Turk J Vet Anim Sci
26 (2002) 1109-1116

Research Article

Comparative Study on the Effects of Wire, Polydioxanone, and Mini Titanium Plate Osteosynthesis Materials on the Healing of Mandibular Fractures: An Experimental Study in Rabbits*

Hasan BİLGİLİ
Ankara University, Faculty of Veterinary Medicine, Department of Orthopedics and Traumatology
06110, Dışkapı, Ankara - TURKEY

Sibel ORHUN
Emergency and Traffic Accident Hospital 06200, Balgat, Ankara - TURKEY

Received: 17.08.2001

Abstract: In this study, corpus mandibula fractures were experimentally induced on 30 rabbits and 3 different materials were used for fixation. Thirty rabbits were arranged into 3 groups and then wire, polydioxanone and mini plate and screw osteosynthesis materials were used. The fracture healing was examined and compared with clinical, radiological and histological results. From the radiological results the parameters of groups were compared with Lane and Sandhu scale system in terms of callus tissue, mineralization and remodeling. The histological results were evaluated according to the Modified Heiple scoring and compared for histological fracture healing and callus tissue. At the end of the radiological and histological evaluation the 3rd group had the most logical data with mini titanium plate and screws system. In conclusion, with statistical data in mandibular fracture mini titanium plates and screws are found to be the safest way. In addition, the polydioxanone suture material was considered for use instead of wire suture material if necessary.

Key Words: Wire, polydioxanone, mini plate, titanium, osteosynthesis, mandible, fracture, experimental study, rabbit

Mandibula Kırıklarında Tel, Polydioxanone ve Mini Plak Osteosentez Materyallerinin Kırık Kaynamasına Etkilerinin Karşılaştırmalı Olarak Araştırılması: Tavşanlarda Deneysel Çalışma

Özet: Bu çalışmada 30 adet tavşanın mandibulasında deneysel olarak oluşturulan corpus mandibula kırıklarının 3 farklı materyal ile fikzasyonları yapıldı. Onarlı 3 farklı gruba ayrılan olgulara sırasıyla tel, polydioxanone ve mini titanyum plak ve vida osteosentez materyalleri uygulandı ve kırık kaynamasına klinik, radyolojik ve histopatolojik olarak nasıl etkilediklerinin karşılaştırmalı olarak araştırılması yapıldı. Radyolojik olarak kallus dokusu, mineralizasyon ve remodeling parametreleri açısından gruplar karşılaştırıldı ve Lane-Sandhu değerlendirme sistemi uygulandı. Histopatolojik olarak ise, histolojik kaynama ve kallus dokusu açısından gruplar karşılaştırıldı ve Modifiye Heiple değerlendirme sistemi uygulandı. Radyolojik ve histopatolojik değerlendirme sonucunda en iyi puanlamayı ve anlamlı sonuçları mini titanyum plak osteosentez materyali uygulanan 3. gruptan elde edildi. Sonuç olarak mandibula kırıklarının sağaltımında mini titanium plak ve vida sisteminin güvenle tercih edilebileceği istatistiksel olarak da belirlenirken, tel dikiş kullanılmasını gerektiren durumlarda ise, bunun yerine polidioxanone materyalinin güvenle kullanılabileceği kanılarına varıldı.

Anahtar Sözcükler: Tel, polidioxanone, mini plak, titanyum, osteosentez, mandibula, kırık, deneysel çalışma, tavşan.

Introduction

Despite its short anatomical structure, the mandibula is one of the most functional bones, and difficulties may be encountered during surgical intervention because of the large muscles (1-3). Mandibula fractures account for 3-6% of all fractures in canine patients (4-7).

