İstanbul Üniversitesi Diş Hekimliği Fakültesi Dergisi
Cilt: 48, Sayı: 1 Sayfa: 9-18, 2014

HISTOPATHOLOGICAL EXAMINATION OF THE EFFECTS OF THE RESORBABLE AND TITANIUM SCREWS WHICH USED IN AUTOGENOUS BONE GRAFT ON BONE HEALING

Otojen Kemik Greft Fiksasyonunda Kullanılan Rezorbe Olabilen Vidalar ile Titanyum Vidaların Kemik İyileşmesine Etkilerinin Histopatolojik Olarak İncelenmesi

Sabri Cemil İŞLER[1], Zerrin ÇEBİ[1]

Makale Gönderilme Tarihi: 06/11/2013
Makale Kabul Tarihi: 23/12/2013

ABSTRACT

Purpose: Titanium and poly-L-lactide (PLLA) materials are frequently used in oral and orthopedic surgery in order to maintain stabilization and fixation. Complications such as cold sensitivity, radiologic artefacts, corrosion, allergic reactions and stress shielding that can be observed with titanium plates and/or screws may be prevented by using alternative materials such as PLLA substances. The aim of this study was to evaluate the histopathologic findings of the titanium and PLLA fixation screws on bone healing for autogenous graft fixation.

Materials and Methods: The study was performed on twenty-four New Zealand white rabbits. The effects of the titanium and PLLA materials on bone formation was compared with the control group. The animals were sacrified at the 6th weeks following the operation and the samples were evaluated histopathologically.

Results: The new bone formation area was found as between %5-30 in the 12.5% of the control group; %30-60 in the 6.3% of the PLLA group, 12.5% of the titanium group and 25% of the control group. 93.8% of the PLLA group, 87.5% of the titanium group and 43.8 of the control group showed greater new bone formation than 60% (p=0.019).

Conclusion: Resorbable fixation materials showed enough resistance in stability of the autogenous bone grafts. These materials did not present any the risk of the formation of the inflammation, necrosis and fibrosis. No statistically significant difference was observed regarding the new bone formation between the resorbable fixation materials and the titanium fixation materials.

Keywords: *Bio-resorbable plates and screws, Poly-l-lactide, autogenous bone*

ÖZ

Amaç: Titanyum ve PLLA (poli-L laktik asit) materyaller oral cerrahide ve ortopedik cerrahide stabilizasyon ve fiksasyon amacıyla sıklıkla kullanılmaktadır. Titanyum plak ve vidalarla birlikte soğuk hassasiyeti, radyolojik artefakt, korozyon, allerjik reaksiyonlar ve stres dağılımının sağlanamaması gibi komplikasyonların görülmesi araştırmacıları yeni seçenekler için çalışmaya itmiştir. PLLA materyaller bu komplikasyonların önlenmesinde alternatif olarak sunulan materyallerdir. Bu çalışmada maksillofasiyal cerrahide otojen onley kemik greftlerinin fiksasyonunda kullanılan titanyum ve PLLA fiksasyon vidalarının kemik iyileşmesine etkilerinin histopatolojik olarak incelenmesi amaçlanmıştır.

Gereç ve Yöntem: Çalışmamız 24 adet Yeni Zelanda tavşanı üzerinde gerçekleştirilmiş, titanyum ve PLLA materyallerin kemik iyileşmesi üzerine etkileri kontrol grubu ile karşılaştırmalı olarak incelenmiştir. Deney hayvanları 6. haftada sakrifiye edilmiş ve elde edilen örnekler histopatolojik açıdan değerlendirilmiştir.

Bulgular: Yeni kemik yapımı alanı kontrol grubundaki kesitlerin %12.5'inde %5-30 oranında; PLLA grubunun %6.3'ünde, titanyum grubunun %12.5'inde ve kontrol grubunun ise %25'inde %30 - %60 oranında; PLLA grubunun %93.8'inde, titanyum grubunun %87.5' inde ve kontrol grubunun %43.8'inde ise %60'dan fazla olarak gözlenmiştir (p=0.019).

