal prosthesis fabrication:

Polysulfuride is utilized as the impression material in this Beumer (1979) work. A gauge pad is placed over the imprint prior to polymerization, a single layer of plaster of Paris is applied onto the imprint, the impression is checked for preciseness, and is poured.[28]

S Guttal Using this method, after stage two surgery, the nasal defect is packed with moist gauze to prevent the impression material from leaking into the nasal cavity. Medium-body vinylpolysiloxane impression material is used in a custom tray to create an impression after the impression posts are attached to the implants. Subsequently, the impression posts are taken and attached to the laboratory analogs. The master cast is then made using dental stone.[33]

Fabricating Materials: These are the components that go into making maxillofacial prostheses and the ideal characteristics that materials should have are [28]**:**

Physical and mechanical properties:

1. Low specific gravity
2. Low coefficient of friction
3. Low surface tension
4. High resistance to abrasion

5. High tear strength
6. High edge strength
7. Non inflammable
8. No water sorption

Biological Properties:

a. Should be biocompatible with tissues it should not be toxic or allergic.
b. Resistant to bacterial growth.
c. Maintain Colour and dimensional stability.

According to Beumer[28], the type of materials:

1. **Acrylic Resins:**
   Mostly used at the sites with least mobile tissue bed. Such as ocular and orbital sites. [28]
   Advantage: Good strength, easily relined and repaired,exhibits feather margins and have good shelf life.
   Disadvantage: Rigidity and no duplication possible.[34]

2. **Acrylic copolymers**: Acrylic copolymers is a combination of acrylic and methacrylic acid. Palamed pertains in laboratory packs that include solvent liquid, stain concentrates, and base powder for characterizing the final prosthesis.

3. **Polyurethane elastomers**: Chemically the material is composed of diisocyanate groups and segments of polyol groups and the polymerization process occur by an organotin catalyst.
   A workable product requires the precise proportioning and careful mixing of three ingredients. Usually used at defective sites with mobile tissue beds.
   Advantage: Environmental stability, higher tear resistance, low modulus of elasticity without use of plasticizers, good ultimate strength.
   Disadvantage: Toxic, moisture sensitive leading to gas bubble that causes problem in curing.[35,36]

4. **Silicones:** Silicone is chemically termed as polydimethyl siloxane. Long chain molecules made of silicon and oxygen atoms alternating in a chain; silicones can be made as fluids, resins, or elastomers by varying the length of this silicon-oxygen chain. Based on the vulcanizing temperature, silicones are classified into two main types: There are two types of silicones: RTV - Room temperature vulcanized and HTV - High temperature vulcanized.[35]

5. **Polyvinylchloride and copolymers**:
   It's obvious that the material is odorless and tasteless. The elastomeric effect at room temperature is achieved by adding plasticizers, cross-linking agents, and ultraviolet stabilizers
   Advantage: Flexible, adaptable to intrinsic and extrinsic staining.[37]

6. **Chlorinated polyethylene**: This material is industrial grade thermoplastic elastomer.
   Advantage: This material is biocompatible it is non irritating, nontoxic and nonallergic to the tissue than silicone materials.[37]

Advanced fabricating Materials:

1. ***Siphenylenes*:** These are methyl and phenyl groups present in siloxane copolymers. Compared to the more common polydimethyl siloxane, these have better edge strength, a lower modulus of elasticity, and color stability.[38]
2. ***Silicone Block Copolymers***: The conventional siloxane polymers are positioned alongside blocks of non-silicone polymers in this instance. It has

been demonstrated that silicones' hydrophobic and foreign characteristics can cause issues. These characteristics of silicone copolymer may cause foreign body reactions and lead to the growth of microorganisms, especially at the silicone-tissue affiliate. These issues can be partially resolved by these silicone block copolymers since their amphiphilic polymers' more hydrophilic portion improves wettability and, consequently, tissue compatibility.[39]

