be either fixed or adjustable, one piece or two-piece devices. In general, they consist of form fitting trays that fit over the maxillary and mandibular teeth. The adjustable devices position the mandible forward and are secured to the maxilla by the use of thermoplastic buttons, intraoral elastics, buccal tube and rod attachment (Herbst) and a screw mechanism with which to titrate the oral appliance. They are preferred to non-adjustable as they can be adjusted to patient comfort. With either of them, the initial position of the mandible is generally 70-75% of maximum protrusion relative to maximum retrusion. Almost all MAD require that the patient have sufficient number of teeth so that the device will be highly retentive, generally in one or both the arches, specially the maxillary arch. However, MAD can be fabricated for edentulous patients as well by incorporating it into the complete denture construction. Anterior breathing holes may be necessary to allow oral respiration in some patients specially those with restricted nasal airflow. A MAS should cause minimal vertical opening. A MAS which promotes mandibular opening results in a downward and backward rotation of the mandible with a concomitant posterior movement of both the tongue and soft palate. This can negate the benefits to the airway from protrusion, resulting in the further narrowing of the pharyngeal airway, particularly at the level of the hypopharynx. This may explain why in a recent review of treatment outcomes, as many as 40% of those treated were left with significantly higher AHIs. Full occlusal coverage should be used with the MAS to prevent any unwanted changes in the occlusion resulting from over-eruption of unopposed teeth. It is also important to ensure that the splint is well retained by the dentition, in order to prevent disengagement and thereby loss of the desired antero-posterior opening of the airway achieved though forward positioning of the mandible. The use of short inter-maxillary elastics can help to prevent mouth opening during sleep. Recent innovations include combining the principles and use of CPAP with oral appliance therapy. In one instance, the pressurized air is delivered through the oral appliance directly into the mouth through oral positive pressure. In another, the oral appliance is used in lieu of headgear to retain the air hose as well as deliver pressurized air directly into the nares, thereby reducing any leakage from the borders of the CPAP mask.[21]

American Sleep Disorders Association[7,14] in 1997 commissioned a review of all the articles written about oral appliance therapy for obstructive sleep apnea and snoring. The review found that in all published studies in which snoring was assessed, snoring improved in 73-100% of patients using a variety of type of appliances, the review also looked at 20 publications reporting the efficacy of oral appliances on obstructive sleep apnea. These 20 studies represented 304 patients. Overall 51% achieved normal breathing, as defined by an apnea-hypopnea index (AHI) of fewer than 10 episodes per hour with therapy, 39% of patients with an AHI greater than 20 still had an AHI above that level with therapy. No type of oral appliance appeared to be better than any other in the review. According to the Standards of practice committee of the American Sleep Disorders Association (ASDA),[8,21] appliances are indicated for patients with mild obstructive sleep apnea, who do not respond to or are not appropriate candidates for treatment with conservative measures such as weight loss or sleep position change and for patients with moderate to severe obstructive sleep apnea who are intolerant or refuse treatment with nasal CPAP. Published reports suggest that temperomandibular joint pain and occlusal changes are relatively uncommon with MAD use, but long-term risks of these complications have not been established.

Checklist for patients using dental appliances for treatment of obstructive sleep apnea :[6,21,22]

1) It is important that the patient be diagnosed adequately prior to therapy.
2) An informed consent describing the possibility of side effects is absolutely necessary for all patients including the recommendation that an overnight polysomnography study be conducted.
3) Diagnosing physician should agree that the dental appliance is an appropriate treatment.
4) Because the device may have significant impact on the teeth, temperomandibular joint, an experienced dentist should fit the appliance.
5) No patient should wear the appliance long-term without follow-up polysomnography showing reduction in obstructive sleep apnea symptoms.

Not all patients with sleep apnea are good candidates for a dental device, hence a complete dental examination to evaluate dentition supporting periodontium and temperomandibular health and a baseline cephalometric radiograph are a must. Oral appliances may cause a worsening of obstructive sleep apnea in certain individuals. It is therefore important that patients with moderate to severe disease, treated with MAS, should have regular follow-up visits to monitor compliance, access the need for further appliance modification to ensure maximum clinical effectiveness and to evaluate the health of the dentition and supporting structures. Recalls are necessary minimum at 2 weeks, 1 month and then 6 months. These patients should also undergo an

objective measurement of respiration during sleep, ideally polysomnography with the MAS in-situ, to ensure a satisfactory therapeutic benefit.[6,21]

Advantages of MAS Therapy : These appliances are clinically effective in mild to moderate obstructive sleep apnea. As reported earlier, obstructive sleep apnea improves in the majority of patients, with 70% achieving a minimum of 50% reduction in AHI. Improvements in sleep quality and daytime sleepiness have also been reported. MAS are relatively inexpensive, readily accessible, non-invasive and reversible.[21]

Figure 1 A : Normal upper airway.

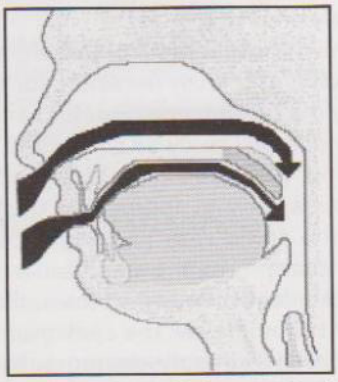

Figure 1 B : Snoring patient with increase in airflow velocity causing vibration of the soft tissue.

Figure 1 C : Obstructive sleep apnea patient with an upper airway blockage that prevents air from reaching the lungs.

Disadvantages of MAS Therapy : Short term side-effects include discomfort in the muscles of mastication, excessive salivation and an abnormal bite on awakening. These effects appear to be transient and without any lasting complications. Later complications may result in TMJ discomfort and changes in the occlusion. Minor changes have been observed in the overjet, overbite, molar relationships and mandibular position.[21]

SURGICAL MANAGEMENT

Surgery was earlier the primary form of therapy until Sullivan reported successful treatment of patients with CPAP, which produced similar results and was much more conservative. In 1996, the American Sleep Disorder Association received the efficiency of surgical modification of the upper airway in adults with obstructive sleep apnea syndrome and they listed the following operations used to treat these disorder. Tracheostomy, mandibular surgery, hyoid bone suspension, nasal septal reconstruction, uvelopalatopharyngoplasty (UPPP), partial tongue resection, linguloplasty, maxillomandibular advancement osteotomy (MMO), inferior mandibular osteotomy, genioglossus advancement with hyoid myotomy and suspension (MOHM).[9]

CONCLUSION

With the rising trend of obstructive sleep apnea, both doctors and dentists should be able to identify potential patients. However, the dentist must not assume the role of a primary health care provider, but he should be able to refer them to a physician for definitive diagnosis.