Sonuç: Rezorbe olabilen fiksasyon materyallerinin otojen kemik greftlerinin stabilizasyonunda yeterli direnci gösterdiklerini, bu materyallerin kullanımlarının enflamasyon, nekroz ve fibrozis oluşumu riskini arttırmadığını ve titanyum fiksasyon materyalleri ile aralarında kemik yapım oranları açısından anlamlı farklılık olmadığını saptadık.

Anahtar kelimeler: *Rezorbe olabilen plak ve vidalar, Poly-l-laktid, otojen kemik*

[1] Istanbul University Faculty of Dentistry Department of Oral and Maxillofacial Surgery

Introduction

Currently, dental implants are commonly used to support functional, and esthetic restorations. Sufficient bone height and width are required to place implants that are correctly positioned. Various amounts of resorption may occur in the alveolar ridge as a result of missing teeth, and excessive periodontal disease in young patients. Contemporarily, in maxillofacial surgery, various biomaterials such as heterografts, xenografts, allografts or homografts, autogenous grafts, and alloplasts are utilized to achieve adequate alveolar ridge width and height (1). In maxillofacial surgery multiple different techniques can be used for alveolar ridge augmentation. Autogenous bone grafts, which may be a cortical block or cancellous particles, are accepted as the gold standard for ridge augmentation (2).

Cortical bone graft do not have a positive effect on osteogenesis despite their structural resistance. However cancellous bone grafts have a positive effect on osteogenesis effect but they do not provide sufficient structural resistance. Corticocancellous bone grafts provide osteoblasts, and growth factors that migrate to the defect region, and they are structurally resistant as an advantage. The surgeon may achieve adequate augmentation of the bone volume with this technique. The rigid fixation of the bone grafts to the recipient site is crucial for the success of the operation (3, 4).

Various studies demonstrated that the titanium screws, and plates provided excellent mechanism in graft stabilization, however they also reported their limitations. The removal of the titanium plates are almost always unnecessary, but in a few instances they may require removal due to complications such as pain, infection etc. Titanium plates may prevent the transmission of the physiological stress to the bone. As a result, stress shielding may occur. Furthermore, using these devices on pediatric patients can cause growing deficiencies, and intracranial migration at the operation area. In addition, metal fixation devices cause radiographical artefacts. The other problems which have been reported associated with these metal devices are corrosion, allerjic reaction, loosening and cold sensibility. Additionally, when the fixation plates are covered by a thin mucosa, these materials may be exposed, and cause considerable discomfort. Consequently, many studies were performed on the use of bioabsorbable implants in maxillofacial surgery (4, 5). Most of the bioabsorbable systems in maxillofacial surgery are composed of polylactic acid (PLA), polyglicolic acid (PGA) copolymers, and some of them may contain trace amounts of trimethyln carbonate (TMC). Current materials contain various mixtures of these polimers, and they indicate differences about their manipulation (6). Poly-L-lactic/polyglycolic acid (PLLA–PGA) copolymers are bioabsorbed relatively quickly, but preserve sufficient structural durability throughout the healing process. These materials are used for treatment of facial fractures, orthognathic surgery, and graft fixation. These materials are completely eliminated from the body without causing any foreign body reaction. Their main disadvantage is their diminished structural support (7-10).

The purpose of this study is to evaluate histopathologically the effects of the titanium and poly-L lactic acid (PLLA) fixation screws on bone healing.

Materials and Methods

This study was performed in Istanbul University, Faculty of Dentistry, at the Department of Oral and Maxillofacial Surgery, in Istanbul University Cerrahpaşa Medical School, Experimental Animal Production, and Research Laboratory and in Department of Oncology, Istanbul University. The experimental protocol and guidelines for the care and use of the laboratory animals were approved by the Institutional Animal Care and Ethics Committee of Istanbul University Institute for Experimental Medical Research. About one year old, 24 New Zealand white male rabbits weighing 2.500–3.000 g were used as test subjects in this study.

Harvesting of the autogenous bone grafts

Test rabbits were starved for 12 hours before the operation. General anesthesia was achieved by 100mg/kg of ketamin HCl (50 mg/ml Ketalar® , Parke Davis) and 10mg/kg of Xylazin HCl (23.32mg/ml Rompun®, Bayer) injection. The harvested femurs were shaved and disinfected with povidone-iodine solution (Baticon, ADECA, Samsun). Local anesthesia was performed subcutaneously with 40mg/ml of articaine HCL (Ultracain® DS forte) including 0.012 mg/ml of epinephrine. The skin incision was performed to reach the femur and musculus tensoris fascia was dissected. Long lateral and semimembraneous muscles were separated to reach the midle region of the femur.