3. ***Polyphosphazenes;*** Reducing the acrylic-to-rubber ratio and using polyphosphazenes with little to no fillers will result in a rubber with an HDA of 25, mimics with human skin. Once a consistent and reasonably priced source of polymer is found, these may replace other materials for a wide range of biomedical applications.[37]
4. ***Foaming silicones***: It contains a kind of RTV material called Silastic 386. The prosthesis's weight reduction is the main goal of the foam-forming silicones. Foamed material's main drawback is that it has less strength and is more prone to straining, which weakens the material.[37]

Retentive aids:

Retentive aids are classified into anatomical, adhesive, mechanical, and implants

Anatomical retention:

SM Parel discussed the retention of orbital prostheses with the use of anatomical undercuts with flexible conformers.[40]

Anatomical retention is of two types intraoral and extraoral.

Intraoral retention: Both soft and hard tissues are used to obtain it. It may originate from the teeth, bony tissues, or mucosa. There are undercuts in the cheek, palatal region, alveolar region, residual teeth, retromolar area, nasal ridge, and anterior nasal aperture

Extraoral retention: The use of the hard and soft tissues in the craniofacial region are taken as extraoral retention. For Examples, any remaining cartilage in the ear or any defect in the bone wall that a prosthetic device component will come into contact with.[41]

Chemical retention:

Adhesives are used to achieve chemical retention. According to Glossary of Prosthodontic Terminology 9, Adhesive for craniofacial prosthetics is “a material used to adhere external prosthesis to the skin and associated structures around the periphery of an external anatomic defect.”

These come in the form of water-based adhesives, latex, spirit gum, or acrylic-based adhesives.

Polymer-based adhesives:

Polymer resin adhesives are composed of Polymer resin dissolved in a water solution, which evaporates to leave behind a rubber-like substance. Rubber dispersions and synthetic resin are now referred to as latex adhesives.

These adhesives can be made to penetrate and wet with controlled ease by adding surfactants and achieving the right particle size. Water must be able to pass through one surface of these adhesives for the dispersion to dry and the bond to form.

Silicone adhesive:

Silicone adhesives are based on room temperature vulcanizing silicones, which are normally dissolved in a solution. The tacky adhesive that remains after application is created when the solvent evaporates and can be contact-bonded to another surface, such as skin. These adhesives have good resistance to weathering and moisture and low water sorption. They can withstand a range of oils and chemicals, sunlight, ozone, and bio-deterioration. One disadvantage of this material is its low adhesive strength.

Pressure-sensitive tapes:
Pressure-sensitive tapes are applied with finger pressure and are used to hold facial prostheses in place without the need of heat or solvents. The backing strip for these tapes is composed of foil, paper, film, laminate, or cloth. strip coated with a pressure-sensitive adhesive. Every surface has adhesive from the tape. The resin-based glue used in the Bi face tape has a lower skin-adhesion than acrylic glue. The bi-face tape can be used on less flexible materials and on people whose abnormalities move very little or not at all.

Rubber-based liquid adhesive:
Rubber naturally exists as latex. This results in a latex that is easily soluble in organic solvents, like petroleum jels or benzene, creating a natural rubber adhesive. The oxidation of the atmosphere causes this mixture to gel quickly. Rubber is made sticky; it becomes hardened by sulfur vulcanization after that. Rubber that has been recovered is dissolved in naphtha to create a rubber cement with superior adhesive properties. The ability of these natural rubber adhesives to stick two newly non-sticky surfaces together is known as their "dry tack".[40]

Mechanical retention:
Mechanical anchorage includes eye glasses and frames, extension from denture, precision attachments, and magnets.