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Abstract

QUANTITATIVE SENSORY NERVE CONDUCTION THRESHOLD (SNCT) EVALUATION OF THE TRIGEMENAL NERVE AT MENTAL FORAMEN AREA

Statement of Problem : *There is a need for a quick, objective, quantitative sensory test of the mandibular inferior alveolar nerve to assess sensory dysfuction due to trauma, infection or disease.*

Purpose : *This study evaluated the reliability & reproducibility of a commercially available electrodiagnostic quantitative sensory nerve conduction threshold (SNCT) evaluation testing method & established normative values for future evaluation of nerve dysfuction.*

Material & Methods : *Rapid correct perception threshold (R-CPT) value were obtained with neurometer CPT/C, an electrodiagnostic SNCT device that administer an alternating constant - current sinuroid waveform stimulus at either 2000 Hz, 250 Hz or 5 Hz at intensity levels ranging from 0.001 to 10 mA. Thirty four healthy subjects were tested then retested by the same operator from 7 days to 153 days. R-CPT evaluation was performed over the mental foramen bilaterally with dual disposable gold-plated electrodes & a hypoallergenic electrode gel held in place using non conductive adhesive tape. Two consecutive identical R-CPT measures were obtained for each stimulation frequency for determination of the final R-CPT value.*

Results : *On the left side, there was no difference between the first & second test ($P>0.005$). On the right side there was a statistical difference between the first & second test for L, M & H, but the confidence interval is very narrow & differences are not clinically significant.*

Conclusion : *From the values obtained, R-CPT testing were reliable for the quantification of sensory function in healthy individuals.*

- Todd H. Lerner, Gary R. Goldstein & Engere Hittelman.
J. Prosthet. Dent. 2000; 84 : 103-7

Titanium in Prosthodontics : A Review

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ABSTRACT

The use of titanium and titanium alloys for dental applications has increased dramatically in recent years. It is an economical and bio-compatible replacement for fixed and removable prostheses. This articles describes the physical and mechanical properties of titanium and its alloys and procedures for titanium casting, joining and porcelain bonding and evaluates its use as a biomaterial for dental implants and dental prostheses, there by evaluating its present status and future trends in its use.

INTRODUCTION:

Titanium is one of over 100 elements that make up our universe[1] and like 75% of them it is a metal which is termed as the mystery metal of implant dentistry[2]. First identified by GREGOR in 1971 who called it menachite and KLAPROTH rediscovered it in 1975 to be known as TITANIUM.

Dr. Wilhelm Kroll, considered the father of titanium industry invented useful metallurgical processes for commercial production of titanium metal.

AVAILABILITY:

Commercially pure titanium (CPT) graded by American society of testing and materials is available in 4 grades based on the incorporation of small amounts of oxygen, nitrogen, hydrogen, iron and carbon during purification procedures[3]. Grade IV CPT is the material used for dental implants.

Titanium is also available as alloys; the ones of interest to dentistry exist in 3 forms[3]:

- Ti-6Al-4V
- Ti-6Al-4V (extra low interstitial)
- Ti-Al-Nb

These types originate when pure titanium is heated, mixed with elements such as aluminium and vanadium in certain concentrations and then cooled. The alloy most commonly used for dental implant contains 6% aluminium and 4% vanadium (Ti- 6Al- 4V).

Key Words : Titanium, Titanium alloys, Dental implants, Biomaterials, Metals and Alloys.

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PROPERTIES:

- In its metallic form at ambient temperature, titanium has a hexagonal, closed, packed crystal lattice (α phase) which transforms into a body-centered cubic form (β phase) at 883°c with a melting point of 1680°c.
- The strength and rigidity of titanium are comparable to those of other noble or high noble alloys commonly used in dentistry.
- It is ductile and the ductility, when chemically pure, is similar to that of many dental alloys.
- It has low density of 4.5 g/cm^3, provides for high strength and light weight.
- It has low thermal conductivity.
- It can be alloyed with other metals, such as aluminium, vanadium or iron, to modify its mechanical properties. Aluminium has been called alpha phase condition stabilizer and increases the strength and decreases the weight of the alloy. Vanadium has been called the beta phase stabilizer. As aluminium or vanadium is added to titanium the temperature at which the alpha to beta transformation occurs changes to a range of temperatures. In this range both the alpha and beta forms may exist. The alloy form desired is maintained at room temperature by quenching the alloy from the temperature at which the desired form is removed.
- Titanium is one of the metals that can be coupled with other metals without fear of losing its passivity.
- It is a highly reactive metal that readily passivates to form a protective oxide layer, which accounts for its high corrosion resistance (Fig. 1). The initial thickness of this layer is 5 - 10 nm. It is this layer that give titanium its bio-compatibility. This protective passive oxide film on titanium, mainly TiO_2 is stable over a wide range of pH's, potentials and temperatures and is specially favoured as the oxidizing character of the environment increases. For this reason, titanium generally resists mild, reducing, neutral and highly oxidizing environments up to reasonably high temperatures that the oxide film breaks down and resultant corrosion may occur. These conditions are not normally found in the mouth.
- Titanium and its alloys develop stable surface oxides with high integrity, tenacity and good adherence. The surface oxide will, if scratched or damaged immediately reheal and restore its self

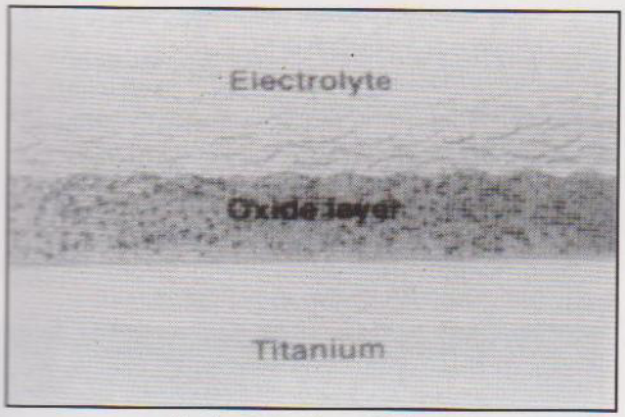

Fig. 1 : Protective oxide layer.

in the presence of air or water. An oxide layer of 10°A thick forms on the cut surface of pure titanium within a millisecond.

- The oxide layer allows for bonding of fused porcelains, adhesives, polymers or in case of endosseous implants, plasma spray or surface-nucleated apatite coatings.
- The high di-electric properties of titanium oxide which exceed those of most metal oxides may in part be responsible for positive biologic response to these implants because they make the surface more reactive to biomolecules via enhanced electrostatic forces. Therefore any contamination or adulteration of this surface before placement will surely have negative effect on the success of the implant. When coupled with metals with greater corrosion potentials, the other metal may corrode by the mechanism of galvanic corrosion. When coupled with metals that, themselves, remain passive (such as co-cr alloys) a stable and passive combination is produced. Therefore metals whish are not strongly passive, such as stainless steel should be avoided.
- Comparison of mechanical properties of pure titanium to heat treated titanium alloy[4] :-

Properties	Ti	Ti-6Al-4V
Density (g/cm^3)	4.51	4.43
Micro hardness (VHN)	130-210	350
Elongation (%)	15-24	10
Yield strength (0.1% MPa)	241-548	890
Melting point (°F)	3035	3200
Modulus of elasticity (psi x 106)[2]	15.0	16.5