Determination of the treatment method for maxillary and mandibular fractures depends on many factors. The presence and absence of teeth (8), size of the soft tissue destruction, age, the usage of the animal, shape of localization and stability of the fracture, economic status of the owner and preference of the surgeons (9,10). Usually in the treatment of mandibular fractures, a quick return to the normal functions (4,11), protection of soft tissue and dental structures from destruction, ideal anatomical reduction (12), and protection of occlusive

* This study was presented at the 31st Voorjaardagen International Veterinary Congress, 24-26 April 1998, Amsterdam-NETHERLANDS and the 8th European Veterinary Dentistry Congress (EVDS) 22-23 September 1999, Lyon-FRANCE.

alignment are all attempted (4,8,11,13,14). Many different fixation techniques like plates and screws (4-6,8,10,15-23), special mini plates (12,24-26), interdental wires (5,7,10,17,18,22,27-29), intraoral splints (4,6,10,19,30), acrylic splints, external fixators (4-6,10,18,19,22,31,32), intramedullar pins (4,6,10, 17,19,33), interfragmental or intraosseing wires (4-6,9,10,17-19,23,27), interarcade wiring (10,22,34), dental composite application (35,36) and muzzles (5,11,18,22,27), and combinations of these devices have been advocated by surgeons (4,5,10,17,28,37,38).

However, there are some advantages and disadvantages of all these methods. It is probable that many complications may result unless a stable and rigid immobilization is provided in mandibular and maxillary fractures (4-6,8,10,13,23,30,33,39-45).

In this study, fixations of experimentally induced corpus mandibular fractures in rabbits were performed using wire, polydioxanone suture material and mini plate-screw systems.

The ultimate aim was to examine how the healing of the fractures was affected by these three different materials and to compare clinical, radiological and histopathological findings.

Materials and Methods

This study was carried out in Research Center of Gülhane Military Medical Academy. Thirty mature White New Zealand rabbits weighing between 2250 and 4100 g were used. Animals were randomly divided into 3 groups and each contained 10 rabbits.

After anesthetizing the rabbits with xylazin hydrochloride 0.1 ml/kg (Rompun, Bayer, Turkey) and ketamine hydrocloride 20 mg/kg (Ketalar, Eczacıbaşı, Turkey) combination. A 5 cm longitudinal skin incision was performed on the right corpus mandibula (46). Later, bone was exposed and the periosteum was elevated with a periost elevator. Finally, osteotomy was performed and experimental fracture achieved. In the first and second groups, holes were made in both fragments by drilling. Fixations were performed using wire (1 mm in diameter) in the first group and polydioxanone suture material (No: 1) in the second group. In the third group, four hole smooth mini titanium plate and screws were used for fixation. Two mini screws were attached to each fragment.

Rabbits were placed in separate cages. Green vegetables and ready made rabbit foods were given. Chewing, drinking and feeding were observed. In the 1st, 3rd, 5th, 7th and 8th weeks, the observation of rabbits was based on x-ray film according to a modified version of Lane and Sandhu's method (47). At the end of the post-operative 8th week, the rabbits were sacrificed using thiopental sodium 0.5 g (Pentothal sodium, Abbott, Italy) and histopathological changes of the fracture area and its surroundings were examined according to the Heiple Evaluation method (48). For the statistical analysis, the Kruskal-Wallis test was utilized.

Results

The first group started being fed in the postoperative 5-8 days (average 7 days). Pain was present at the site of operation. The second group were started being fed on 4-8 days (average 6 days) but pain was diagnosed during mastication and palpation. On the other hand, group 3 started being fed on 2-4 days (average 3 days) and the sense of pain was low.

The evaluation of the radiographic results was performed according to the Lane and Sandhu Evaluation Scale ranging between 0 to 4 (0 for least healing, 4 for optimal healing). The total was 12 as the sum of the callus tissue, fracture healing and remodeling. The evaluations of the results were performed by three different orthopedists. The Kruskal-Wallis test was utilized for the statistical analysis.

The findings were compared in terms of the callus tissue, fracture healing and remodeling, and it was found that group 3 differed significantly from the other two groups ($P < 0.05$, $P < 0.001$ and $P < 0.001$ respectively). Group 3 also differed significantly from the other two groups in terms of total scoring ($P < 0.001$). Groups 1 and 2 did not differ significantly from each other. In group 1, the occurrence of callus in the fracture line, the disappearance (healing) and full-cortex remodeling in 7-8 weeks postoperative were observed (Fig. 1). These data were 6-8 in group 2 (Fig. 2), and 4-5 weeks in group 3 (Fig. 3).