Eye glasses: Parr GR suggested that patients who have had surgery to remove their nose bridge may be able to keep their nasal prosthesis by wearing specially made eyeglass frames. To avoid retention marks showing, the colour of the eyeglass frame should be opaque.[42]
Extension from denture: Since they are the least expensive, the most common types of retentive aids—acrylic buttons, retentive clips, and cast clasps—are still in use.[43]

Precision attachment*:* The most popular precision attachment for joining prostheses to implants and between prosthesis components is a bar clip. Telescopic crowns and extracoronal ball attachments are used in maxillofacial prosthesis cases to increase retentive force.
Magnets: Because of their size and powerful attractive forces, magnets are widely used in the field of craniofacial prosthetics. These qualities allow them to be incorporated into prosthetics without being apparent in the mouth. For complete dentures, hemi-maxillectomy, obturators, sectional dentures, or ridges that have undergone significant atrophy, magnets can be used as a retentive aid. There are two main types of alloys used to make magnets which are cobalt-samarium, iron, neodymium, and boron.[44]
Implants:
Insufficient bone volume is the primary concern when it comes to facial implant placement. Contrary to intraoral implants, extraoral implants were intended dimension of 3-5 mm in length and 5 mm in width because bone thickness in the temporal and supraorbital regions—which are appropriate locations for implant placement—ranges between 2.5 and 6 mm. Longer implants, however, might also be utilized in cases where there is sufficient thickness of bone mass like orbital and nasal regions. The implants used for maxillofacial prosthetics are intraoral, extraoral and zygomatic implants.[45]

Application area for implants:
The classification of the bone regions in which Jensen and his colleagues' facial implants could be positioned was interpreted as follows[45] :
A-bone regions: These areas have a bone volume of at least 6 mm and allow the use of both dental and zygomatic implants. These areas include the zygoma, zygomatic arch, and anterior aspect of the maxillary.

B-bone zones: 4 mm craniofacial implants can be used in bone with thickness of 4-5 mm. The majority of the superior, lateral, and inferolateral orbital margins contain these bone regions, particularly the mastoid margin of the zygoma and temporal bone.

C-bone zones: The bone mass in the margin areas is 3 mm or less. The nasal bone, zygomatic arch, infraorbital margin, and pyriform edge are a few regions of the temporal bone in the face. They demand that 3 mm or smaller craniofacial implants be used. There are certain principles that should be followed when implanting implants in maxillofacial prostheses.

Implant systems used in extraoral prostheses

In bar systems, a retentive lock is positioned inside a bar that joins the implants to one another. The diameter of the gold alloy bars used in these systems is around 2 mm. For auricular prostheses, these retention methods are particularly recommended. Ensuring passive alignment between the implants and the bar is necessary to attain the desired force distribution.

Disadvantage: Bar systems require additional space inside the prosthesis; thus, the silicone structure needs to be sufficiently thick to conceal the substrate's grayish reflection and keep the silicone from cracking.[46]

Magnetic systems:

These systems are used to keep a facial prosthesis in place in areas where there is a lot of muscle activity next to the prosthesis, when hand function is limited, the bone is thin, and an implant is preferred to lessen the forces acting on the bone[46]

Intra-oral implants

Principles supporting Implantation in Intra-oral Defective area:

A traditional prosthesis places more pressure on auxiliary teeth in intraoral defect, causing periodontal damage. In particular, for large and one-sided defects, the cross-arch stabilization and resistance against prosthesis vertical movement are lost. This may lead to the extraction of teeth that are necessary for gripping. By lessening the load on the auxiliary teeth, stabilizing the cross arch, and providing strong resistance to forces that could shift the teeth's positions, a few implants placed in or close to the defect area can help stop that loss. Implants utilizing bone grafts enable advanced osseo-integration. After iliac crest grafts are placed in the zygomatic arc region and skull grafts are placed on the infra-orbital region, implant placement can provide contraarc stabilization.[47]

Extra-oral implants

Principles behind the Implantation in Extraoral Defects

1. Abutments of implants need to be as good as the skin covering them;
2. The Subcutaneous layer of skin need to be surgically thinned to prevent destructive forces; this procedure needs to be carried out 10 mm away from abutments;
3. Implants ought to be spaced one centimeter apart for sanitary reasons.
4. Bars positioned in between abutments have to match the natural facial contours and be made to meet the necessary hygienic requirements.
5. Hairy skin must be at least 7 mm away from implants. If that's not feasible, you'll need to apply a skin graft .[47]

