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BIOABSORBABLE OSTEOFIXATION MATERIALS IN MAXILLOFACIAL SURGERY: PROGRESS AND FUTURE DIRECTIONS

Matchanov Bobur Bakhtiyor o'g'li
Assistant of the Department of Maxillofacial Surgery and
Dentistry of the Tashken State Medical University
boburmatchonov5@gmail.com

Abstract
Rigid fixation is a cornerstone of maxillofacial surgery. Titanium plates and screws have been the gold standard for decades, but complications such as growth restriction in children, radiological artifacts, and the need for secondary removal surgeries have led to the development of bioabsorbable fixation devices. This review summarizes advances in polymer-based and magnesium-based osteofixation systems, their clinical applications, limitations, and future perspectives.

Keywords: Bioabsorbable fixation; Osteofixation; Maxillofacial surgery; Biodegradable polymers; PGA; PLLA; PLGA; Hydroxyapatite composites; Magnesium alloys; WE43; ZK60; Biocompatibility; Degradation; Clinical applications; Orthognathic surgery; Pediatric maxillofacial trauma; 3D printing; Nanostructured coatings.

Introduction

Titanium plates and screws provide high mechanical stability and biocompatibility, making them the standard choice for maxillofacial osteofixation. However, they are not without drawbacks: they can cause growth disturbance in pediatric patients, interfere with radiological imaging, and often necessitate secondary operations for removal. These drawbacks have driven research into bioabsorbable osteofixation materials. Among them, polymers and magnesium-based systems have emerged as the most promising alternatives.

2. Polymer-Based Bioabsorbable Materials

Polymeric systems were the first generation of bioabsorbable fixation devices. The most common are polyglycolic acid (PGA), poly-L-lactic acid (PLLA), poly-D-lactic acid (PDLA), and their copolymers such as PLGA and PLDLA.

Table 1. Polymer-Based Bioabsorbable Systems

Material / Product	Composition	Degradation Time	Notes
PGA (Biofix® SR-PGA)	Self-reinforced PGA	6–12 months	Rapid strength loss, limited use
PLLA (Biofix® SR-PLLA)	Self-reinforced PLLA	5–7 years	First-generation, slow degradation
PLDLA (ResorbX®, PolyMax®)	PLLA/PDLA copolymer	2–3 years	Improved degradation profile
PLGA (Lactosorb®, Rapidsorb®)	PLLA/PGA copolymer	8–15 months	FDA-approved, stable
u-HA/PLLA (Osteotrans-MX®)	PLLA + 30–40% HA	4–5 years	Osteoconductive, radiopaque

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These materials degrade by hydrolysis into lactic and glycolic acid, which are metabolized through the citric acid cycle. Advances in self-reinforcement technology have improved their mechanical stability.

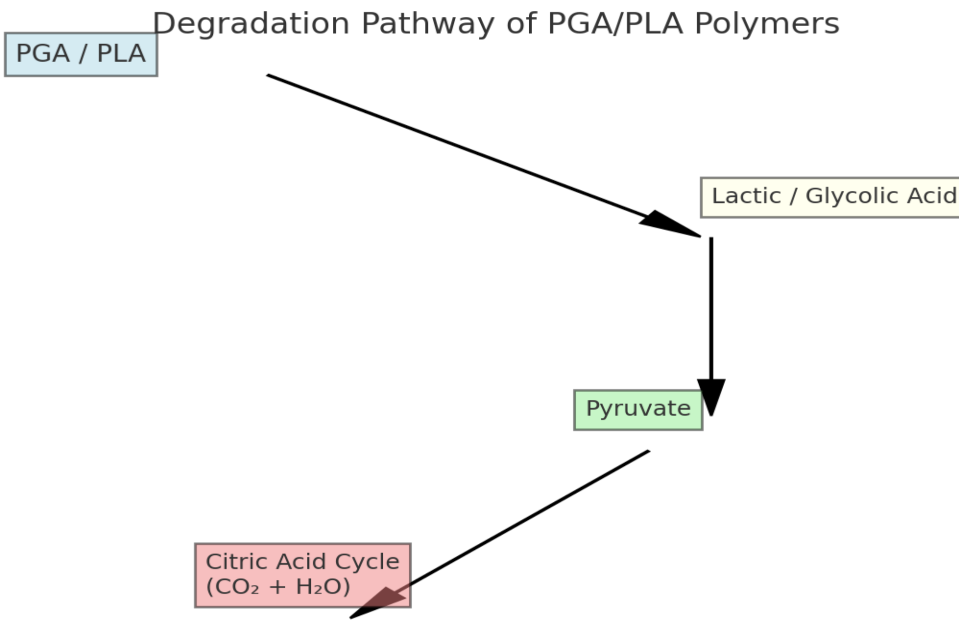

Figure 1. Schematic illustration showing the degradation of PGA and PLA polymers and copolymers.