The evaluation of the histopatological findings was performed according to modified Heiple Scoring ranging from 0 to 4 (0 for the least healing, 4 for the optimal healing). The total point was 8 as the sum of the callus

Figure 1. Radiographical appearances of fixation by cerclage wire (VD and LL).

Figure 2. Radiographical appearances of fixation by polydioxanone suture material (VD and LL).

Figure 3. Radiographical appearances of fixation by mini plate and screws (VD and LL).

tissue, and histological fracture healing. The Kruskal-Wallis test was utilized for the statistical analysis.

In group 1 generally fibro cartilaginous healing diffuse callus tissue formation fibrous tissue isles were observed (Fig. 4). However, in group 2 excessive cartilage formation and isolated cartilage calcification and diffusion of fibrous tissue isles into cartilage tissue were seen (Fig. 5). In group 3 completed cortical and trabecular ossification, diffuse and bridging callus tissue formed from osteoid trabecular isles were noted (Fig. 6).

Comparisons of the histological fracture healing and callus parameters revealed that group 3 was significantly different from the other two groups ($P < 0.001$ and $P < 0.001$ respectively). In total scoring, group 3 exhibited a significant difference while the other two groups did not differ significantly (Table 1).

Discussion

The principles in healing of long bone fractures are similar to those in mandibular fractures. In addition, the presence of teeth in the mandible causes differences from other bones (43). After osteotomy of the mandible, an extra osseous blood flow occurs via the soft connective tissue until a normal vascular path is developed after the disruption of the blood flow to the rostral fragment (33). Therefore the completeness of rostral soft tissue is important for revascularization of the bone and the prognosis of callus formation. In this study standard osteotomy was performed in exactly the same sides in all groups and damage to the rostral soft tissues and teeth was minimized.

In the treatment of mandibular fractures in dogs, rigid internal fixation materials such as plate and screws are commonly used (13,15,16,26,39). Plate and screws provide perfect fixation in bilateral and complicated

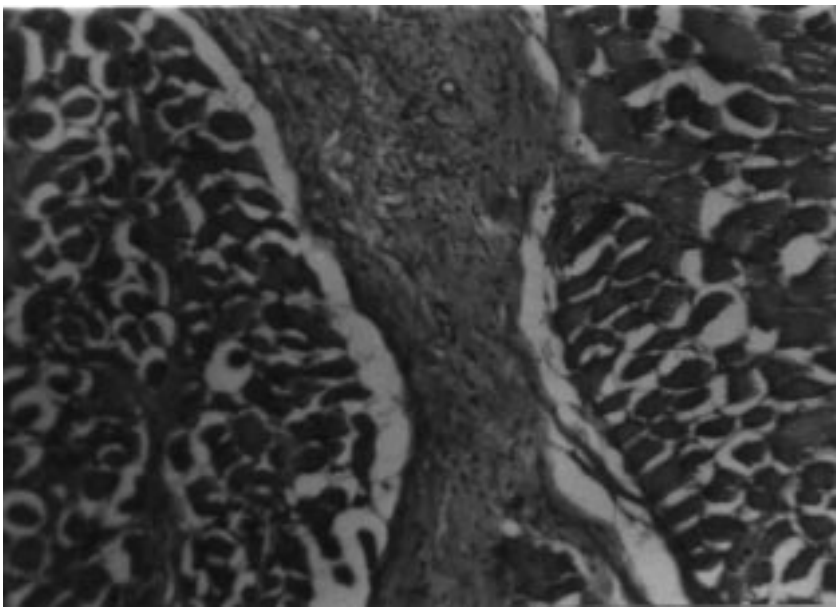

Figure 4. Histopathological appearances of fixation by cerclage wire (HxE, X40).