After careful elevation of the periosteum, 2 autogenous 5 mm diameter bone grafts were obtained with trephine drill. Afterwards the bone was fixed by 6 punctured 2 mm titanium plates (Trinon Titanium GmbH, Karlsruhe, Germany) to avoid post operative fracture in the mentioned region) (Image 3.4)

Subcutaneous tissues were sutured with 3.0 chromic catgut (Doğsan, İstanbul, Türkiye) and the skin was sutured with 3.0 silk suture (Doğsan, İstanbul, Türkiye).

Fixation of the autogeonus bone grafts

After shaving, and disinfecting the medial faces of the right tibiae, 40 mm long skin incision was performed to reach the medial faces of the tibiae. The medial faces of the tibiae were reached with blunt dissection.

One of harvested grafts was fixed with 2 mm titanium screws (Trinon Titanium GmbH, Karlsruhe, Germany) and the other harvested graft was fixed with 2 mm bioresorbable screws (Inion CBS, Optima, Finland) on the bone after careful periosteal elevation (Figure 1).

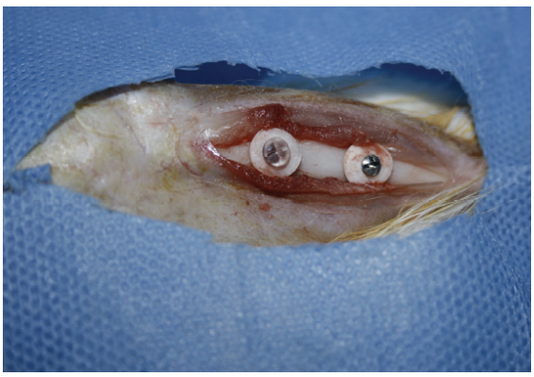

Figure 1. The fixation of the autogenous grafts with titanium and PLLA screws.

Harvested bone blocks which belong to the control group were placed on bone surface without fixation. Muscles were sutured with 3.0 chromic catgut and the skin tissue was sutured with 3.0 silk suture IM 100mg/kg.

Experimental groups

Twenty-four experimental animals were randomly divided into three groups including 8 experimental animals. The distribution of the grafts and the fixation methods are reported below:

Two 5 mm bone grafts were harvested from 8 animals femurs using the trephine drill on first stage. One of the harvested graft was fixed with titanium screw and the other one was fixed with the resorbable screw on the surface of tibia.

Another two 5 mm bone grafts were harvested from 8 experimental animal femurs using trephine drill on second stage. One of harvested graft was fixed with the titanium screw, the other harvested graft was place without using any fixation.

Finally two 5 mm bone grafts were harvested from 8 experimental animal femurs using trephine drill on the third stage. One of the harvested graft was fixed with the PLLA screw, the other graft was placed without fixation on the surface of tibia.

All experimental animals were sacrificed 42 days after the operation. Intraperiteonal high dose of tiopenthal sodium USP (Penthotal® Sodium 0.5g ABBOTT) was injected for the sacrification. The sacrification process of the animals were completed after the lethal effects of anesthesia in reversible period.

Extracted rabbit tibiae were fixed in 10% buffered formaldehyde solution, and submitted to the Department of Tumor Pathology and Oncology Cytology, Institute of Oncology for the histopathological evaluation. The specimens were decalcified in 10 % nitric oxide aqueous solution for ~72 h, with the solution changed daily, until their consistency enabled easy cutting with a histology knife without any resistance or sound, and were embedded in paraffin. The paraffin blocks were prepared, and 5-7 μm thickness section were obtained from the paraffin blocks, stained with hematoxylin-eosin, and prepared for examination under a light microscope. Forty-eight histological sections obtained from the experimental animals were divided into three groups of 16 section, according to the type of fixation procedure as follows (n=16 for each group):

Control group: No fixation material was used

Titanium group: Titanium screws were used for the fixation of the grafts

PLLA group: PLLA screws were used to fix the bone grafts

Experimental groups were evaluated in accordance with following scores regarding the new bone formation, inflammation, necrosis and fibrosis.

