

A REVIEW ON BIORESORBABLE MATERIALS: APPLICATION IN ORAL AND MAXILLOFACIAL SURGERY

Paramjot Kaur¹

1. Reader, Department Oral and Maxillofacial Surgery, Baba Jaswant Singh Dental College & Research Institute, Ludhiana

ABSTRACT:

Bioresorbable implants have been an area of interest to multidisciplinary researchers since yester years. with newer advancements and increasing research interest in past and newer topics, bioresorbable materials have also gained the focus of attention of dental and maxillofacial surgeons recently .

Key words: polylactide, polyglycolide, polydioxanon, maxillofacial, dental, implants



INTRODUCTION:

Bioresorption/biodegradation is the process of removal of a material from the body by cellular activity. In other words, biodegradation is the body's way of breaking down a polymer and bioresorption is the clearing out the polymer by the body. Resorbable internal fixation devices are known to degrade; yet the time course in humans they do so remains unclear.^[1]

Resorbable materials are composed of a various combinations of poly α -hydroxy polyesters such as polylctic acid and polyglycolic acid with each combination yielding a product of different mechanical and degradative properties. Polylactate, ployglycolate and polydioxanon are few of the biodegradable materials that have undergone the scrutiny of human testing for more than 40 years. The products are initially hydrolyzed, then phagocytized

and finally excreted in the expired gas and urine through the krebs cycle^[2].

HISTORY

The experimental investigation of resorbable polymers has been ongoing since their introduction as medical implants in 1960s as resorbable sutures. Although there clinical use in orthopedic surgery has occurred since 1980's, only recently this technique made its transition to craniomaxillofacial surgery with clinical reports in paediatric surgery^[21,26], facial fractures, maxillary osteotomies and aesthetic facial soft tissue anchoring.^[3]

BIOCHEMISTRY

(1) Biomechanical Principles^[5]

- (a) Be easily adaptable and moldable
- (b) Be cost effective

- (c) Have sufficient stiffness to maintain rigid fixation and strength to resist deformation
- (d) Be completely biocompatible, with no local or general adverse effects
- (e) Fully disintegrate after sufficient fixation time
- (f) Be flat and not palpable through the soft tissues
- (g) Not conduct inflammation from exposed plate parts to the deeper the deeper tissue

(2) Biomechanical properties-

(a) Material composition ^[21]:

Homopolymers (eg; polylactide and polyglycolide) are composed of repeating identical units of monomers that are derived from α -hydroxyl acids. Polylactide contains a methyl group (CH₃) that makes polylactide more hydrophobic and thus more resistant to hydrolysis than polyglycolide. Both glycolic acid and lactic acid are produced during normal cell metabolism. Lactic acid has two enantiomeric forms, L-lactic acid and D-lactic acid. Polylactide that has been used so far in clinical applications has commonly been pure poly L-lactide. Polymers exhibit a glass transition temperature, above which the polymer is soft and malleable. The glass transition temperature of Poly lactide is 57⁰c and polyglycolide is, 36⁰c ^[21].

Copolymers ^[21]:

When two or more monomers are used to make a polymer, the resulting polymer is called a copolymer (e.g. (P/DL) LA and PLGA). In pure poly L-lactide the polymer chains can be tightly packed, which makes the polymer partly crystalline. Crystallinity and hydrophobicity make poly L-lactide very resistant to hydrolysis and biodegradation. Adding D-isomers into an L-isomer based polymerization system gives winding polymer chains which cannot be tightly packed. Thus P/DL LA is amorphous and more susceptible to hydrolysis and biodegradation. Also the physical characteristics of the slowly degrading poly L-lactide and the very rapidly degrading polyglycolide can be modified by the copolymerization of various proportions of homopolymers. Amorphous polymers can be reinforced as in devices made of self reinforced P (L/DL) LA (70L/30DL) and self reinforced PLGA. The self reinforced PLGA copolymer consisting of 80 mole% of lactic acid and 20 mole% of glycolic acid has been used recently in paediatric patients (Biosorb Pdx, elite performance technologies). An example of nonreinforced PLGA copolymer is Lactosorb (82% Lactic acid, 18% glycolic acid) which has been used mainly in craniomaxillofacial surgery in less loaded or non loaded osteosynthesis. Non reinforced plates must be heated over the glass transition temperature to be shaped and then cooled down before implantation. Self reinforcing increases the strength of the devices considerably

and makes the self reinforced plates more moldable in room temperature.

Self-Reinforcing can be used to fabricate polyglycolide, polylactide or their copolymers into osteofixation devices. Melt molding usually produces devices that are either too brittle or too flexible to be used for osteofixation. Compression molding or injection molding produces strong devices. Ultrahigh strength(bending strength upto approximately 400 megapascal) self reinforced implants can be developed by sintering and by solid state deformation techniques [21].

