ISSN 2618-1584 Vol. 5, Issue 2: 77-81, DOI: 10.25236/FMSR.2023.050213

Current status of absorbable internal fixation materials in maxillofacial fractures

Amannisahan Jiapaer[1], Ayidana Wulaerbieke[1], Qi He[1], Bin Ling[1,2,*]

[1]Oncological Department of Oral and Maxillofacial Surgery, the First Affiliated Hospital of Xinjiang Medical University, School/Hospital of Stomatology Xinjiang Medical University, Urumqi, 830054, Xinjiang Uygur Autonomous Region, China
[2]Stomatological Research Institute of Xinjiang Uygur Autonomous Region, Urumqi, 830054, Xinjiang Uygur Autonomous Region, China
[*]Corresponding author: 34527623@qq.com

Abstract: *In the internal fixation treatment of maxillofacial fractures, with the development of new polymer materials, absorbable internal fixation materials are increasingly used, which fully demonstrate their own advantages compared with metal strong internal fixation materials. This article presents a review on the development and application status of resorbable internal fixation materials in maxillofacial fractures.*

Keywords: *resorbable material, internal fixation, maxillofacial fracture*

1. Introduction

With the rapid development of modern society, traffic accidents and work-related injuries occur frequently, and the maxillofacial region is extremely susceptible to fractures when traumatized, followed by changes in facial morphology, restricted opening and varying degrees of masticatory function, which have a great impact on patients' facial appearance, function and psychological health[1]. In the treatment of maxillofacial fractures, anatomical repositioning of the fracture and restoration of the occlusal relationship are particularly important and are the basis for restoring facial shape and function, and surgical incision and internal fixation have also become the optimal treatment method[2]. Therefore, metal internal fixation has been widely used in clinical practice, and as the scope of application continues to expand, its disadvantages are increasingly exposed, such as severe stress masking and radiation blocking effects[3] , corrosion by saliva and other fluids in the body, release of metal ions, causing local inflammation, and the need for secondary surgical removal in up to 40% of cases, again increasing the pain and economic burden of patients[4-6].If metal internal fixation materials are used in developing children, the titanium plates and nails are prone to separation or have the possibility of limiting bone development as the bones grow[7,8].The rapid development of polymer materials has led to the increased use of new absorbable internal fixation materials for the treatment of oral and maxillofacial fractures, and they have fully demonstrated their advantages and are well received by physicians and patients. The ideal bioresorbable material should have the appropriate mechanical properties and degradation rate according to the purpose of its application, play a mechanical fixation role at the initial stage of implantation, and gradually degrade to transfer the stress to bone healing and eventually be completely absorbed.

2. History of resorbable materials in maxillofacial surgery

Since the first attempt to apply bioresorbable materials for internal fixation of maxillofacial fractures by Cutright DE et al[9] in 1971, more and more polymers have been used in the treatment of maxillofacial surgery. Maxillofacial resorbable materials have been developed over decades and have made great progress. The main types of bioresorbable fixation plates and screws are as follows:

2.1 Polyglycolic acid (PGA)

PGA is a bioresorbable polymer with a high crystalline structure with an average molecular mass between 2.0×10^4 and 1.45×10^5.PGA is tough and hard, and was the first absorbable material used in

ISSN 2618-1584 Vol. 5, Issue 2: 77-81, DOI: 10.25236/FMSR.2023.050213

orthopedic surgery for pins, screws and fixation plates. After approximately 4-7 weeks of implantation, PGA is less used in maxillofacial surgery because of its rapid degradation rate, early mechanical strength loss in vivo, and adverse effects such as swelling, fluid accumulation, and sinus tract formation[10].

2.2 Polylactic Acid (PLA)

PLA is another polymer (molecular weight 1.8-5.3 × 10^5) with high modulus of elasticity (3.5-3.8 GPa) and tensile strength (48-110 MPa)[11], which has four stereoisomers:Ploy L Lactic Acid(PLLA), Ploy D Lactic Acid,(PDLA), Ploy D,L Lactic Acid(PDLLA),and meso-Ploy Lactic Acid(meso-PLA).PLLA is the first generation of bioresorbable bone synthesis material, which is a more widely used internal fixation material, with the advantages of high mechanical strength and good biocompatibility, but the complete degradation time in vivo is too long[12], and it is easy to produce foreign body reaction.PDLA has better biocompatibility, and the main shortcoming is that it starts to degrade 1 month after implantation, and the mechanical strength is insufficient.