Advancements In Maxillofacial Prosthetics:

Rapid Prototyping:

Mechanical models are produced using graphical computer data in this type of computer-aided prototyping, or RP. Subtractive and additive methods are both possible. Self-growing robots can be developed with the help of additive manufacturing, which produces complex, customized parts quickly.[48]

Computer-aided design/computer-aided manufacturing:
Because it could be digitally designed and manufactured, it is a quicker method of producing temporary prostheses. In addition, it improves patient comfort, restores patients' aesthetics, and is affordable and simple to use.[48]

Conclusion

Maxillofacial prostheses restore form, function, and aesthetics to the missing anatomical structure area, helping patients with maxillofacial deformities regain their social confidence and self-esteem. These patients benefit psychologically from this. It needs to resemble any missing structures as well as the surrounding skin's color, texture, form, and translucency. The effective treatment results are obtained through the use of retentive aids and careful material selection during fabrication. It is obvious that 3D RP plays an important role in the development of maxillofacial prostheses and that 3D bioprinting is a great way to create intricate organs and tissues like muscle tissue as well as to fabricate and develop the extra segments using biomaterials. As a result, the clinicians must be adequately informed about the pros and cons of each material utilized in the fabrication process, in addition to its unique properties. It is anticipated by clinicians that 3D printing technology will be utilized shortly in many dental specialties, especially maxillofacial rehabilitation

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FIGURES

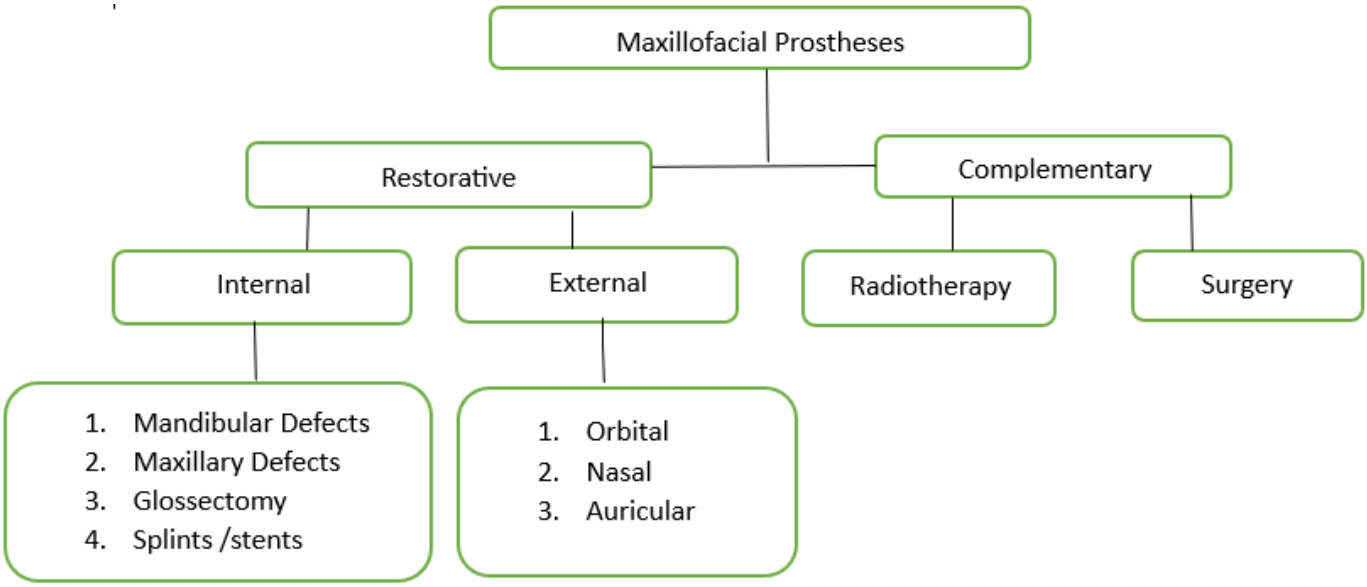

Figure 1