MYSTERY METAL IN IMPLANT DENTISTRY[4]

- The mystery to form an intimate bond with bone lies in its oxides, which forms instantaneously at all temperatures.
- Clinical success of an implant = OSSEOINTEGRATION + PROSTHETIC RESULT.
- The implant body is composed of Titanium, chosen for its biocompatibility, light weight, strength, corrosion resistance and long history of successful mechanical function in loaded applications.
- When an implant is introduced into the body, complex reactions begin to take place at the oxide / bio-environment interface. The oxide film grows as ions diffuse outward from the metal and inward from the environment.
- If an implant metal is oxidized and the oxide does not break down under physiologic conditions, the metal is said to be easily passive or passivated. Titanium and its alloys are easily passivated forming a stable TiO_2 surface that make it corrosion resistant. In the passive state the rate of dissolution of TiO_2 is extremely low. With time little change can be seen on the surface of the metal implant but an accumulation of titanium in tissue can be observed. Normal level of titanium in human tissue is 50ppm, values of 100 to 300ppm are frequently observed in soft tissues surrounding Ti implants. At these levels, tissue discolouration with Ti pigment can be seen.
- The most common alloy (Ti - 6Al- 4V) used as an implant material, after heat treatment possess many favorable physical and mechanical properties such as they are light, strong, and highly resistant to fatique and corrosion. They are stiffer than bone, their modulus of elasticity is closer to bone than any other important implant material, and the only exception is pure Ti. This property leads to a more even distribution of stress at the critical bone-implant interface, because the bone and implant will flex in a more similar fashion.
- The passivating oxide on the implant surface permits close apposition of physiological fluids, proteins and hard and soft tissues to the metal surface. This process where by living tissue + implant become structurally and functionally connected is called OSSEOINTEGRATION.

KEY FACTORS FOR OSSEOINTEGRATION[5] (FIG 2)

- Characteristics of the material.
- Design of the fixture.

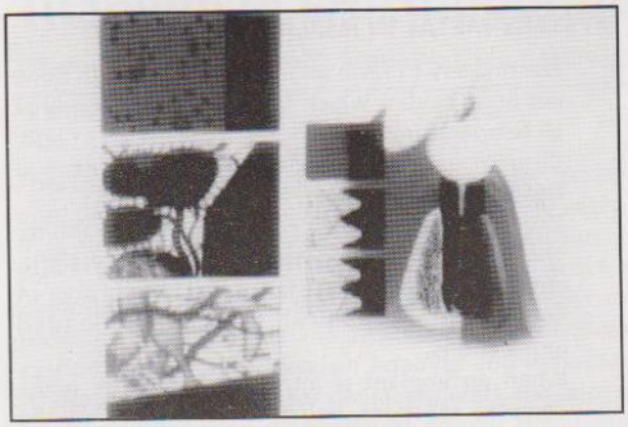

Fig. 2 : Osseointegration.

- Prevention of excessive heat generation during the bone drilling procedures.
- Requirement of maintaining fixtures within the bone without occlusal forces or loads onto the fixtures.

TITANIUM IMPLANT SURFACE TECHNOLOGY[6]

The topographic modification of CPT surfaces to enhance good integration includes :-

- Coatings - Titanium plasma sprays (TPS) (Fig 3), thin layer of calcium phosphate ceramic (hydroxyapatite), the biologic benefit of which has been applied via a flame or plasma spray technique. An activated sintering process has been developed that enables HA to be chemically bound to the titanium cylinder using modification of the plasma flame spray technology.

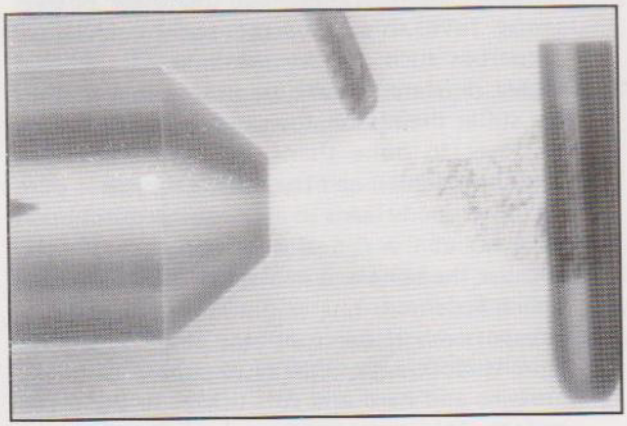

Fig. 3 : Titanium plasma spray.

- Abrasions - TiO_2 blasting or soluble/ resorbable blasting materials.
- Blasting modified sand blasting - Accelerates bone healing process of dental implants through improvement of osteoblastic functional differentiation.
- Laser Induced surface roughening (Fig 4)
- Etching- H_2So4/HCl (Fig 5)
- Anodizing
- Cold working (dimpling).
- Sintering
- Magneteron sputtering- CaPo4 apatite's
- HA allows for a non-resorbable, highly biocompatible implant bone interface.-
  A bridging type of structure occurs between bones and HA known as biologic apatite.

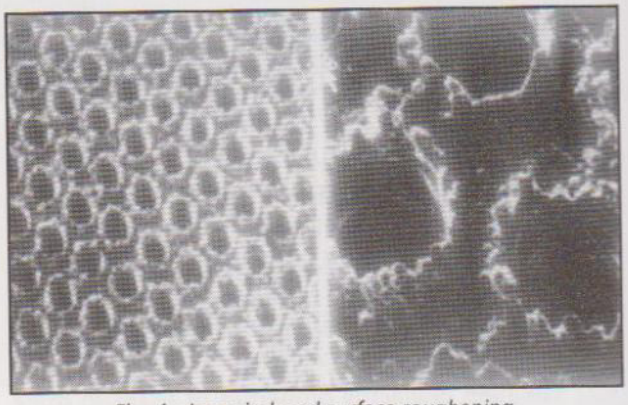

Fig. 4 : Laser induced surface roughening.

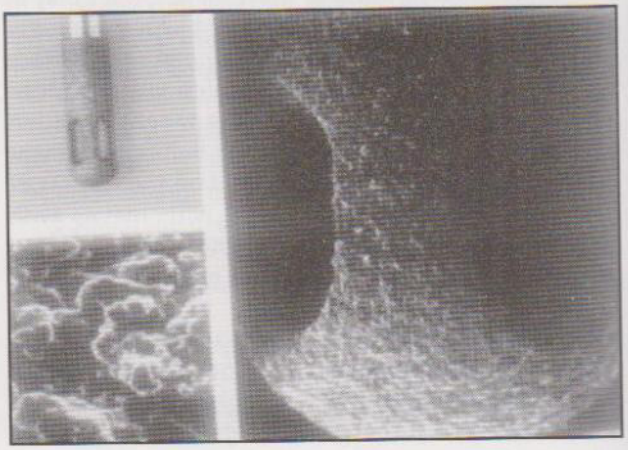

Fig. 5 : H_2So4 / HCl etching.