2.3 Copolymers of PGA, PLLA and PDLA

Copolymers of PGA, PLLA and PDLA are known as second generation bioresorbable bone synthetics, where copolymers of different polymers allow the materials to complement each other in terms of properties, faster absorption rates and higher biocompatibility than the first generation polymers. Resorbable copolymers with different mechanical properties and degradation rates can be obtained with degradation products of carbon dioxide and water[13,14]. Moreover, absorbable materials made using self-reinforcement technology have better stiffness, strength and chemical resistance, but the fixed plates made are generally thicker.

2.4 Hydroxyapatite: u-HA/PLLA

Composites of unsintered Hydroxyapatite(u-HA) and PLLA are not only biodegradable but also osteoconductive, showing higher mechanical strength in shear and bending strength convenience, and are third generation bioresorbable bone synthetics[15]. In addition, they are radiolucent, can take X-rays for follow-up[16], and are more widely used in maxillofacial surgery, but their degradation properties are still unclear.

3. Absorbable materials in maxillofacial surgery

3.1. Resorbable materials in mandibular fractures

Mandibular fractures account for a large proportion of maxillofacial fractures, and due to the pulling of facial muscles, the fracture fragments are prone to displacement, occlusal misalignment, and restricted mouth opening, which seriously affects the daily life of patients, so anatomical repositioning of the fracture and stable internal fixation are the basic principles of treatment[17], however, different types of internal fixation materials have different effects on surgical results and prognosis. Titanium plates and nails were commonly used in the past because of their excellent mechanical strength and biocompatibility, and because the metallic material cannot be absorbed by degradation, which in turn produces stress-blocking effects and often requires secondary surgery[18], resorbable materials are gradually being accepted in mandibular fractures.

3.1.1 Application in mandibular body, mandibular branch, and mandibular angle fractures

In animal experiments, Leng D et al[19] prepared linear fractures in the middle mandible of 12 dogs, and the experimental group was treated with L/DL-polylactic acid resorbable material for internal fixation, while the control group healed on its own without any fixation measures, and the gross and histological observations revealed that the tissue response to L/DL-polylactic acid was in accordance with the tissue response process of biocompatible materials, and the fracture severed ends healed well, and no No significant osteogenesis inhibition was found, and the fracture ends healed as stage I healing.

In a clinical trial, Wang JT [20] treated 144 patients with mandibular fractures with strong internal fixation using poly-L-lactic acid (PLLA) resorbable material and miniature titanium plate nail material, and the data showed that internal fixation with PLLA resorbable material could improve masticatory

ISSN 2618-1584 Vol. 5, Issue 2: 77-81, DOI: 10.25236/FMSR.2023.050213

function, enhance mandibular stability, improve the treatment effect, and reduce the occurrence of complications in patients with mandibular fractures. Sun TS et al [21]conducted a trial of 68 patients with mandibular fractures treated with the same internal fixation material and found that the complication rate in the PLLA group was lower than that in the micro titanium plate combined with screw group, and the data also showed that fixation with PLLA resorbable material shortened the healing time of mandibular fractures. Ding LL et al[22] also performed PLLA resorbable splints and titanium plate fixation in 54 patients, and the wound healed well in both groups, with no swelling or infection in the operated area. 3 months after surgery, panoramic films of both groups showed blurred fracture lines and fracture scab formation, and 1 year after surgery, panoramic films of both groups showed complete disappearance of fracture lines. A clinical trial conducted by Chen B et al[23] found that the rate of secondary surgery in the PDLLA material group was lower than that in the pair of titanium plate material group, which shows that the advantages of resorbable materials in mandibular fractures such as reduced re-operation and good stability are more prominent.

3.1.2 Application in condylar sagittal fractures

Condylar fractures account for approximately 29%-52% of mandibular fractures[24], and because of their anatomical structure and functional peculiarities, previous conservative treatment often leads to problems such as joint ankylosis, restricted mouth opening, and misalignment of the bite, and if they occur in children, because the condyle is the developmental center of the mandible[25], improper treatment can affect the growth and development of children and cause problems such as facial asymmetry. Surgical incision and internal fixation of condylar fractures has become the current routine treatment[26], but metal screw internal fixation has shown more and more unavoidable disadvantages, so resorbable materials are becoming more and more popular in the treatment of condylar fracture internal fixation.