0% showed the lack of new bone formation, (+) involves 5% to 30 % region, (++) involves %30 to %60 region, (+++) involves more than %60 region.

Statistical Analysis

Statistical analysis were performed with GraphPad Prisma V.3 packaged software. Chi square test was used to compare qualitative data, and McNemar's test was used in recurrent measurement. Results were considered in significance level $p<0.005$.

Results

Statistical significance difference was observed regarding the inflammation and necrosis in experimental groups (Table 1, Table 2).

Table 1. Statistical comparison of the inflammation regarding the inflammation.

Comparison between the groups			P
PLLA	**/**	**TITANIUM**	**-**
PLLA	**/**	**CONTROL**	**0.049**
TITANIUM	**/**	**CONTROL**	**0.049**

Table 2. Statistical comparison of the necrosis regarding the necrosis.

Comparison between the groups			P
PLLA	**/**	**TITANIUM**	**-**
PLLA	**/**	**CONTROL**	**0.049**
TITANIUM	**/**	**CONTROL**	**0.049**

Statistically significant difference was not observed regarding the fibrosis in experimental groups in PLLA group, titanium group and in control group. Statistical significance difference was observed with regard to the new bone formation in experimental groups (Table 3).

Table 3. Statistical comparison of the new bone formation between groups.

Comparison between the groups			P
PLLA	**/**	**TITANIUM**	**0.544**
PLLA	**/**	**CONTROL**	**0.021**
TITANIUM	**/**	**CONTROL**	**0.046**

The new bone formation between the groups are summarized in Table 4 and Figure 2.

Table 4. The distribution of the new bone formation in the groups (x^2:15,16, p=0.019).

		PLLA		Titanium		Control	
		n	%	n	%	n	%
New bone formation	(-)	0	0.0	0	0.0	3	18.8
	(+)	0	0.0	0	0.0	2	12.5
	(++)	1	6.3	2	12.5	4	25.0
	(+++)	15	93.8	14	87.5	7	43.8

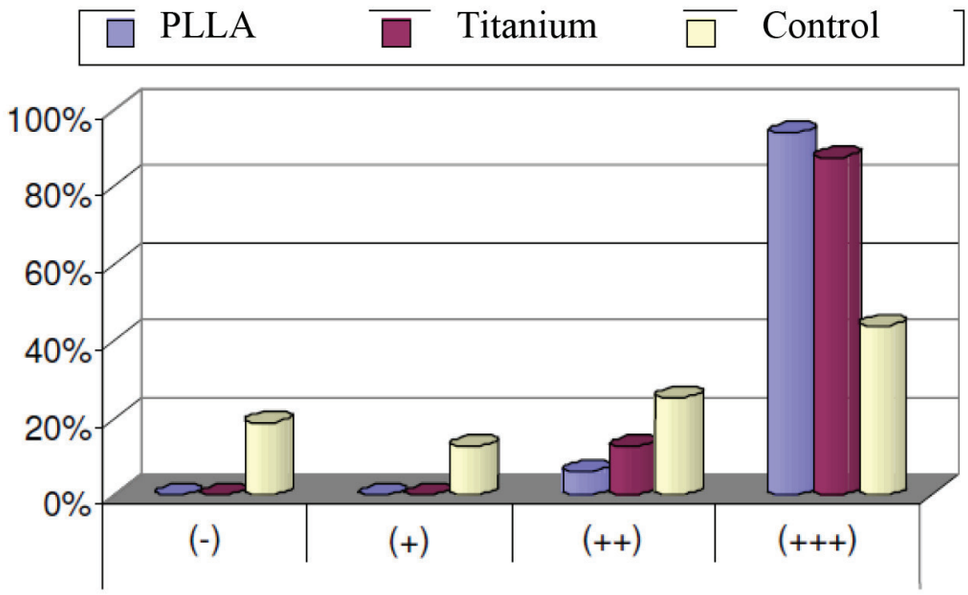

Figure 2. New bone formation between the groups.