STRESS CORROSION CRACKING OR CORROSION FATIGUE:

- They are important in implant systems because they can lead to complete mechanical failure of the implant. This phenomenon is unknown in CPT under physiologic conditions; however Ti alloys are theoretically susceptible to this phenomenon under physiologic conditions.
- Presence of aluminium > 6% concentration makes the alloy susceptible due to formation of $Ti\ Al_3$ compounds.
- Presence of vanadium supresses the formation of these $Ti\ Al_3$ compounds.

GLOW DISCHARGE TECHNIQUE[7] (FIG. 6)

- Adopted for use in cleaning and sterilizing implants
- Uses a vacuum chamber and a radio frequency generator that activates the gas into a plasma state which is characterized by a visible glow discharged cause by electrically excited species returning to low energy levels.
- Impactions of the plasma ions and electrons on objects within the chamber acts to sputter away and then microash any organic surface contaminants from inorganic objects (implants) leaving them sterile, high surface energy states that improve their wettability, there by facilitating adhesion by organic materials resulting in improved bone growth and regeneration around the GD treated endosseous implants.
- GD treatment modifies the superficial oxide layers in two steps:
  1- Removing the contaminated layer rich in hydrocarbons.
  2- Then leveling the sub-adjacent, irregular oxide layer remaining from prior manufacturing procedures resulting in a clean, more coherent and corrosion-resistant electro-chemically passive implant surface.

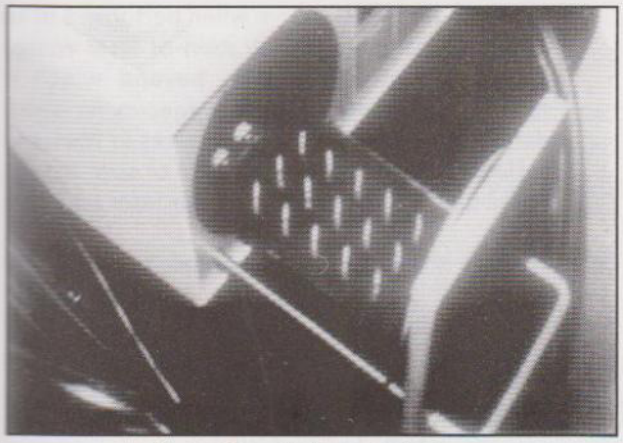

Fig. 6 : Glow discharge technique.

TITANIUM CASTING[8]

- Since titanium melts at 1668°c and the oxide layer forms instantaneously at all temperatures, but at high temperatures it forms so rapidly that the heat of the reaction causes the metal to catch fire. Thus like other metals which can be melted in open crucibles, titanium can only be melted in a vacuum furnace.
- Three different types of specially designed Ti casting systems are presently available, namely
  I. A pressure/ vacuum casting system with separate melting and casting chamber.
  II. A pressure/ vacuum system with one chamber for melting and casting.
  III. A vacuum/ centrifuge casting system.
- Dental castings are made via pressure vacuum or centrifugal casting methods. The metal is melted using an electric plasma arc or inductive heating in a melting chamber filled with inert gas or held in a vacuum. The molten metal then is transferred to the refractory mold via centrifugal or pressure- vacuum filling.
- Casting of titanium commonly is used to fabricate crowns, bridge frameworks.

INVESTMENT MATERIALS

- Investment materials with low reactivity are used to prevent surface reaction with the molten metal and materials with high setting expansion are used to compensate for the high casting shrinkage of titanium.
- The thickness of surface reacted layer differed in degree among investment materials. Micro hardness increased in the surface layer of Ti casting as a result of O_2 diffusion, mold Ti reaction and even thernocycling of metals during porcelain application.
  Conventional investment materials had heavy reactions with Ti and provided zero expansion for the compensation of metal shrinkage at the recommended mold temperature (200°C) during casting.
- Ti reacted little with a new AL_2O_3 - Mg O - based investment materials which had the best compensation for Ti shrinkage.
- Radiographic digital imaging analysis indicated that the centrifugal casting method showed best results.
- Internal porosity of Ti casting can be easily detected on routine dental radiographs.
- Ti casting made under an argon pressure of 50 mmHg are significantly more porous than are casting made under a pressure of 400mm Hg.
- Non vented moulds of a highly permeable refractory material yield most sound castings.
- Porosity is reduced when a large individual sprue (6-gauge) is used.

TITANIUM MACHINING[9] (FIG 7)

- Dental implants generally are machined from billet stock of pure metal or alloy.
- As an alterative to lost-wax casting the procera (CAD / CAM) system machining system with titanium machining has been developed by

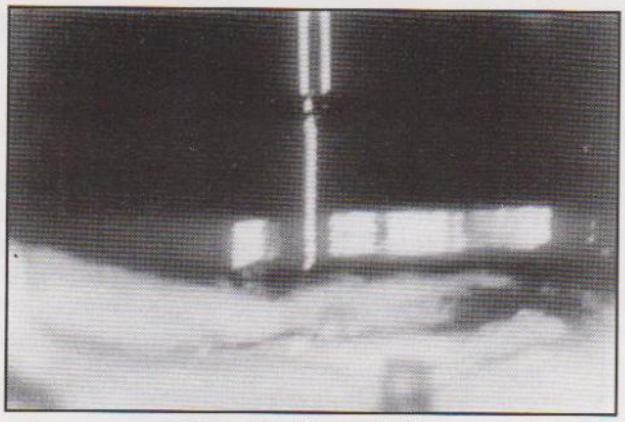

Fig. 7 : Titanium machining.

Andersson et al for the fabrication of unalloyed titanium crown and fixed partial dentures.

- The external contour of a titanium crown or coping can be shaped out of a solid piece of Ti by a mechanical milling machine,
- The internal contour of the titanium crown is spark eroded with a carbon electrode. (Fig 8) This process is called Electrical Discharge Machining (EDM) or Spark Erosion Process which is a metal removal process using a series of electrical sparks to erode metal from a work piece in a liquid medium.
- Spark erosion process, creates internal cavity of the crown coping. Single titanium crowns can be fabricated with this method and multiple units can be laser welder/ electric spot welded. A crown produced by the procera CAD/CAM process is well within the clinically acceptable range for marginal opening gap dimensions of less than 100 μm.

ACCURACY OF FIT:

- The fit is inferior to that of silver palladium crowns but superior to that of Ni-Cr crowns.
- Casting shrinkage occurs particularly along the horizontal axis in the plane of the shoulder.
- Titanium crowns / copings can be cast with acceptable fitting accuracy.
- There no significant differences in marginal opening between cast and machined Ti crowns.

TITANIUM AND PARTIAL DENTURE FRAMES:

- RPD frame works that are 0.7 mm thick had better castibility than did 0.35 mm thick RPD frameworks, suggesting that if Ti is used for RPD frameworks, a thicker wax pattern is needed than is used with Co-Cr alloys.
- Titanium fails to cast perfect mesh specimens.
- Titanium castings are more accurate than the best Co- Cr castings.
- Clasps made from Ti alloy are able to maintain more of their retention than are Co- Cr clasps. Cast titanium clasps are consistent in their mechanical properties. Their flexibility is intermediate between that of Ni-Cr wire and cast Co- Cr alloy. Ti clasps do not show permanent deformation suggesting that Ti may be a superior material for cast RPD clasps.