3. Magnesium-Based Bioabsorbable Materials

Magnesium (Mg) and its alloys have re-emerged as attractive biomaterials due to their biocompatibility, natural presence in the human body, and mechanical properties similar to cortical bone. Challenges include rapid corrosion and hydrogen gas release, which can compromise healing.

Table 2. Magnesium Alloys Investigated for Maxillofacial Application

Alloy	Composition	Mechanical Properties	Notes
Pure Mg	≥98.8% Mg	Tensile strength ~86 MPa	Rapid corrosion, weak
Mg–Ca–Zn	Mg + 5% Ca + 1% Zn	Strength ~210 MPa	Improved corrosion resistance
WE43	Mg + Y + Nd + Zr	Strength ~260 MPa	Animal models, promising biocompatibility
Extruded WE43	Processed WE43	Strength ~303 MPa	Better mechanical properties
ZK60 + PLLA coating	Mg + Zn + Zr + polymer coating	Strength ~328 MPa	Coating slows degradation

Recent approaches focus on alloying (Ca, Zn, Mn, Zr) and applying protective coatings such as calcium phosphate or PLLA to slow degradation.

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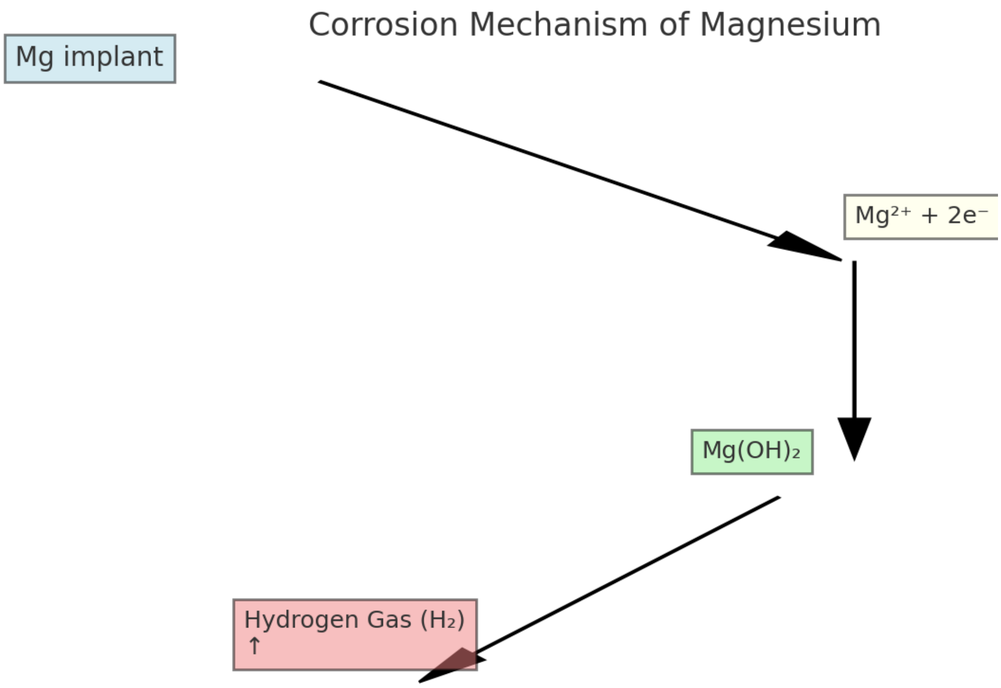

Figure 2. Schematic illustration showing the reactions associated with the corrosion mechanism caused when Mg is exposed to aqueous conditions

4. Clinical Applications

Polymer-based devices have been successfully applied in trauma, orthognathic, and pediatric maxillofacial surgery. They eliminate the need for secondary removal surgery but may be associated with local inflammatory reactions. Magnesium-based devices are still experimental, with encouraging animal data and the first clinical cases. Leonhardt et al. (2017) reported successful use of Mg-based screws for condylar fractures without complications.

5. Limitations and Complications

Polymers: relatively low mechanical strength, difficulties in handling, risk of aseptic abscess formation.

Magnesium: rapid corrosion, hydrogen gas accumulation, and potential for hypermagnesemia if degradation is uncontrolled.

6. Future Perspectives

Future developments include hybrid polymer-metal systems, patient-specific 3D-printed implants, nanostructured coatings, and drug-eluting fixation devices. Randomized controlled clinical trials are needed to validate safety and long-term outcomes.

7. Conclusion

Bioabsorbable osteofixation systems represent a transformative advance in maxillofacial surgery. Polymer-based devices are clinically established, while magnesium alloys show strong potential but

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require further validation. Collaborative translational research will be key to bringing next-generation materials into clinical use.

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