In animal experiments, Meng FW et al[27] used four treatment methods, including lateral titanium screws with double cortical bone fixation and lateral resorbable screws (PLLA) with double cortical fixation, to experimentally study condylar fractures in sheep, and histological observations revealed that the cartilage on the surface of the condyle and articular fossa in the group with lateral resorbable screws with double cortical fixation did not show significant pathological changes, and could achieve reliable fixation and good therapeutic results as metal screws, and could degrade and resorb harmlessly on their own without secondary surgery.

In a clinical trial, Liu ZJ et al[28] used an absorbable internal fixation system and a titanium plate and titanium nail sturdy internal fixation system in 72 patients with bilateral condylar fractures, and the results back showed that:the fracture healing time of the absorbable group was significantly shorter than that of the pair of titanium plate and titanium nail group, and the speed of fracture healing was accelerated, and the maximum opening, masticatory efficacy, mobility to the affected side, and complication rate of the absorbable material group were better than that of the titanium plate and titanium nail group. Tao JQ et al[29] also confirmed the stability and safety of autogenous reinforced polypropylene copolymer fixation plates for surgical treatment of condylar fractures through clinical trials.

3.2. Application in zygomatic-zygomatic arch fractures

The zygomatic arch is located on the lateral side of the face, and the bones are brittle and prone to fracture when subjected to strong blows[30,31], so the traditional titanium plate and titanium nail internal fixation method can sometimes touch the titanium plate and nail due to the superficiality of the zygomatic bone, which affects the aesthetics, so the absorbable material also plays an advantage in zygomatic arch fracture.

Yuan XP[32] performed surgical incisional reduction and fixation of 16 patients with zygomatic arch fractures using a Finnish Baiyu absorbable internal fixation implant, and all of them had stage I healing, stable severed ends, and restored normal facial shape with an opening of three transverse fingers. Follow-up at 1-3 years revealed that all patients had no problems with bone displacement or facial collapse, no significant rejection or inflammatory reactions, and the implant was completely inaccessible to touch at 3 years postoperatively. Li KL[33] treated 146 patients with zygomatic arch fractures with titanium plate internal fixation and resorbable splints internal fixation, and the resorbable material could achieve similar fracture internal fixation results as miniature titanium plates with fewer complications and without the need for secondary surgery. Moreover, the resorbable material avoids both immunorejection and prevents osteoporosis due to stress masking compared to titanium plates[34].

ISSN 2618-1584 Vol. 5, Issue 2: 77-81, DOI: 10.25236/FMSR.2023.050213

4. Advantages and disadvantages of absorbable materials

The application of resorbable materials to maxillofacial fractures has the following advantages: 1. With the healing of the fracture, the bioresorbable material gradually degrades and absorbs autonomously in the body, avoiding secondary surgery, reducing scarring, and providing high patient satisfaction[35,36]; 2. With the degradation and strength reduction of the material, the load is gradually transferred to the bone, well avoiding the stress masking effect, promoting the healing and reconstruction of the fracture, and reducing stress masking induced osteoporosis; 3.No interference with CT and MRI examinations and no effect on postoperative radiotherapy for tumor patients[36]. Even so, nowadays, resorbable internal fixation materials still cannot completely replace metallic internal fixation materials, mainly because: 1. the strength of resorbable materials cannot really match that of metallic materials, and when there is a large amount of bone loss and fractures in weight-bearing areas, resorbable materials cannot achieve stable fixation treatment[36]; 2.the possibility of aseptic abscess formation during degradation[5]. However, it is believed that resorbable materials will continue to be improved with the continuous progress of materials and biotechnology, and their application prospects are worth looking forward to.