TITANIUM BONDING:

- Conventional degassing procedure is not suitable for porcelain-titanium restorations and the firing cycle should be below 8000c to minimize the metallic oxide formation of the Ti surface.
- The coefficient of thermal expansion of porcelain must match that of metal.
- The oxidation mechanisms and reasons for development of a non-adherent oxide layer, while not perfectly understood are well characterized for Ti and its alloys.
- Studies have shown that porcelain fired to Ti under inert atmosphere resulted in improved bonding.

TITANIUM JOINING[10]

Different methods to join titanium have been investigated.

- Laser welding - is effective when performed in an argon environment. Penetration of laser energy should be up to 0.9 mm, beyond which it remains unwelded. Welded specimens show defects such as gas pores and cracks at fractured surfaces. The size and distribution of such defects seemed to be dependant on the laser variables used.
- Electric arc welding- Disrupted the granular pattern and generated highly lamellar acicular structures such that these joints were highly resistance to tensile stresses while fatigue strength ranged among the lowest.
- Gold & Ti-Cu-Ni filler brazing- increases grain size and alters their shape
- Electron beam welding- It augments the brazing phenomenon and yields grain sized that encompassed the full diameter of the joints.
- Plasma welding and inert gas method.

Welded specimens showed defects such as gas pores and cracks at fractured surfaces.

It is concluded that tungsten inert gas method demonstrates overall better results in terms of tensile strength and ductility. No conclusion could be done concerning long term serviceability of welded titanium frame works.

CONCLUSION:

- Based on their physical properties and bio compatibility titanium and its alloys have emerged as the metals of choice in dental implant dentistry.
- Processing difficulties have however limited titanium usefulness in fixed and removable prostheses.
- Titanium is economical and readily available, but the technologies of machining, casting, welding and veneering it for dental prostheses are expensive and not readily available.
- Increased use of titanium in prosthodontics depends on research and clinical trials to compare its effectiveness as an equivalent or superior metal, to existing metals.

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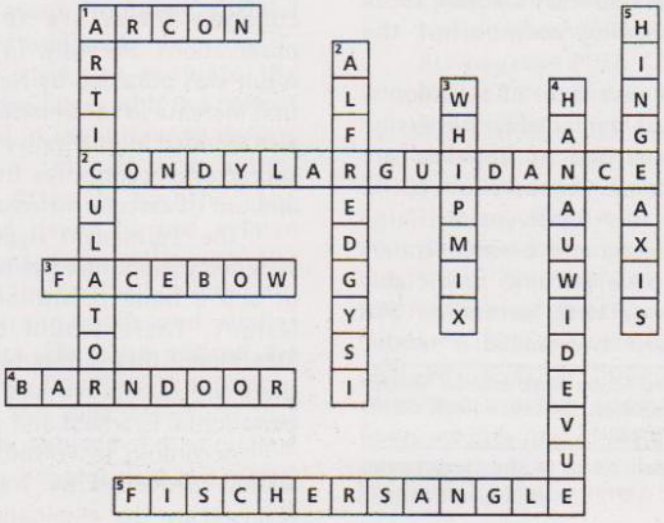
ANSWER : PROSTHODONTIC WORD POWER - 10



Periodontal Considerations for Prosthodontic Treatment

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ABSTRACT

The hopeless tooth of the new millennium is entirely different from that of the earlier century. Advent of several biomaterials has given rise to a plethora of avenues to salvage such teeth, which can be a real boon to the patient. A review of such biomaterials, their requirements and mechanisms, advantages and disadvantages have been discussed in this article. Product information also has been provided. Review concludes with a brief note on future for these materials.

INTRODUCTION

The hopeless, untreatable tooth of the new millennium is far different from its counterpart a half century ago. The advances since the 1950s and 1960s in technology, biomaterials, delivery systems, surgical and non-surgical therapies, scientific evidence, and access to continuing education have been remarkable. The modern dental practitioner can accomplish what his/her predecessor of a few decades ago would have considered impossible.

There are two major factors that most commonly relegate a strategic tooth to the "hopeless" status : Restorability and Periodontal support. The tooth that cannot be restored or that has inadequate, unmanageable periodontal support is hopeless. (Harrison, Timothy, 1999)[1].

Periodontal disease may cause destruction of the periodontal support of a tooth to the extent that it becomes a hopeless cause. But modern treatment and maintenance capabilities have made tremendous advances in allowing the periodontally involved tooth to continue as a functioning member of the masticatory apparatus.

In the past decade, a new form of periodontal treatment has proved to be remarkably successful. Many teeth previously regarded as hopeless are salvageable via Guided Tissue Regeneration (GTR). Badly involved class II furcation involvements, large three-walled intrabony defects, and osseous craters that were non-treatable have become predictably treatable. Recent advances with extensive GTR procedures have made most two-walled infrabony defects routinely treatable. Multiple-tooth GTR procedures are becoming increasingly successful; even groups of teeth with more than 50% loss of attachment can be maintained with regenerated support.

A brief review of such methods and materials used have been discussed in this article.

Key Words : Periodontitis, Guided Tissue Regeneration, Guided Bone Regeneration, Barrier membranes, Carriers, Enamel Matrix Protein, Bone Morphogenetic Protein.

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CAUSES FOR LOSS OF ATTACHMENT LEADING TO MOBILITY :

The physiologic tooth mobility depends basically on

a. Quality or viscoelastic properties of the periodontal tissues and
b. The anatomical characteristics like amount of supporting alveolar bone and width of periodontal ligament space. Other factors like number, shape and length of the roots or the intrinsic elasticity of the tooth itself also have to be considered.

Giargia and Lindhe,[2] in 1997, reviewed various aspects of tooth mobility and the disease status of the periodontium. The widely accepted major cause for pathologic tooth mobility is trauma from occlusion. Hyper mobility of teeth has been grouped under two categories, e.g. developing (phase of Progressive Mobility) and Permanent (Phase of Stabilized Hyper mobility).

In 1974, Svanberg reported several characteristic histological findings related to "Developing Mobility" phase of hyper mobility. Enlargement of Periodontal Ligament space, osteoclastic alveolar bone resorption, vascular alterations and degenerative phenomena in periodontal membrane and reduced number of collagen fibers are to name a few of these observations. Recently, in 1992, another interesting result was obtained by Neiderud et al. They reported that increase in tooth mobility due to occlusal trauma also resulted in qualitative changes, in composition of supracrestal connective tissue. It exhibited increased amount of vascular structures than collagen content.

The "Permanent Hyper mobility" phase exhibits widened periodontal ligament space without any signs of active bone resorption and acute inflammatory lesions. There would be no connective tissue attachment loss in this type of hyper mobility. Thus, there are qualitative and quantitative alterations of periodontal ligament and supraalveolar soft tissues.