Self reinforcing implies formation of a composite structure made of (1) a certain partially crystalline or amorphous polymeric material comprised of oriented self reinforcing units such as fibrils, fibers or extended chain crystals; and (2) binding matrix, both having the same chemical structure. The most advanced self-reinforcing technique, partial fibrillation by orientational solid state drawing has given the self-reinforcing implants with the best properties. The high degree of molecular orientation makes the reinforcing elements still and strong in the direction of their long axis, resulting in high strength of the composites. The bending strength of the composites has been increased with the self reinforcing technique several times compared with the initial values enabling reliable and secure bone fixation. Non reinforced implants must be manufactured thicker and larger to compensate for brittleness,

with a subsequent increased risk of complications. The microstructure of self reinforced plates involves orientation in two perpendicular directions. Biaxial orientation makes the self reinforced plates strong and malleable in room temperature. The plate can be bent four times its mechanical properties start to decrease significantly. The tendency to straighten(memory) is as slight as that of metallic plates, and similar slight over-bending is recommended [21].

(b) Degradation and Absorption [21]:

Biodegradable refers to solid polymeric materials and devices that break down as a result of macromolecular degradation with dispersion in vivo, but there is no proof of elimination from the body. Fragmentation or other degradation of byproducts occurs that may move away from their site of implantation but not from the body. In contrast bioresorbable refers to a solid polymeric material that can degrade and further resorb in vivo, and is eliminated through natural pathways of filtration or by being metabolized. This process reflects the fact that the material is totally eliminated without residual side effects.

The degradation of polylactide and polyglycolide begins with the random hydrolysis of the polymer chains, leading to the reduction of the molecular weight and strength properties and fragmentation of the polymeric implant into smaller particles. Enzymes can possibly enhance the degradation. In cell

metabolism lactic acid and glycolic acid are metabolized into water and carbon dioxide. Biodegradation is affected by microstructural, macrostructural and environmental factors, such as the polymer molecular weight, molecular orientation, monomer concentration, presence of low molecular weight compounds, geometric isomerism, crystallinity and conformation. It is also affected by surface area-weight ratio and porosity and site of implantation. Macrophages and giant cells are thought to be responsible for the ultimate digestion of the polymeric debris. This is associated with transient mild microscopical foreign body reaction, which is not necessarily clinically manifested [21].

BIOCOMPATIBILITY [16]

Although they show promising results in a variety of applications, the biocompatibility of the PLGA scaffolds is under debate. The degradation products of PLGA (lactic and glycolic acid) can decrease the pH in the surrounding tissues, causing inflammation or foreign body reactions in vivo. Also, the acidic degradation products have the potential to inhibit apatite crystals formation, leading to presumably deficient osteointegration. The hydrophobic properties of the bioresorbable polyesters negatively influence their cell adhesion. Moreover, in an attempt to reduce the inflammation and improve the biocompatibility of PLGA different particles have been incorporated with promising results into the PLGA

materials: titanium nanoparticles, tripolyphosphate nanoparticles, demineralized bone particles, and nanoapatite particles. Also the PLGA scaffolds were functionalized with fibronectin [and the PLGA fibers were coated with apatite layer. Another problem is the fact that salivary born aerobic and anaerobic microorganism adhered significantly more to PLGA compared to other polymeric (PLLA and PLLA-TCP) scaffolds. *E. faecalis* (a bacteria present in recurrent endodontic infections) and *P. gingivalis* (a periodontitis related pathogen) showed the highest adhesion to the PLGA scaffold, rising concerns about possible implant-associated infections (moanes et al, 2015) [16].

BIORESORBABLE POLYMERS REVIEWED IN LITERATURE FOR MAXILLOFACIAL IMPLANTS IN CHILDREN AND ADULTS ARE LISTED AS FOLLOWS:

Poly-L-Lactide

Self-reinforcing poly-L-lactide

P(L/DL)LA and self-reinforced P(L/DL)LA

Polyglycolide and self-reinforced polyglycolide

PLGA and self-reinforcing PLGA copolymers.

Commercially available resorbable or bioabsorbable devices for osteofixation [10] is shown in table 6

ADVERSE REACTIONS [21]

No clinically manifested adverse inflammatory reactions specific to absorbable devices have been recorded with the self-reinforced implants used in craniomaxillofacial surgery.

Nonreinforced biodegradable devices manufactured with other techniques have been used as large implants to compensate for their brittleness and low strength. Analysis revealed polylactide crystals encapsulated in thick fibrous tissue. clinically manifested inflammatory reactions are remote with nonreinforced biodegradable devices and self-reinforced polylactide (around 0.1 percent¹²³ in orthopedic patients), we think that surgeons should be aware of the possibility.

Homopolymeric polyglycolide implants have caused transient foreign body reactions in the treatment of ankle fractures. Microscopic examination of fluid accumulations revealed a nonspecific foreign body reaction, composed mainly of neutrophils and foreign body giant cells phagocytosing the polymer debris. Few patients, however, needed repeated surgical treatment and admission to hospital. This phenomenon is probably due to an imbalance between the rapid rate of degradation and the slower rate of absorption. The use of polyglycolide implants is, therefore, limited to pediatric surgery, because the intense metabolism of bone tissue in children makes adverse reactions rare. Because of their optimal degradation characteristics, amorphous copolymeric

P(L/DL)LA or PLGA implants have caused no clinically significant foreign body reactions.