Acknowledgements

Fund source: Autonomous Region Science and Technology Aid Xinjiang Project (Key Technology Research in Maxillofacial Repair Based on Bioresorbable Material Welding Technology, 2020E02130)

References

[1] Mostoufi B,Sands J,Patel M,et al.Fracture propagation associated with intermaxillary fi xation screws in maxillofacial trauma[J]. Int J Oral Maxillofac Surg,2020,49(4):491-495.
[2] Yang LJ, Wang XG, Zhang ZL. Study on the clinical value of sturdy internal fixation technique in oral and maxillofacial surgery [J]. Wisdom Health, 2022, 8(13):32-34.
[3] Gareb B, Roossien CC, van Bakelen NB, et al. Comparison of the mechanical properties of biodegradable and titanium osteosynthesis systems used in oral and maxillofacial surgery. [J]. Sci Rep. 2020; 10(1):18143.
[4] On SW, Cho SW, Byun SH, Yang BE. Bioabsorbable Osteofixation Materials for Maxillofacial Bone Surgery: A Review on Polymers and Magnesium-Based Materials. Biomedicines. 2020; 8(9):300.
[5] Gareb B,van Bakelen NB, Dijkstra PU,et al. Biodegradable versus titanium osteosyntheses in maxillofacial traumatology: a systematic review with meta-analysis and trial sequential analysis. Int. J. Oral Maxillofac. Surg. 2020; 49(7):914–931.
[6] Kim D.Y., Sung I.Y., Cho Y.C.,et al . Bioabsorbable plates versus metal miniplate systems for use in endoscope-assisted open reduction and internal fixation of mandibular subcondylar fractures. [J]. Cranio-Maxillofacial Surg. 2018; 46(3):398–412.
[7] Fang DD. Clinical study of resorbable bone fixation system for the treatment of maxillofacial fractures [J]. Journal of Oral and Maxillofacial Surgery, 2016, 26(06):415-419.
[8] Sukegawa S., Masui M., Sukegawa-Takahashi Y.,et al. Maxillofacial Trauma Surgery Patients With Titanium Osteosynthesis Miniplates: Remove or Not?[J]. Craniofac. Surg. 2020; 31(5):1338–1342.
[9] Cutright D.E., Hunsuck E.E., Beasley J.D. Fracture reduction using a biodegradable material, polylactic acid. [J]. Oral Surg. 1971; 29(6):393–397.
[10] Schumann P, Lindhorst D, Wagner MEH, et al. Perspectives on Resorbable Osteosynthesis Materials in Craniomaxillofacial Surgery.[J]. Pathobiology, 2013,80(4):211-217
[11] Wei ZC, Xi YW, Weng YX. Research status and progress of poly(lactic acid)-based composite bone tissue repair materials[J]. China Plastics, 2021, 35(09):136-146.
[12] Pihlajamaki H., Bostman O., Hirvensalo E., et al. Absorbable pins of self-reinforced poly-L-lactic acid for fixation of fractures and osteotomies.[J]. Bone Jt. Surg. Br. Vol. 1992;74(6):853–857.
[13] WU CS, TSOU CH. Fabrication, characterization, and application of biocomposites from poly (lactic acid) with renewable rice husk as reinforcement. J Polym Res. 2019; 26(2):44-53.
[14] Peltoniemi H, Ashammakhi N, Kontio R, et al. The use of bioabsorbable osteofixation devices in craniomaxillofacial surgery[J]. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2002, 94(1): 5-14.
[15] On SW, Cho SW, Byun SH, et al. Bioabsorbable Osteofixation Materials for Maxillofacial Bone Surgery: A Review on Polymers and Magnesium-Based Materials. Biomedicines[J]. 2020;8(9):300.
[16] Shikinami Y, Okuno M. Bioresorbable devices made of forged composites of hydroxyapatite (HA)

ISSN 2618-1584 Vol. 5, Issue 2: 77-81, DOI: 10.25236/FMSR.2023.050213

particles and poly-L-lactide (PLLA): Part I. Basic characteristics[J]. Biomaterials, 1999, 20(9): 859-877.

[17] Wang B, H LB, Peng HY, et al. Efficacy of implantable titanium nail intermaxillary traction combined with miniature titanium plate internal fixation in the treatment of jaw fractures[J]. Journal of trauma surgery, 2019, 21(05):391-392.

[18] Xie LQ, Huang ZC, Wang GS, et al. Parathyroid hormone intervention in cartilage healing after free reduction of high mandibular condylar fractures in rabbits [J]. Chinese Tissue Engineering Research, 2020, 24(32):5114-5121.