According to Polson, Lindhe, and Ericsson, the lesions provoked by traumatic occlusion can be reversed by the elimination of the trauma. Normal

tooth mobility, normal width, reorganization of the periodontal fibers and regeneration of alveolar bone can be achieved in as short as 10 weeks after removal of the occlusal trauma.

REGENERATION POTENTIAL OF PERIODONTIUM

The hypothesis originated by Melcher and established by Karring et al, suggests that selected cell populations residing in the periodontium can produce new cementum, alveolar bone and periodontal ligament, provided that these populations are given the opportunity to occupy the periodontal wound. Such opportunity arises when other cell populations, such as epithelial cells or gingival fibroblasts, which also would invade the wound space is effectively excluded. This provision to exclude specific tissues during the healing phase of a periodontal defect has generated an impetus for the development of periodontal devices, commonly called barriers or membranes, for guided tissue regeneration.

Periodontal regeneration implies the formation of a new connective tissue attachment (new cementum with inserting collagen fibers) and a new Alveolar bone. It is a type of healing that occurs following periodontal surgery using guided tissue regeneration techniques/materials. These techniques/ materials have been described in detail in the later part of this article.

REGENERATION POTENTIAL OF PERIODONTAL LIGAMENT FIBERS : (GTR)

The Periodontal Ligament consists of, fibroblasts, collagen fibers and oxytalan fibers. The regenerative potential of oxytalan fibers, that are part of Periodontal Ligament, have been studied in great detail by Sculean et al, in 1997.[3] The experiments were carried out in primates. Results demonstrated that Oxytalan fibers were present in newly formed Periodontal Ligament connective tissue.

They conducted the study to evaluate the regenerative capacity of these fibers with the help of PDGF growth factors placed in the intrabony defects iatrogenically created and covered with a bio-resorbable membrane. After 5 months, the histological study revealed newly formed aytalan fibers inserting into cementum. Although the filaments were thinner than their normal counterpart, they displayed similar arrangement and similar morphological characteristics. They also noticed the formation of new alveolar bone in the region. However, one drawback of this experiment was that the teeth were not previously deprived of their original periodontal ligament. Hence, it is argued that it merely studies the survival capability of the existing oxytalan fibers rather than their regeneration capacity.

Normal oxytalan fibers maintain homeostasis of Periodontal Ligament, thereby preventing ankylosis. They are elastic in nature and are oriented apico-occlusally. They are inserted to cementum in a perpendicular direction and are located more close to cementum than alveolar bone. They consist of bundles of filaments approximately 15 nm in diameter with an amorphous substance in between of same diameter.

Ultra structurally, the regenerated fibers were similar to those observed in original periodontal ligament. Although the fibers were thinner than those from original periodontal ligament, they had similar array and morphological characteristics. Also, these were closer to cementum than to alveolar bone inserting into newly formed cementum. Same observation has also been made earlier by Kohl and Zanders, in 1962 and 1972, respectively.

In 2003, Murakami et al,[4] identified that the periodontal ligament fibroblasts have higher potential to produce osteoblast-related extra cellular matrix proteins and that they show higher alkaline phosphatase activity than the fibroblasts of gingiva. They attempted, with success, to isolate those populations of the periodontal ligament fibroblasts that have these capacity to induce bone due to osteogenic property. The immuno magnetic method was used to investigate the expression of basic fibroblast growth factor receptor (bFGF) and transforming Growth Factor receptor (TGF) - β in fibroblast from both periodontal ligament (PDLF) and gingiva. Also, osteoblast- related molecules (Osteocalcin and bone Sialoprotein), alkaline phosphatase (ALP) activity, and effect of bFGF on proliferation were analyzed.

The results were encouraging, in that,

a. Expression of FGF receptor and TGF-β receptor was significantly higher in ALP positive PDLF than ALP-negative PDLF. ALP positive PDLFs produced higher Calcin and Sialoproteins.
b. The immuno-magnetic method could be used to successfully isolate osteoblastic/cementoblastic subsets from PDLF population
c. This is a useful tool in obtaining the cells with potential for mineralization on root surface.

But, "TRUE PERIODONTAL REGENERATION" refers to reformation of functionally oriented Periodontal Ligament (PDL) with collagen fibers inserted in both regrown alveolar bone and reformed acellular cementum on the diseased root surface. Oxytalan fibers are only part of the periodontal ligament, which have been shown to exhibit the capacity to regenerate as described earlier.

REGENERATION POTENTIAL OF BONE : (GBR)

The use of barrier membranes to facilitate bone healing was originally developed by Hurley and Boyne. Guided Bone Regeneration (GBR) refers more precisely to the goal of the membrane application rather than guided tissue regeneration. It promotes bone formation by protection against an invasion of competing, non-osteogenic tissues. Bone defects are tightly covered with either absorbable or non-absorbable membranes of suitable permeability. This creates a secluded space for invasion of blood vessels and osteoprogenitor cells which laydown bone tissue.

Callus Distraction method developed by Ilizarov in 1965 is another alternative for regeneration where bone grafts cannot achieve required result. This refers to lengthening of bones by stretching the callus in its early stages of formation. Controlled daily distraction of about 1mm can be achieved with the help of fixators. However, the density of the new bone achieved is low and it takes months for its corticalization and years for reconstruction of a true cortex via haversian remodeling. Weight bearing can start much earlier with the fixation device in place. Fixator can be removed long before the completion of remodeling.

Osteo induction consists of two types of induction of bone formation as differentiated by Friedenstein. There are two types of osteo precursor cells, one set called as Determined cells and the other Inducible cells. Determined cells are found in direct vicinity to bone like bone marrow stroma, in the periosteum, endosteum and intra cortical canals. These cells proliferate and differentiate into osteoblasts directly due to induction. This type of bone induction is known as Orthotopic bone induction/formation. (Direct bone formation). It has a lag phase of 1 to 3 days.

Where as the other group of cells called Inducible cells is found far from bone, areas like subcutaneous connective tissue, skeletal muscles, and spleen and kidney capsule. They react to inductive stimuli from materials like BMP and mimic endochondral bone formation. There is formation of intermediate cartilage leading to indirect bone formation. This type of bone induction is known as Heterotopic bone induction/ formation. This type of bone formation has a lag phase of 10 - 11 days as compared to Orthotopic induction.

Local regeneration of bone can be activated by Growth factors (Insulin GF, Transforming GF, Fibroblast GF, Platelet-derived GF) released by the bone in the defects and by the bone-related inducers like Interleukin-1 (IL-1), tumor necrosis factor-a (TNF-a). Other bone inducers are Lacroix's Osteogenin and BMP of Urist.

In addition to GBR, there are some means by which promotion and support of bone regeneration can be achieved. Osteo-conduction with the help of bone grafts and bone substitutes, and callus distraction are other methods to achieve this.

Cancellous autografts, Allografts and some bone-derived or synthetic bone substitutes all have osteoconductive property.