APPLICATION IN ORAL AND MAXILLOFACIAL SURGERY

FACIAL BONE PLATING

When these isomers are copolymerized bone plates and screws of adequate strength and low inflammatory response can be manufactured in contrast to copolymers manufactured by injection molding or heat processing ^[2]. The estimated length of complete biodegradation of the copolymer poly L/DL Lactide implant is 2-3 years. While, that of polylactide and poly glycolide was found to be 90-120 days ^[7,8]. Clinically the absorption time of self reinforcing plates takes 6 to 12 months, for pure poly-L lactides it takes approximately 5 years or more. Bioabsorption of self-reinforcing PLGA takes 1 to 1^{1/2} years ^[21].

Bioresorbable materials have been used worldwide over four decades. First they were mainly used as sutures and membranes. The first use of absorbable synthetic suture material for internal fixation of the fractures of mandible was in 1974 by Roed Peterson ^[5]. However, the first clinical report on the use of resorbable polylactic plates were published in 1980's in international literature and was approved by US food and drug (FDA) for use in non load bearing areas of craniofacial skeleton in 1996(Lactosorb) ^[1,2].

It is a technological advance to offer an improvement in bone fixation that offers the potential to avoid secondary device related complications and the need for operative reentry^[3]. Titanium plates and screws are the gold standard rigid fixation plates used in maxillofacial trauma^[4]. Fixation of unstable zygomatic fractures with metallic bone plates and screws is a method used by many clinicians. However, a major drawback of this method is that after healing metallic plate has to be removed to prevent atrophic changes of the underlying bone due to lack of functional stimuli^[6]. There are disadvantages inherent to rigid fixation systems and include growth disturbance^[3], interference with radiation therapy^[3], plate migration^[3], the need for subsequent removal⁽⁴⁾, incompatibility with future imaging needs^[3], long term palpability and thermal sensitivity^[3]. There is thus a need for a biocompatible and biodegradable material that gives sufficient stability during healing and is slowly resorbed by the body.

Although biodegradable bone plates and screws have been used for more than a decade, a reliable composition, strength, duration, presence of an inflammatory response and proper design have been problematic^[2]. Clear disadvantages are cost, screw breakage, dimensions of plates and screws and the required vertical screw to plate position^[5]. The choice of plating system should be based on plating preference, biocompatibility, computerized tomographic compatibility and unit cost^[5].

Sukegawa et al 2016^[27] in their study compared the surgical management of zygomatic fractures using newly developed thinner bioresorbable materials or conventional titanium miniplates. Twelve patients with zygomatic fractures were randomly divided equally into 2 groups each having 6 patients of zygomatic fractures. one group received newly developed thin flat-type bioresorbable plate system GRAND FIX composed of a monopolymer of PLLA and in the second group MatrixMIDFACE titanium miniplate system was used. By using standard surgical procedures according to Arbeitsgemeinschaft für Osteosynthesefragen principles. Zygomatic fractures were stabilized using 2- or 3-point fixation. follow up was done every 2 months. The amount of soft-tissue volume increased at the injured operated side relative to the uninjured healthy side using bioresorbable plates was 131.1% (range: 101.5–165.8). The amount of soft-tissue volume increase at the operated side relative to the healthy side using titanium miniplates was 126.4% (range: 102.2–167.6). There was no statistically significant difference ($P \leq 0.05$; >0.05) in the amount of soft-tissue volume increase at the operated side relative to the healthy side at the frontozygomatic sutures between patients treated with the bioresorbable material and those treated with titanium miniplates. it was concluded that this newly developed thinner flat-type bioresorbable plate system could be considered clinically

useful in the treatment of zygomatic fractures even in easily palpated areas, such as the infraorbital rim or zygomaticofrontal sutures, without any healing differences in skeleton as compared with conventional titanium miniplates.

High osteogenic potential of pediatric mandible allows nonsurgical management to be successful in younger patients with conservative approaches. Maxillofacial surgeons generally justify the use of plate- and screw-type internal fixation to be reserved for difficult fractures. Specific subsets of mandibular fractures, including displaced fractures of the body or angle, fractures of the condylar neck with significant barriers to movement, complex fractures, and fractures in non-toothbearing areas necessitate open reduction and internal fixation. The use of resorbable plates is an increasingly attractive option in the treatment of pediatric mandibular fractures. It is both well-tolerated and effective. It enables realignment and stable positioning of rapidly healing fracture segments while obviating any future issues secondary to long-term metal retention. Major concerns for using resorbable materials in the maxillofacial region are the strength of the material and its ability to withstand masticatory forces, and the extent of inflammation as the materials begin to degrade^[28].

Filente GT et al^[28] used both systems of metallic and resorbable hardware for fixation of pediatric mandible fractures.

Limited number of cases and follow-up demonstrated no difference between the stability and healing capacity of the two systems. Resorbable materials have the advantage of avoidance of secondary removal operations. Limited number of long-term studies and high cost when compared to the metallic hardware are among the drawbacks of biodegradable systems. However, ongoing studies demonstrating the advantages of the resorbable plates indicate that they are going to be preferred more in the future.