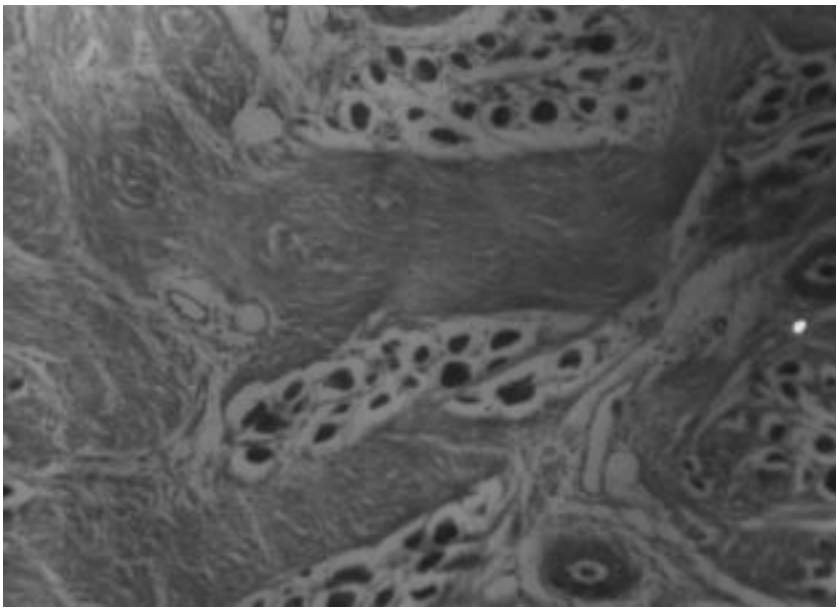

Figure 5. Histopathological appearances of fixation by polydioxanone suture material (HxE, X100).

mandibular fractures (23). Fixation with plates provides a painless, rigid and quick functional regain, although they are expensive. In addition, plates can disturb the vascular support of bone fragments, can harm dental structures, tooth routes and neurovascular structures and can cause endodent diseases (6,40,43). For this reason, a lateral or ventral approach must be preferred to avoid the tooth roots and mandibular nerve during plate application (46). The small size of mini titanium plates and screws provided a facilitated usage and minimal soft tissue dissection. Therefore, tooth roots, dental tissues and neurovascular structures were not damaged.

By plate application, dynamic load from jaw functions must be balanced by the static load from plates (8). In this study, it was clearly determined that mini titanium plates provide such a balance.

Interfragmental or intraosseous wire application can only be performed for the treatment of transversal or short oblique mandibular fractures, especially if the other

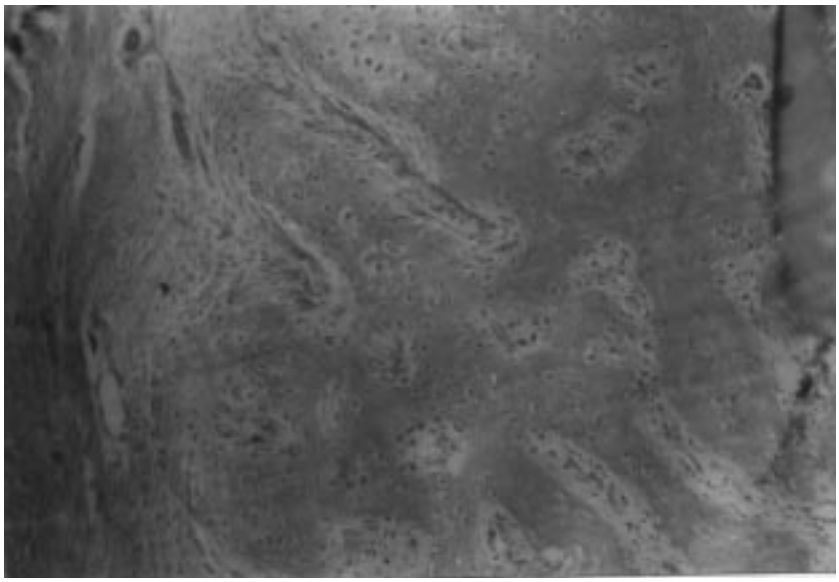

Figure 6. Histopathological appearances of fixation by mini plate and screws (HxE, X40).