All the materials used for regeneration of bone have been described in later part of this article.

DISCUSSION

BIOMATERIALS USED TO AFFECT PERIODONTAL REGENERATION / (GTR / GBR)

A Biomaterial is defined as a nonviable material used in a medical device, intended to interact with biological systems. Any device introduced into the body to address a particular need has to fulfill mainly two requirements, like, safety and efficacy.

Safety refers to the Biocompatibility of the device. By definition, biocompatibility is the ability of a material to perform with an appropriate host response in a specific situation, which means that neither the material adversely and significantly affects the body nor the physiological tissue environment adversely and significantly affects the material. Biocompatibility can be assessed with the help of Cell culture cytotoxicity, skin irritation, mutagenicity, sensitization and histological tissue reactions.

Efficacy depends on the design of the device based on the tissue properties.

The list of various materials used for GTR and GBR is given below:

Materials for GTR	Materials for GBR
	GTR barriers
	Allografts (Osteoconductive)
Non-absorbable	Bone Inducing materials
Absorbable	(Osteo-inductive)
	Carriers for inducers - GTR barriers

GUIDED TISSUE REGENERATION - MATERIALS AND MECHANISMS

General Requirements

Design criteria, other than the above said Biocompatibility for Periodontal Guided Tissue Regeneration devices are listed below:

a. Cell Exclusion
b. Space maintenance (tenting)
c. Tissue integration
d. Ease of use
e. Biological activity

CELL EXCLUSION refers to isolation of gingival tissues from the maturing fibrin clot in the wound space. The

device used for GTR must incorporate structural elements to achieve this along with overall shape of the device and how it adapts to the site.

The GTR device also should be able to PROVIDE ADEQUATE SPACE for the regenerating alveolar bone, Periodontal Ligament and cementum. This is achieved by the structural features which allow them to withstand the forces exerted by the overlying flaps or those forces transmitted through the flaps e.g., mastication and other physiological forces.

The devices that are used as barrier must allow TISSUE INTEGRATION resulting in stabilization of the wound and inhibition of the epithelial migration. Flap stabilization through tissue integration of the membrane prevents wound failure and subsequent epithelialization of the tooth-gingival flap interface during early healing phase. This results in increased connective tissue attachment.

Thus, a device used for tissue regeneration while providing space for the growth of the periodontal tissues, also should STABILIZE the overlying gingival flap thereby excluding the unwanted cells from occupying the space.

Tatakis, Promsudhthi and Wikesjo, in 1999,5 differentiated two major types of devices used for Guided Tissue Regeneration (GTR). They are:

a. Non absorbable
b. Absorbable (Biodegradable)

NON-ABSORBABLE DEVICES:

These are first devices that were approved for clinical use. They have good compositional and design stability, which provide the operator with good control over time of application. However, they require a second surgical procedure for their removal, as their function is temporary and it is required to remove it once it is completed.

Examples of such devices are:

1. Polytetrafluoroethylene (PTFE) or expanded polytetrafluoroethylene (ePTFE)
2. Reinforced Expanded Polytetrafluoroethylene
3. Rubber dam
4. Resin-ionomer barrier
5. Knitted nylon fabric
6. Paper filter

Most of the non-absorbable materials are made up of either poly tetrafluoroethylene (PTFE) or expanded poly tetrafluoroethylene.(e-PTFE). Basically, both are similar chemically, i.e., they are fluorocarbon polymers with chemical structure as (-CF(-CF(-)n. PTFE is solid and nonporous. It does not allow tissue ingrowth and does not elicit a foreign-body reaction in tissue. Where as, e-PTFE exhibits minimal inflammatory tissue reaction and allows tissue in growth if properly constructed. It has been used as vascular graft material for over 20 years. It is manufactured by subjecting the PTFE to tensile stress, thereby making it only different in physical structure. It has porous microstructure of solid nodes and fibrils. The optimal size of fibrils and inter nodal distance depends on the type of application the device is intended for. It can be controlled through changes in the processing conditions. There are basically two structural designs.

a. An open microstructure collar, which corresponds to the coronal aspect of the device promotes connective tissue in growth, supports wound stability and inhibits epithelial apical migration. It is 1.0 mm thick, low in density (0.2g/ml) and 90% porous (100 - 300 microns between nodes).
b. A partially occlusive part, serving to provide a space for regeneration and as a barrier for gingival flap tissue invasion or collapse onto root surface. It is 0.15 mm thick, high in density (1.5g/ml) and 30% porous (<8 microns between nodes).

REINFORCED EXPANDED POLYTETRAFLURO-OETHYLENE:

The Expanded Polytetrafluroethylene has been modified with the help of titanium, which is set between its two existing layers, to improve the mechanical strength. It supports improved space provision and maintenance.

RUBBER DAM AS GTR MATERIAL:

It offers little rigidity, can be tedious to manipulate and exhibits no tissue integration.

Cortellini and Prato, in 1994,[6] documented five cases where in a Rubber dam was used to achieve tissue regeneration in infrabony defects. According to the results obtained by them, this material did not cause any side effects even after 5 weeks of its placement. At the same time, the periodontal healing was achieved with tissue regeneration with the help of rubber dam by Salama et al,[7] in 10 cases of advanced periodontal diseases.

Both studies showed good results with 1year clinical attachment gain, ranging from 1 - 8 mm. In addition, complete resolution of the infra bony defect occurred in couple of sites treated with rubber dam. Mean osseous fill for all sites was 4.25 mm. Bone remodeling was caused by a combination of marginal resorption of the most coronal part of the crest of the bone and filling of the apical part of the infra bony component.

The rubber dam is a non-resorbable barrier, which is impermeable for guaranteed separation

between the space and the epithelial cell. The elasticity nature favors its positioning and stability over the defect and around the adjacent teeth. In addition, its elastic tension provides an effective support for the gingival flap.

It has been argued that, the biocompatibility of this material is in par with some of the medical catheters and drains like Foley Catheter and Penrose drains. Stereo metric surveys demonstrated comparable number of inflammatory cells as with control sites without rubber dams. They have theorized the reasons for this success saying that the rubber dam promotes drainage while its non-porous surface reduces plaque adherence. They also concluded that the amount of regeneration is determined by the position of the barrier membrane. While the observed advantages of rubber dam was commendable, it was not without any disadvantages:

a. Abnormal greenish coloration of the gingiva - only temporary. As it is a non-resorbable barrier, it will be removed after the regeneration is achieved.
b. Main disadvantage observed by Salama et al, is its inability to cause tissue integration.

Advantage of tissue integration includes stabilization of membrane and surgical flaps, limitation of epithelial migration on the flap's inner surface. This may be due to the non-porous nature of the material. This aspect makes maintenance of the area more demanding. Also, because of the resulting lack of flap stabilization, recession was a frequent finding causing esthetic problems especially in anterior segments.

However, in general, a new dental use for rubber dam as an acceptable barrier membrane has been evolved through these studies.