Developments in the fabrication of absorbable osteofixation devices have provided craniomaxillofacial surgeons with strong, reliable devices. Long-term follow-up of craniomaxillofacial patients treated surgically with selfreinforced devices has been encouraging. The list of applications of absorbable plates and screws is growing. Currently, the most suitable polymers seem to be P(L/DL)LA copolymers (with different monomer ratios) and PLGA, especially in the self-reinforced form^[21].

FACIAL IMPLANTS

Autogeneous bone grafting has been the gold standard to provide framework for facial skeleton and orbital walls. Disadvantages of autogeneous bone grafts include nerve and blood vessel injuries, chronic donor site pain, gait disturbances and cosmetic disturbances^[10]. Biodegradable alloplasts have numerous advantages over other alloplastic materials and bone grafts as their use is time sparing, straight

forward procedure that allows for primary reconstruction and avoids additional donor site morbidity which goes along harvesting a bone graft ^[10].

The main disadvantage of the current biodegradable material available for repair of defects of inferior orbital wall is the premature loss of mechanical properties before the healing process is complete. Consequently more rigid material are best suited for reconstruction of large defects to prevent sagging of the material for displacement into the maxillary antrum and or ethmoid sinuses ^[10].

Nonvascularized bone grafts for mandibular reconstruction offer the following advantages over free tissue transfer with microvascular anastomosis ^[18].

- 1) decreased intraoperative time,
- 2) decreased length of hospital stay,
- 3) decreased donor-site morbidity,
- 4) less sensitivity to technique,
- 5) in select cases a more optimal reconstruction for dental implant prosthetic rehabilitation.

However, although this option seems better tolerated by the patient and is less involved for the reconstructive surgeon, it is fraught with lack of predictability. It also requires more than 1 operative intervention, because a 2-stage (“delayed”) approach is usually required to allow for healing of oral

mucosa and decontamination of the future graft recipient site. (Shanti RM et al 2015) describe 2 cases of segmental continuity defects of mandible treated successfully with ultrasound-aided resorbable mesh (SonicWeld Rx, KLS Martin, Jacksonville, FL) for containment of the graft and maintenance of the vertical dimension of the graft to assist in development and maintenance of the surgical bed for grafting material. The SonicWeld Rx System uses a resorbable poly- (D,L)-lactide (PDLA) copolymer that is thought to be better tolerated than poly-(L)-lactide because it does not generate crystalline remnants during its breakdown process. ^[18]

Cartilage tissue engineering, which constructs cartilage in scaffolds with a predetermined shape such as nose, outer ear, TMJ and trachea has attracted much attention in recent years. Non woven mesh made of PGA, PLA and their copolymers are used because of their ideal 3 dimensional structure, good mechanical properties and adjustable degradation speed compared with natural matrices. Promising results have been obtained with synthetic biodegradable polymers as tendon replacements, in a resurfacing arthroplasty cup and as rods for fixation of osteochondral fragments or osteotomies. However considerable chemical and technical problems will have to be overcome before it will be possible to manufacture a screw made of biodegradable polymer which can be used for limb fractures, though the screw made of polydioxanone have

already been used in the surgery of mandible^[8].

Advantages of Self-Reinforced Devices^[9, 21,22,23,24,25]

The cost-effectiveness of using absorbable devices in orthopedic and trauma patients was partially achieved by avoiding removal procedures. The cost of the hardware is reduced by using one larger biodegradable panel plate that can be cut into multiple small plates. The exact cost-effectiveness is worth studying. Absorbable plates can be cut with scissors or hot-looped and tailored according to the size required. Additional holes can be drilled into these plates when needed. Should a screw break, there is no need for removal; it can be drilled through, so there is no need to relocate the plate to a less favorable position. Selfreinforced devices have high initial strength and an appropriate modulus, and they show a ductile mode of deformation during their degradation in vivo. With the self-reinforcing technique it is possible to produce small but strong biodegradable devices and, hence, reduce the risk of complications. Self-reinforced devices can be sterilized with gamma-irradiation, which breaks long chains of the polymer and leads to faster degradation. Gamma-irradiation obviates sterilization with ethylene oxide (commonly used to sterilize bioabsorbable implants) and avoids its toxic remnants. New self-reinforced plates can be manipulated or bent at room temperature without affecting their performance, avoiding

time-consuming heating with a heat gun, heating bags, thermal packs, or an electric heating device. A decrease of 20 percent in the flexural modulus of PLGA plates was observed when the plates were heated in excess of the glass-transition temperature. The plates needed 2 minutes of cooling to regain 50 percent of their stiffness, but after 1 week (in vitro), the mechanical properties of the heated and nonheated type of PLGA plates were identical. Bent plates may return to their prebent shape because of memory, leading to insecure fixation. In amorphous self-reinforced polylactide copolymer plates, such memory effect is minimal. Selfreinforced devices are manufactured in a way that is biaxially oriented in their structure. This means that their elastic memory is very low (2 to 3 percent). They are quite plastic in their behavior. The low range of memory can be balanced by overmolding the plated to the desired shape at the time of the operation, which we found easily achievable during our procedures.