Table 1. Data of Groups.

	Group I (Cerclage wire)		Group II (Polydioxanone suture material)		Group III (Mini plate and screw)	
Results and Scores	X	Sx	X	Sx	X	Sx
Radiological results						
Bone formation	1.60	0.22	1.80	0.25	3.40	0.22
Fracture union	2.00	0.00	2.30	0.21	3.00	0.33
Remodeling	2.00	0.00	2.00	0.00	3.00	0.33
Radiological total scores	5.60	0.22	6.10	0.46	9.40	0.88
Histological results						
Callus	1.50	0.17	1.80	0.25	3.40	0.22
Fracture union	2.10	0.10	2.20	0.13	3.40	0.22
Histological total scores	3.60	0.27	4.00	0.38	6.80	0.44

mandible is undamaged and can function as a splint (23,27). This technique, often used in mandibular fractures (5,7), is multifunctional and economical when correctly applied and must be thought of the as the standard technique for the internal fixation of mandibular fractures (19). However, in interfragmental wire application, tooth roots must be avoided, small holes must be drilled (0.045-0.062 inches), wires must be twisted and must be cut short and best downwards to avoid mucosal irritation (9). In the first group where interfragmental wiring was used, tooth roots were avoided during drilling, small holes were placed and care was taken to avoid soft tissue damage by the wire ends. Using cerclage wire implant is insufficient and taking the implant off the operation site is disadvantageous. In order to counter these disadvantages, polydioxanone, a bio-absorbable suture material, was used in the second group and the same results were obtained as in the first group.

Although the recovery period for mandibular fractures was reported to be 3 to 6 weeks, this time can lengthen (5,17,35). The fractures in the premolar area in the canine mandible were observed to have healed averagely in the 9th week. In addition, mandibular fractures can usually not tolerate small malalignments, which are well tolerated in diaphyseal fractures in long bones (13). Eight weeks after stabilization performed with 3 different implants, the induced fractures in rabbit

mandibulas were completely healed and the best radiological and histological union was obtained from the group in which mini titanium plates were used.

Some complications are seen in many techniques used in mandibular fractures. These are malunion, malalignment (8) or malocclusion (5,6,30,41,42,45), damage to tooth roots and neurovascular structures (8,13,23,33,39,43), delayed union due to expend movement (33), nonunion (5,40,41), infection and osteomyelitis (5,8,42,44), delayed functional regain, inhalation pneumonia (5), food storage between the implant and gingival and exudation (23), stomatitis, gingivitis (30), sequester of the bone, pin-track infection, soft tissue sepsis (4,44), facial deformity, and oronasal fistula (10). Malocclusion was observed in 2 cases in the first group and in 1 case in the second group. This complication was absent in the third group.

It does not matter which system is used in mandibular fractures because for the plate application to be successful implant material should be extremely biocompatible, resistant to corrosion and must possess suitable mechanical properties. In addition, it must have suitable dimensions so as to maintain strength in the fracture side, but it must not be too thick and bulky, which would make it difficult to use in the facial skeleton (8). The high biocompatibility, anticorrosive structure, antitoxic and antimagnetic properties and small dimensions of the mini titanium plates used in the study facilitated the performance.

According to clinical, radiological and histopathological findings, using mini titanium plate material in the third group showed that this material provided a rigid fixation, maintained maximum immobilization and the rabbits were able to start eating shortly after the operation. Because of its small size, it also reduces the operation trauma and peripheral soft tissue injuries.

It was concluded that mini titanium plates and screws can be used safely in the treatment of mandibular fractures, whereas polydioxanone suture material may be preferred to wire suture material.