RESIN-IONOMER BARRIER:

Has excellent space making properties, but is difficult to fabricate in situ. Its tissue integration properties are unknown.

KNITTED NYLON:

This material has been bonded with semipermeable silicone membrane and coated with collagen peptides (BioBrane). It is well tolerated by the tissues, but exhibits limited space providing capacity and its regenerative response was mixed in nature.

PAPER FILTER:

It is the earliest clinical devices used. It is made up of Cellulose acetate. This is the original GTR material designed by Nyman et al. It persisted in the tissues for six months after implantation.

ABSORBABLE BARRIERS:

They do not require additional surgery for removal, leading to patient comfort, less chair-side time, related cost and eliminates surgery-related morbidity. However, unlike non-absorbable barrier, the operator has limited control over the length of application, or the degradation process initiates as soon as the material comes in contact with the tissues. They might elict inevitable tissue reactions that may influence wound healing.

Absorbable barriers are of two types :

	Natural	Synthetic
1.	Collagen	Poly (lactic acid)
2.	Dura mater	Poly (glycolic acid)
3.	Cargile membrane	Poly (glycolide-lactide)
4.	Oxidized cellulose	Polyurethanes
5.	laminar bone	

NATURAL ABSORBABLE BARRIERS:

Collagen:

Mostly used in biomedical devices. Among all types of Collagen, Type I is most abundant. It is in fibrillar form. Tendon, Bone and skin have a uniquely high type I collagen content. 60% of gingival connective tissue is made up of collagen.

Collagen used for medical devices is derived from several animal sources like, bovine skin, tendon, intestine or sheep intestine. Isolation and purification is done in two ways:

a. Enzymatic preparation of soluble collagen
b. Chemical extraction of fibrillar collgen from collagenous tissue.

After the above process of isolation and purification, it is processed by cross-linking, by glutaraldehyde treatment. Cross-linking limits the tissue toxicity of the final product. Increased cross-linking results in decrased water absorption, decreased solubility, decreased susceptibility to enzymatic degradation, increasd tensile strength, increased biodegradion time and decreased immunogenicity. Collagen is mainly degraded by enzymatic activity of infiltrating macrophages and polymorphonuclear leukocytes.

A Type I collagen which has been approved for Guided Tissue Generation procedures is obtained from boving deep flexor tendon. (Bio-Mend). It is semi-occlusive (pore size 0.004 microns). It gets completely absorbed in four to eight weeks.

Another Type I collagen is derived from calf pericardium and cross-linked by diphenylosphorylazide. This membrane induces significant inflammatory reaction and resorbs within two weeks.

One more collagen barrier (Avitene) has been derived from bovine corium. Another collagen, (Collistat), which is also a hemostatic material shows good potential as regeneration material.

Dura mater is another material, which is being used for regeneration purposes. It is an irregular network of collagen fibers obtained from cadavers. it has been processed to eliminate antigenic and pyrogenic activity and then lyophilized and sterilized. This material resorbs in six weeks after surgery, shows limited tissue integration within two weeks, limited inflammatory reaction and inhibition of epithelial apical migration. Main disadvantage of this material is the risk to acquire Creutz-Feldt-Jakob disease not only for the receipient but for the operator also.

Cargile membranes are procured from bovine intestines (Ox Cecum) and processed in a manner similar to chromic gut sutures. It provides limited inhibition of epithelial apical migration. Material resorbs in four weeks after surgery.

Oxidized Cellulose mesh is a hemostatic dressing. It can be used as GTR material. It can resorb completely within four weeks of implantation. Provides limited space provision and maintenance and cell exclusion. It may delay wound healing in bone due to its acidic nature.

Laminar Bone is a strip of cortical bone of 300 to 500 microns thick. It is a processed bone similar to demineralized freeze-dried bone allografts.

Connective tissue grafts also have been used as natural barrier for GTR.

SYNTHETIC ABSORBABLE MATERIALS:

These are made from Oraganic Aliphatic Thermoplastic polymers, like poly (α-hydroxy acids), which include, poly (lactic acid), poly (glycolic acid), and their copolymer(s), poly (glycolidelactide).

Poly (glycolic acid) and poly (lactic acid) are widely used for sutures and drug controlled-release devices. They are manufactured by catalytic polymerization of monomers.

Main advantage of these materials is their degradation by hydrolysis. The decomposition products get metabolized to carbon dioxide and water through Krebs cycle. However, the rate of degradation depends on the pH, presence of mechanical strain, enzymes, infection and composition. Composition modification of poly (L-lactide) by cross-linking or additionof D-lactide or glycolide results in more rapid degradation.

During hydrolysis, the monomers like lactic and glycolic acids are released along with their linear dimers and oligomers. If these by-products are in too high concentration, they may be toxic to the cells causing adverse effects.

One material, which was the first to gain approval for use as GTR material, is a double-layered device (GUIDOR) made of poly (lactic acid) (containing both L-and D-lactic acid enantiomers) and a citric acid ester (acetyl-tributylcitrate). The external layer allows integration of the overlying gingival flap. It consists of rectangular perforations (400-500/cm^2). The internal layer has smaller circular perforations (4000-5000/cm^2) and it has an outer spacer to ensure a space between the barrier and the root surface. The coronal portion of the internal layer has a bar intended to provide a seal between the barrier and the tooth, while the coronal portion of the interspace houses a biodegradable suture, which is used to fasten the device to the tooth. The area between these external and internal layers consists of more spacers creating a space into which tissue can grow. This material gets resorbed completely within 6 to 12 months.

Another synthetic material is RESOLUT. It is a composite material consisting of an occlusive membrane of glycolide and lactide copolymer and a porous structure of bonded polyglycolide fiber. The occlusive part serves the cell-exclusion function. The porous part serves the tissue integration function, while the stiffness of the devices serves the space maintenance function. It is supplied with a polycaprolate coated polyglaycolic acid (RESOLUT) suture, which is used to secure the device to the tooth.

VICRYL Periodontal Mesh is a material made of Fiber of polyglactin 910, a copolymer of glycolide and L-lactide (90/10 molar ratio). Polyglactin 910 sutures are placed at its coronal margin to facilitate anchoring on the tooth. This device has also been modified with bovine type I and III collagen.

The ATRISORB Barrier is a GTR material, which can be manufactured at the chair-side. It is a poly (DL-lactide) polymer in flowable form dissolved in N-methyl-2 pyrrolidone. Polymer forms 37% and the solvent 63% by weight. When this is exposed to 0.9% saline solution for 4 to 6 minutes in a special cassette, it can be cut to desired shape. It is 600 - 750 microns thick, with modest adhesive properties and is used on the defect with gentle pressure. It does not require suturing. It gets absorbed in 6 to 12 months.

Other absorbable membranes are based on polyurethanes, which are organic polymers with urethane group, -NH-CO-O. Earlier polyurethanes are absorbable containing poly (ester urethanes) where as later ones containing poly (ether urethanes) are more stable. According to studies by Warrer et al, these membranes are not useful for guided tissue regeneration as they produced more pronounced inflammation and recession and the material tended to swell.