DENTISTRY AND IMPLANTOLOGY

Bioresorbable materials are used in a multitude of ways, from developing screws for bone fixation, treating periodontal pathogens, and producing buccal mucosa or in direct pulp-capping procedures^[11].

PLGA materials, scaffolds and nanoparticles prove to be effective in a wide variety of dental applications as shown in table 1,2,3,4,5.^[11]

PERIODONTICS

PLGA can be used in periodontal treatment, for better local administration of antibiotics and to decrease the systemic side effects of general antibiotic delivery, in the form of PLGA implants, disks, and dental films. A wide range of membrane materials have been used in experimental and clinical studies to achieve GBR and GTR in relation to periodontal tissues including polytetrafluoroethylene (PTFE), expanded PTFE (ePTFE), collagen, freeze-dried fascia lata, freeze-dried dura mater allografts, polyglactin 910, polylactic acid, polyglycolic acid, polyorthoester, polyurethane, polyhydroxybutyrate, calcium sulfate, micro titanium mesh, and titanium foils. (Hämmeler & Jung. 2000)^[19].

PLGA membranes were studied for periodontal regeneration. Scaling and root planning procedures followed by placing PLGA membranes resulted in significant clinical attachment and bone gain in defects distal to the mandibular second molars^[11, 12, 13].

Virlan MJR et al 2015^[11] in their review on several studies on the in vivo behavior of different membranes such as collagen, polylactide/polyglycolide copolymer, and citric acid copolymer showed no statistical differences between these membranes. Also, the PGA/PLA polyglycolic/polylactic acid copolymer membrane led to relatively similar results compared with the application of collagen membranes.

Moreover, no statistically significant differences were observed when connective tissue grafts were used instead of the PLGA membranes, suggesting that better results were obtained when hydroxyapatite was added to the polymer membrane. Overall, the process of adding bone promoting factors or other materials to the PLGA membranes seems to improve the results in bone tissue regeneration.

ORAL SURGERY

(Virlan MJR et al 2015)^[11] Because alveolar bone is easily accessible during the extraction procedure, local application in the sockets may represent an ideal adjuvant therapy to limit alveolar ridge resorption. Tooth extraction is an acute but brief periodontal trauma, with progressive alveolar bone resorption occurring in the first few weeks. To avoid repeated local applications during this period, statin has been administered only once with a carrier (PLGA or gelatin hydrogel) for slow, long, and controlled release.

Gel composite fabrics of PLGA can be used in bone regeneration, as high degradable PLGA and SiO₂-CaO gel nonwoven fabrics that were exposed to simulated body fluid for 1 week led to a deposition of a layer of apatite crystals on their surface. Granular composite of gatifloxacin-loaded PLGA and b-tricalcium phosphate is local delivery means in the treatment of osteomyelitis, as the composite managed to slowly deliver gatifloxacin and showed

sufficient bacterial activity in vitro against *Streptococcus milleri* and *Bacteroides fragilis*, microorganisms responsible for osteomyelitis. Also, after only 4-week implantation GFLX-loaded PLGA and β TCP managed to significantly reduce the inflammation and support the osteoconduction and vascularization of the treated sites in rabbit mandible [11].

Moreover, sterilized PLGA scaffold is a promising material for producing tissue-engineered buccal mucosa [11].

ENDODONTICS

Additionally, PLGA composites with bioceramics can be used in direct pulp capping either by incorporating growth factors into PLGA microparticle or by direct pulp capping with PLGA composites of mechanically exposed teeth. However no hard tissue was observed in direct pulp capping with PLGA and pulp necrosis was evident due to the low adhesion of PLGA to the pulp despite the biocompatibility shown in cellular test. So, PLGA composites with bioceramics remain a better option than PLGA alone in pulp capping, with better tissue response as compared to calcium hydroxide. The promising results of the PLGA materials suggest the need for further studies mainly in the domain of delivery of substances to the dental tissues or concerning the pulp-capping abilities exhibited by the PLGA composites [11].

A wide range of membrane materials have been used in experimental and clinical studies to achieve GBR and GTR in relation to periodontal tissues including polytetrafluoroethylene (PTFE), expanded PTFE (ePTFE), collagen, freeze-dried fascia lata, freeze-dried dura mater allografts, polyglactin 910, polylactic acid, polyglycolic acid, polyorthoester, polyurethane, polyhydroxybutyrate, calcium sulfate, micro titanium mesh, and titanium foils. (Ha`mmerle & Jung. 2000).

DENTAL IMPLANTOLGY

Dental implants function to replace a missing or lost tooth without having to take support from adjacent teeth. They generally have a structure which enables one part of the implant to be located beneath the oral soft tissues osteointegrated with the alveolar bone. The other part protrudes into the oral cavity which supports the crown, bridge or artificial denture. Stainless steel has been used for this purpose but recently has been replaced by titanium implants. Tooth root implants constructed from titanium have been successfully used since 1965. The titanium surface may be sandblasted or electro-polished. Titanium has great potential for osteogenesis and promotes osteointegration. (Pietrzak. 1997) [20]

Alveolar ridge augmentation, much needed in dental implant therapy, could also profit due to the PLGA materials [11], as atrophic sites were reconstructed

using bioresorbable PLGA, bone allograft, and an osteoinductive protein such as rhBMP-2^[11,15].