[19] Leng D, Yang T, Song B Q, Hua Z Q, et al. Histological observation of canine mandibular fractures fixed with absorbable fixation material (L/DL-polylactic acid)[J]. Journal of Clinical Military Medicine, 2015, 43(07):766-768+770.

[20] Wang JT. Application of strong internal fixation with poly-L-lactic acid resorbable bone fixation system in patients with mandibular fractures[J]. Huaihai Medicine, 2022, 40(03):302-304.

[21] Sun T.S., Wang R. Effect of strong internal fixation with poly-L-lactic acid resorbable bone fixation system for mandibular fractures[J]. Henan Medical Research, 2019, 28(13):2370-2372.

[22] Ding LL, Zhang YL, Yang MJ, et al. The value of poly-L-lactic acid resorbable splints in internal fixation of mandibular fractures[J]. Journal of trauma surgery, 2020, 22(04):267-270.

[23] Chen B, Guo CB, Zhang B. Clinical application effect analysis of poly-L-lactic acid resorbable splints in internal fixation of mandibular fractures[J]. Contemporary Medicine, 2022, 28(01):40-42.

[24] Marwan H, Sawatari Y. What Is the Most Stable Fixation Technique for Mandibular Condyle Fracture? J Oral Maxillofac Surg. 2019; 77(12): 2522.e1- 2522.e12.

[25] Li Y, Chen LL, He PH. Bone morphometry of TMJ after condylar fracture based on CBCT condylar volume analysis[J]. Journal of Tissue Engineering and Reconstructive Surgery, 2022, 18(4): 336- 338.

[26] Wang QQ, Han R, Ding X, et al. Application of modified auriculotemporal incision combined with submaxillary incision in intracondylar capsular fracture[J]. Chinese Journal of General Surgery, 2020, 18(09): 1446-1448+1461.

[27] Meng FW, Liu MX, Wang JW, et al. Experimental study of sagittal fracture of sheep condyle fixed by absorbable screws with double cortical bone[J]. Chinese Journal of Oral and Maxillofacial Surgery, 2015, 13(01):16-20.

[28] Liu ZJ, Yang ML, Si WY. Study on the clinical effect of absorbable internal fixation system in bilateral condylar fracture surgery[J]. Chinese Journal of Practical Dentistry, 2021, 14(4):466-469.

[29] Tao JQ, Zhang HZ. Comparison of the efficacy of different fixation materials in the treatment of mandibular condylar fractures[J]. Journal of Modern Traditional Chinese and Western Medicine, 2013, 22(34): 3797-3798.

[30] Giudice A, Cristofaro MG, De Cicco D, et al. Percutaneous Reduction of Isolated Zygomatic Arch Fractures: A 5-Year Experience. J Oral Maxillofac Surg. 2020; 78(6):973-978.

[31] Wen Y. Application of combined incision combined with micro titanium plate in the treatment of zygomatic arch fractures [J]. World Compound Medicine, 2021, 7(05):75-77+81.

[32] Yuan SP. Application of self-reinforced resorbable internal fixation system in zygomatic arch fractures [J]. China Medical Guide, 2013, 11(08):1.

[33] Li KL. Treatment of zygomatic arch fractures with local small incision combined with absorbable splints for internal fixation [J]. Practical Integrative Chinese and Western Medicine Clinical, 2017, 17(04): 70-71.

[34] Kou QY, Li QL, ZHAO Hui, LI Wen-Qiang. Application and clinical results of resorbable internal fixation materials in incomplete zygomatic fractures [J]. Journal of Clinical Dentistry, 2017, 33(09): 542- 544.

[35] Yan G, Chuo W, Zhang R, Zhou Q, Yang M. Evaluation of the Effect of Bioresorbable Plates and Screws in the Treatment of Condylar Fractures, Assisted by Digital Preoperative Planning. J Oral Maxillofac Surg. 2019; 77(7): 1434.e1 -1434.e16.

[36] Gareb B, Van Bakelen NB, Vissink A,et al. Titanium or Biodegradable Osteosynthesis in Maxillofacial Surgery? In Vitro and In Vivo Performances [J]. Polymers (Basel). 2022; 14(14):2782.