The histopathological evaluation shows the new bone formation in Figure 3 and Figure 4 regarding the titanium and the resorbable groups.

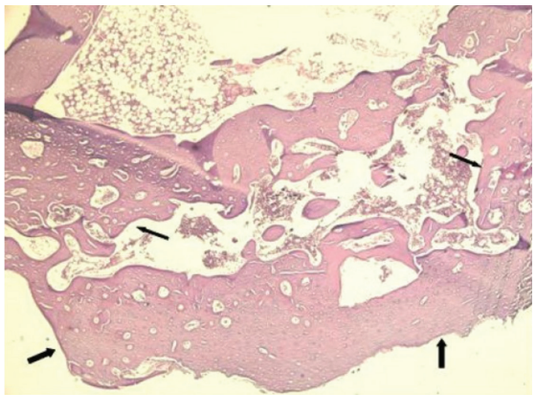

Figure 3. New bone formation areas around the bone graft in PLLA group.

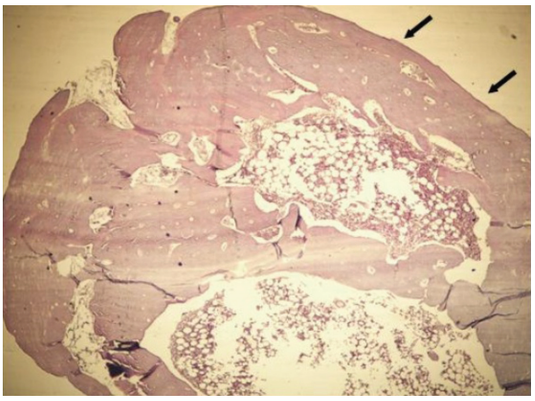

Figure 4. New bone formation and bone marrow in titanium group.

Discussion

Bioabsorbable fixation materials (BFM) were applied for fixation in orthognatic surgery and in the management of fractures. These materials were evaluated according to such parameters as inflammation, relapse, bone fragment mobility, resistance to mastication force, dehiscence formation, and foreign body reaction (11-18).

Eppley (11) reported an experimental study to determine the suitability of the biodegradable screws for fixation of mandibular sagittal split osteotomies and the resorbable devices appeared to be adequate to withstand the forces of mastication. We also determined

that bioresorbable screws have sufficient resistance for graft stabilization.

Mazzonetta et al. (12) reported that no clinical complications such as infection, discoloration, or discharge at the osteotomy sites and no radiological changes in the osteotomy sites were observed on 30 patients who underwent orthognathic surgery using a bioresorbable self-reinforced (70L:30DL) polylactide plating system. They determined that self-reinforced (70L:30DL) polylactide was considered to be comparable to other forms of rigid internal fixation devices for orthognathic surgery.

Cheung et al. (13) did not discover any differences in the intra- and postoperative morbidities and complications between resorbable and titanium plating systems for fixation in orthognathic surgery. A total of 60 patients with 177 osteotomies were included in this study. Eighty-seven osteotomies fixated with titanium plates, whereas 90 osteotomies fixated with BFM plates. Objective parameters including wound dehiscence, rate of infection, plate exposure and palpability assessed by surgeons in both groups showed no significant difference. Bioresorbable fixation devices offer similar function as titanium in fixation for orthognathic surgery and do not impose an increase in the clinical morbidities.

Edwards et al. (14) evaluated the capability, and effectiveness of resorbable bone fixation devices in genioplasty. Twenty patients underwent different genial movements that were stabilized with either 2.5-mm polylactic-polyglycolic acid lag screws or 2.0-mm polylactic-polyglycolic acid plates and screws. Intraoperative stability was satisfactory in all cases. There were no postoperative infections or segmental instability up to 6 months after surgery. Resorbable polylactic-polyglycolic acid lag screw and plate and screw fixation is a viable alternative for fixation of anterior horizontal osteotomies of the mandible.

The success of the resorbable plate systems in the management of the mandibular fractures is controversial as reported by many researches (15-18).

Laughlin et al. (15) reported their prospective study consisted of a sequential enrollment of 50 fractures. The resorbable plates and screws (Inion CPS system, Tampere, Finland) used and there was no need for revision surgery in this series of patients; 12 screw heads were fractured during screw placement and immediately replaced without significant fracture sequelae. In our study bioresorbable screws showed sufficient resistance for the graft stabilization.