A resorbable nut system can provide adequate primary stability for osseointegration of dental implants in the posterior maxilla and ensure simultaneous implant insertion with

maxillary sinus floor elevation, if the amount of bone height is ≤ 4 mm^[17].

CONCLUSION

Use of bioresorbable implants in both children and adults have reported successful clinical application in Oral and Maxillofacial Surgery.

REFERENCES:

1. Ricalde P, Posnick JC. Degradation rate of delta (resorbable) internal fixation: report of 2 cases. *J Oral Maxillofac Surg.* 2004 Feb;62(2):250-5.
2. Turvey TA, Bell RB, Tejera TJ, Proffit WR.. The use of self reinforced biodegradable bone plates and screws in orthognathic surgery. *J Oral Maxillofac Surg.* 2002 Jan;60(1):59-65.
3. Richard CE, Kevin DK, Barry LE. The fate of resorbable poly-L-lactic/polyglycolic acid (Lactosorb) bone fixation devices in orthognathic surgery. January 2001 Volume 59, Issue 1, Pages 19–25
4. R. Bryan Bell, Craig S. Kindsfater. The Use of Biodegradable Plates and Screws to Stabilize Facial Fractures. January 2006 Volume 64, Issue 1, Pages 31–39.
5. Landes, Constantin A.; Kriener, Susanne, Menzer, Michael, Kovács, Adorján. Resorbable Plate Osteosynthesis of Dislocated or Pathological Mandibular Fractures: A Prospective Clinical Trial of Two Amorphous L-/DL-Lactide Copolymer 2-mm Miniplate Systems. *Plastic & Reconstructive Surgery*: February 2003
6. Bos, R. R., Boering, G., Rozema, F. R. & Leenslag, J. W. Resorbable poly(L-lactide) plates and screws for the fixation of zygomatic fractures. *J. Oral Maxillofac. Surg.* 45, 751–753 (1987)
7. Böstman O1, Hirvensalo E, Mäkinen J, Rokkanen P. Foreign-body reactions to fracture fixation implants of biodegradable synthetic polymers. *J Bone Joint Surg Br.* 1990 Jul;72(4):592-6.
8. Böstman O, Vainionpää S, Hirvensalo E, Mäkelä A, Vihtonen K, Törmälä P, Rokkanen P. Biodegradable internal fixation for malleolar fractures. A prospective randomised trial. *J Bone Joint Surg Br.* 1987 Aug;69(4):615-9.
9. Young-Wook Park. Bioabsorbable osteofixation for orthognathic surgery. *Maxillofac Plast Reconstr Surg.* 2015 Dec; 37(1): 6).
10. J Al-Sukhun et al. A Comparative Study of 2 Implants Used to Repair Inferior Orbital Wall Bony Defects: Autogenous Bone Graft Versus Bioresorbable Poly-L/DL-Lactide [P(I/DI)la 70/30] Plate. *J Oral Maxillofac Surg* 64 (7), 1038-1048. 7 2006. .
11. Maria Justina Roxana Virlean, Daniela Miricescu, Alexandra Totan, et al.,

- “Current Uses of Poly(lactic-co-glycolic acid) in the Dental Field: A Comprehensive Review,” *Journal of Chemistry*, vol. 2015, Article ID 525832, 12 pages, 2015. doi:10.1155/2015/525832
12. M. Aimetti, E. Pigella, and F. Romano, “Clinical and radiographic evaluation of the effects of guided tissue regeneration using resorbable membranes after extraction of impacted mandibular third molars,” *The International Journal of Periodontics and Restorative Dentistry*, vol. 27, no. 1, pp. 51–59, 2007.
 13. M. Aimetti and F. Romano, “Use of resorbable membranes in periodontal defects treatment after extraction of impacted mandibular third molars,” *Minerva Stomatologica*, vol. 56, no. 10, pp. 497–508, 2007.
 14. Z. Wu, C. Liu, G. Zang, and H. Sun, “The effect of simvastatin on remodelling of the alveolar bone following tooth extraction,” *International Journal of Oral and Maxillofacial Surgery*, vol. 37, no. 2, pp. 170–176, 2008.
 15. B. P. Levin, “Alveolar ridge augmentation: combining bioresorbable scaffolds with osteoinductive bone grafts in atrophic sites. A follow-up to an evolving technique,” *The Compendium of Continuing Education in Dentistry*, vol. 34, no. 3, pp. 178–187, 2013.
 16. Erwan de Monès, Silke Schlaubitz, Sylvain Catros, and Jean-Christophe Fricain, “Statins and alveolar bone resorption: a narrative review of preclinical and clinical studies.” *Oral Surg Oral Med Oral Pathol Oral Radiol* 2015;119:65-73.
 17. Uckan S1, Eroglu T, Dayangac E, Araz K. Use of a resorbable nut system for simultaneous implant insertion and maxillary sinus floor elevation. *J Oral Maxillofac Surg*. 2007 Sep;65(9):1780-2.
 18. Rabie M. Shanti, Andrew Yampolsky, Maano Milles and Hani Braidy. Ultrasonic Welded Resorbable Mesh (SonicWeld Rx System) in Reconstruction of Segmental Mandibular Defects: Technical Note and Report of 2 Cases *J Oral Maxillofac Surg* 73:2241-2250, 2015.
 19. Ha`mmerle Christoph H. F. & Ronald E. Jung. *Periodontology* 2000, Vol. 33, 36– 53, 2003.
 20. Pietrzak, D.R. Sarver and M.L. Verstynen, Bioabsorbable polymer science for the practicing surgeon, *J Craniofac Surg* 8 (1997), pp. 87–91.
 21. Nureddin Ashammakhi,, Hilikka Peltoniemi, Eero Waris, Riitta Suuronen, Willy Serlo, Minna Kellomäki, Pertti Törmälä, and Timo Waris. *Developments in Craniomaxillofacial Surgery: Use of Self-Reinforced Bioabsorbable Osteofixation Devices. PLASTIC AND RECONSTRUCTIVE SURGERY*, July 2001.
 22. Waris, T., Pohjonen, T., and Törmälä, P. Self-reinforced absorbable polylactide (SR-PLLA) plates in craniofacial surgery: A preliminary report on 14 patients. *Eur. J. Plast. Surg.* 17: 236, 1994.
 23. Fuente del Campo, A. F., Pohjonen, T., Törmälä, P., and Waris, T. Fixation of horizontal maxillary osteotomies with biodegradable self-reinforced absorbable polylactide plates: Preliminary results. *Eur. J. Plast. Surg.* 19: 7, 1996

24. Serlo, W., Kaarela, O., Peltoniemi, H., et al. Self-reinforced polylactide osteosynthesis devices in craniofacial surgery: A long-term follow-up study. *Scand. J. Plast. Reconstr. Surg. Hand Surg.* (in press)
25. Shintaro Sukegawa, Takahiro Kanno Naoki Katase, Akane Shibata, Yuka Takahashi, and Yoshihiko Furuki, Clinical Evaluation of an Unsintered Hydroxyapatite/Poly-L-Lactide Osteoconductive Composite Device for the Internal Fixation of Maxillofacial Fractures. *J Craniofac Surg.* 2016 Sep; 27(6): 1391–1397
26. Singh M, Singh R.K , Passi D, Aggarwal M, and Kaur G. Management of pediatric mandibular fractures using bioresorbable plating system – Efficacy, stability, and clinical outcomes: Our experiences and literature review. *J Oral Biol Craniofac Res.* 2016 May-Aug; 6(2): 101–106.
27. Sukegawa S, Kanno T, Nagano D, Shibata A, Sukegawa-Takahashi Y, Furuki Y. The Clinical Feasibility of Newly Developed Thin FlatType Bioresorbable Osteosynthesis Devices for the Internal Fixation of Zygomatic Fractures: Is There a Difference in Healing Between Bioresorbable Materials and Titanium Osteosynthesis? *The Journal of Craniofacial Surgery* Volume 27, Number 8, November 2016
28. Filinte GT, Akan IM, Çardak GNA, Mutlu OO, Aköz, T. Dilemma in pediatric mandible fractures: resorbable or metallic plates? *Ulus Travma Acil Cerrahi Derg*, November 2015, Vol. 21, No. 6

TABLES:

APPLICATION OF PLGA MEMBRANES IN DENTISTRY (Table 1,2,3,4,5) ^[11]

Table 1: PLGA membranes in human studies.

Type of PLGA membranes	Clinical application	Species
PGA/PLA membrane + deproteinized bovine bone	Guided bone regeneration of bony defects	Humans
PGA/PLA membranes	Periodontology (class II furcation)	Humans
PGA/PLA membranes + hydroxyapatite	Periodontology (class II furcation)	Humans
PLGA membranes	Bony defects distal to mandibular second molars	Humans
PLGA membranes	Guided bone regeneration around dental implants	Humans

Table 2: Applications of PLGA scaffolds in dentistry.

Type of PLGA scaffold	Additional substances	Application
PLGA	BMP-2 (bone morphogenetic protein-2)	Bone regeneration around dental implants
PLGA	PEG1 (prostaglandin E1)	Alveolar ridge preservation/augmentation
PLGA	Simvastatin	Bone formation in extraction sockets
PLGA-gelatin sponge	rhBMP-2 (recombinant human bone morphogenetic protein-2)	Alveolar ridge augmentation
PLGA/calcium phosphate cement		Bone ingrowth
PLGA + autogenous		Bone regeneration around implants

bone graft		
PLGA/low crystalline apatite		Bone regeneration
PLGA/calcium phosphates		Maintaining alveolar bone height/augmenting alveolar bone height through standard sinus lift approaches
PLGA + beta-tricalcium phosphate		Bone and cementum regeneration
PLGA/CaP (calcium phosphate)		Periodontal regeneration of class II furcation defects
PLGA + bone allograft	rhBMP-2 (osteoinductive protein)	Alveolar ridge augmentation
PLGA	Simvastatin and SDF-1 α (stromal cell derived factor-1 α)	Bone regeneration
PLGA/ β -tricalcium phosphate	Fibroblast growth factor-2	Bone augmentation

Table 3: Applications of PLGA scaffolds in regenerative dentistry.