Bell and Kindsfater (17) reported two hundred eighty-one patients that met the criteria for inclusion in the study with follow-up of 3 weeks to 3 years. Favorable healing can be observed through the use of biodegradable PL plates and screws to stabilize selected midface fractures in patients of all ages, as well as mandible fractures in early childhood.

Bergsma et al. (18) reported the initial results of 10 treated patients with solitary, unstable, displaced zygomatic fractures using resorbable poly (L-lactide) (PLLA) plates and screws. Their article described the long-term results in these patients. Three years postoperatively, four patients returned because they were concerned about an intermittent swelling at the site of implantation. All patients were examined clinically, and six patients were operated again for the evaluation of the swelling and to investigate the nature of the tissue reaction. The swelling was classified as a nonspecific foreign body reaction to the degraded PLLA material.

Weisberg and Eppley (19) reported that the resorbable fixation systems offer significant theoretical advantages. Tissue tolerance of these plates have been found to be excellent. Similarly we did not determine any foreign body reaction in our study.

Suzuki et al. (20) determined whether a resorbable poly-l-lactide (PLLA) miniplate system could be used to treat mandibular condylar process fractures. Fourteen patients who had mandibular condylar process fractures treated with PLLA implants were recalled for follow-up clinical and radiologic examinations at 3 years. They reported that the PLLA miniplate system provide reliable stability when used for the fixation of mandibular condylar process fractures.

Many researchers demonstrated the benefits of bioabsorbable plates and screws in pediatric craniofacial surgery (21-24).

Eppley et al. (21) reported a combined prospective and retrospective analysis performed on 1883 craniosynostosis patients who used the same type of resorbable bone fixation devices (poly-L-lacticpolyglycolic copolymer) in their research. Long-term experience in large numbers of patients demonstrated that resorbable poly-L lacticpolyglycolic plate and screw fixation is as safe and effective as metal devices, with no added risks of infection or reconstruction instability. They eliminate the need for any secondary device-related procedures; this is their major advantage.

Another study reported by Eppley et al. (25) informed that the present clinical results with polymeric plates demonstrate their safety and efficacy for use in the pediatric craniofacial skeleton.

Conclusion

As a result, the stabilization of autogenous bone grafts were provided by resorbable material that showed adequate resistance. These materials did not increase the risk of inflammation, necrosis and fibrosis. No significant difference was found in new bone formation between titanium fixation materials. The present study also demonstrated advantages of resorbable materials which may be a good alternative in oral surgery practice.

REFERENCES

1. Narang R, Wells H. Stimulation of new bone formation on intact bones by decalsified allogeneic bone matrix. Oral Surg Oral Med Oral Pathol 1971;32(4):668-76.

2. Elsalanty ME, Genecov DG. Bone graft substitute: a review of literature. Bone grafts in Craniofacial Surgery. Craniomaxillofac Trauma Reconstr 2009;2(3):125–34.

3. Eppley BL, Sadove AM. A comparison of resorbable and metallic fixation in healing of calvarial bone grafts. Plast Reconstr Surg 1995;96(2):316-22.

4. Chacon GE, Ellis JP, Kalmar JR, McGlumphy EA. Using resorbable screws for fixation of cortical onlay bone grafts: an in vivo study in rabbits. J Oral Maxillofac Surg 2004;62:1396-402.

5. Sanger C, Soto A, Mussa F, Sanzo M, Sardo L, Donati PA, Di Pietro G, Spacca B, Giordano F, Genitori L. Maximizing results in craniofacial surgery with bioresorbable fixation devices. J Craniofac Surg 2007;18(4):926-30.

6. Bergsma JE, de Bruijn WC, Rozema FR, Bos RR, Boering G. Late degradation tissue response to poly(L-lactide) bone plates ans screws. Biomaterials

1995;16(1):25-31.