Type of PLGA scaffolds	Cells seeded on scaffolds	Application
PLGA+calcium phosphate	Bone marrow derived cells	Bone formation
PLGA	Osteoblast cells	Maxillary sinus augmentation
PLGA	Bone marrow stem cells	Bone regeneration
PLGA+calcium phosphate	Bone marrow stem cells	Bone regeneration

PLGA+ nanohydroxyapatite	Tooth bud cells	Cell proliferation and differentiation
PLGA/hydroxyapatite	Dental pulp stem cells	Osteoblastic differentiation
PLGA/hydroxyapatite	Dedifferentiated fat cells	Bony defects closure
PLGA nanofibers	Dental pulp stem cells	Bone regeneration
PLGA	Adipose-derived stromal cells	Regeneration of bone, periodontal ligament and cementum
PLGA	Dental pulp stem cells	Dentine/pulp-like tissue
PLGA	Dental pulp stem cells	Dentine-like structure
PLGA + tricalcium phosphate	Tooth bud cells	Dentin-like and pulp-like tissues
PLGA + CCN3 (nephroblastoma overexpressed)	Dental pulp stem cells	Dentinogenesis

Table 4: Applications of PLGA microparticles in dentistry.

Field	PLGA microparticles	Loaded with
Endodontic therapy	PLGA microparticles with added zein	Amoxicillin
Dental caries vaccination	PLGA microparticles coated with chitosan	Recombinant Streptococcus mutans glucan-binding protein D
Dental regeneration (tertiary dentin)	PLGA microparticles in a PLGA/calcium phosphate cement	Growth factors
Haemostatic device	PLGA microparticles	Thrombin
periodontal	PLGA microparticle	Hydroxyapatite

treatment	es	ofloxacin
	PLGA microparticles	Chlorhexidine
	PDLLA-PLGA microparticles	Growth and differentiation factors
	PLGA and poly(epsilon-caprolactone)	Doxycycline
	PLGA microparticles	Simvastatin
Bone regeneration	PLGA microparticles	Alendronate sodium
	PLGA microparticles	Dexamethasone
Implant therapy	PLGA microparticles in collagen membrane	Dexamethasone
	PLGA microparticles in PLGA membrane	VEGF (vascular endothelial growth factor)
	PLGA microparticles	Insulin
	PLGA microparticles	Basic fibroblast factor
	PLGA microparticles	Fluvastatin
	PLGA microparticles	rhBMP-2 (recombinant human bone morphogenetic protein-2)

Table 5: Applications of PLGA nanoparticles in dental medicine.

Type of PLGA nanoparticles	Loaded with	Dental field
PLGA nanoparticles	Minocycline	Periodontal infections
Dental implants coated with PLGA nanoparticles	Basic fibroblast growth factor	Implantology

PLGA nanoparticles	Methylene-blue photosensitizer	Endodontic infections
PLGA nanoparticles	Methylene-blue photosensitizer	Periodontology (reduction of dental plaque biofilms)
PLGA nanoparticles heparin-conjugated	BMP-2 (bone morphogenetic protein-2)	Bone regeneration (osteogenic differentiation of bone marrow stem cells)
PLGA nanoparticles	Simvastatin	Bone regeneration (enhanced osteogenesis of bone marrow mesenchymal stem cells)

Table 6 ^[10](Young-Wook Park. Bioabsorbable osteofixation for orthognathic surgery. Maxillofac Plast Reconstr Surg. 2015 Dec; 37(1): 6).

Commercially available resorbable or bioabsorbable devices for osteofixation

Product	Manufacturer	Year of invention	Conformation	Biodegradation period
Biofix®	BionX	1984	SR-PGA	6 weeks
Orthosorb®	Depuy	1991	PDS	6 months
FixsorbMX®	Takiron	1994	PLLA	2 years
Lactosorb®	Walter Lorenz	1996	PLLA/PGA	12-18 months
MacroSorb®	Macropore	1999	P-L/D-LA	2 years
ResorbX®	KLS martin	2001	P-L/D-LA	2 years
Inion CPS®	Inion	2001	P-L/D-LA	2 years
BiosorbFX®	Bionix Implants	2001	P-L/D-LA	2 years
PolyMax®	Synthes	2003	P-L/D-LA	2 years
Delta System®	Stryker	2004	P-L/D-LA /GA	2 years
OsteotransMX®	Takiron	2007	u-HA/PLLA	5.5 years
Inion CPS®	Inion	2007	P-L/D-LA/TMC	2 years

SR-PGA: Self-reinforced polyglycolic acid.

PDS: Polydioxanone.

PLLA: Poly-L-lactic acid.

PDLA: Poly-D-lactic acid.

u-HA: unsintered hydroxyapatite.

TMC: trimethylenecarbonate.