7. Coelho RC, Zerbinati LP, de Oliveira MG, Weber JB. Systemic effects of LLLT on bone repair around PLLA-PGA screws in the rabbit tibia. Lasers Med Sci 2013; Jul 6. [Epub ahead of print]

8. Magaña FG, Arzac RM, De Hilario Avilés L. Combined use of titanium mesh and resorbable PLLA-PGA implant in the treatment of large orbital floor fractures. J Craniofac Surg 2011;22(6):1991-5.

9. Bhatt K, Roychoudhury A, Bhutia O, Trikha A, Seith A, Pandey RM. Equivalence randomized controlled trial of bioresorbable versus titanium miniplates in treatment of mandibular fracture: a pilot study. J Oral Maxillofac Surg 2010; 68(8):1842-8.

10. Fedorowicz Z, Nasser M, Newton JT, Oliver RJ. Resorbable versus titanium plates for orthognathic surgery. Cochrane Database Syst Rev 2007;18(2):CD006204.

11. Eppley BL. Bioabsorbable plate and screw fixation in orthognathic surgery. J Craniofac Surg 2007;18(4):818-25.

12. Mazzonetto R, Paza AO, Spagnoli DB. A retrospective evaluation of rigid fixation in orthognathic surgery using a biodegradable self-reinforced (70L:30DL) polyactide. Int J Oral Maxillofac Surg 2004;33(7):664–9.

13. Cheung LK, Chow LK, Chiu WK. A randomized controlled trial of resorbable versus titanium fixation for orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;98(4):386-97.

14. Edwards RC, Kiely KD, Eppley BL. Resorbable fixation techniques for genioplasty. J Oral Maxillofac Surg 2000;58(3):269-72.

15. Laughlin RM, Block MS, Wilk R, Malloy RB, Kent JN. Resorbable plates for the fixation of mandibular fractures: a prospective study. J Oral Maxillofac Surg 2007;65(1):89-96.

16. Landes CA, Ballon A. Indications and limitations in resorbable P(L70/30DL) LA osteosyntheses of displaced mandibular fractures in 4.5-year follow-up. Plast Reconstr Surg 2006;117(2):577-87.

17. Bell RB, Kindsfater CS. The use of biodegradable plates and screws to stabilize facial fractures. J Oral Maxillofac Surg 2006;64(1):31-9.

18. Bergsma EJ, Rozema FR, Bos RR, de Bruijn WC. Foreign body reactions to resorbable poly(L-lactide) bone plates and screws used for the fixation of unstablezygomatic fractures. J Oral Maxillofac Surg 1993;51(6):666-70.

19. Weisberger EC, Eppley BL. Resorbable fixation plates in head and neck surgery. Laryngoscope 1997;107(6):716-9.

20. Suzuki T, Kawamura H, Kasahara T, Nagasaka H. Resorbable poly-L-lactide plates and screws for the treatment of mandibular condylar process fractures: a clinical and radiologic follow-up study. J Oral Maxillofac Surg 2004;62(8):919-24.

21. Eppley BL, Morales L, Wood R, Pensler J, Goldstein J, Havlik RJ, Habal M, Losken A, Williams JK, Burstein F, Rozzelle AA, Sadove AM. Resorbable PLLA-PGA plate and screw fixation in pediatric craniofacial surgery: clinical experience in 1883 patients. Plast Reconstr Surg 2004;114(4):850-6; discussion 857.

22. Eppley BL. Use of resorbable plates and screws in pediatric facial fractures. J Oral Maxillofac Surg 2005;63(3):385-91.

23. Imola MJ, Hamlar DD, Shao W, Chowdhury K, Tatum S. Resorbable plate fixation in pediatric craniofacial surgery: long-term outcome. Arch Facial Plast Surg 2001;3(2):79-90.

24. Imola MJ, Schramm VL. Resorbable internal fixation in pediatric cranial base surgery. Laryngoscope 2002;112(10):1897-901.

25. Eppley BL, Sadove AM, Havlik RJ. Resorbable plate fixation in pediatric craniofacial surgery. Plast Reconstr Surg 1997;100(1):1-7; discussion 8-13.

Corresponding Author:
Cemil İŞLER
Istanbul University
Faculty of Dentistry
Department of Oral and Maxillofacial Surgery
34390, Fatih-Istanbul / Turkey
Phone: (0212) 3414 20 20 (30289)
e-mail: dtcemil@yahoo.com