References

1. Sinn, DP., Hill, SC., Watson, SW.: Mandibular fractures. In: Surgery of Facial Bone Fractures. (eds: Foster, C.A., Sherman, J.E.), Churchill Livingstone Inc, New York, 1987; 171-211.
2. Strom, D., Holm, S., Clemensson, E.: Gross anatomy of the craniomandibular joint and masticory muscles of the dog. Arch. Oral Biol, 1988; 33: 597-604.
3. Evans, H.E., Christensen, G.C.: Axial Skeleton. In: Anatomy of the Dog. WB Saunders Co, Philadelphia, 1979; 146-148.
4. Maretta, S.M., Schrader, S.C., Matthiesen, D.T.: Problems Associated with the Management and Treatment of Jaw Fractures. In: Problems in Veterinary Medicine (ed: Maretta SM), JB Lippincott Co, Philadelphia, 1990; 220-247.
5. Umphlet, R.C., Johnson, A.L.: Mandibular fractures in the dog. A retrospective study of 157 cases. Vet. Surgery, 1990; 19: 272-275.
6. Chambers, J.N.: Principles of management of mandibular fractures in the dog and cat. J. Vet. Orthop., 1981; 2: 26-36.
7. Umphlet, R.C., Johnson, A.L.: Mandibular fractures in the cat. A retrospective study. Vet. Surgery, 1988; 17: 333-337.
8. Ardary, W.C.: Plate and screw fixation in the management of mandible fractures. Clin. Plast. Surg., 1989; 1: 61-67.
9. Egger, E.L.: Skull and Mandibular Fractures. In: Textbook of Small Animal Surgery (ed: Slatter DH), WB Saunders Co, Philadelphia, 1993; 1910-1921.
10. Scott, H.W.: The Skull and Mandible. In: Manual of Small Animal Fracture Repair and Management, (eds: Coughlan A, Miller A). Fordingbridge, UK, 1998; 115-132.
11. Denny, H.R.: A Guide to Canine and Feline Orthopaedic Surgery. 3rd edition, Blackwell Scientific Publ, 1993; 111-121.
12. Vérez-Fraguela, J.L., Vives Vallés, M.A.: Maxillofacial surgery: Maxillary osteosynthesis craneomaxillofacial CMS-titanium plates. Vet. Comp. Orthopaed., 2000; 13: 119-122.
13. Weigel, J.P.: Trauma to Oral Structures. In: Veterinary Dentistry (ed. Harvey CE), WB Saunders Co, Philadelphia, 1985; 140-155.
14. Taylor, R.A.: Surgical Repair of Mandibular Fractures. In: Current Techniques in Small Animal Surgery (ed: Bojrab MJ), 4th Ed, Williams & Wilkins Co, Baltimore, 1998; 977-980.
15. Leach, J.B.: Stabilization plating of the canine mandible. Vet. Med. Small. Anim. Clin., 1973; 68: 985-988.
16. Summer-Smith, G., Dingwall, J.S.: The plating of mandibular fractures in giant dogs. Vet. Rec., 1973; 92: 39-40.
17. Brinker, W.O., Piermattei, D.L., Flo, G.L.: Fractures and Dislocation of the Upper and Lower Jaw. Handbook of Small Animal Orthopedics and Fracture Treatment. WB Saunders Company, Philadelphia, 1997; 659-675.
18. Dixon, B.C., Bone, D.L.: Fractures of the Skull and Mandible. In: Current Techniques in Small Animal Surgery (ed: Bojrab MJ), 4th Ed, Williams & Wilkins Co, Baltimore, 1998; 973-984.

19. Rudy, R.L., Boudrieau, R.J.: Maxillofacial and mandibular fractures. Semin. Vet. Med. Surg., 1992; 7: 3-20.

20. Harvey, C.E., Emily, P.P.: Oral Surgery. In: Small Animal Dentistry. St. Louis, Mosby Yearbook, 1993; 156-212.

21. Kern, D.A., Smith, M.M., Stevenson, S., Moon, M.L., Saunders, G.K., Irby, M.H., Dyer, K.R.: Evaluation of three fixation techniques for repair of mandibular fractures in dogs. J. Am. Vet. Med. Assoc., 1995; 206: 1883-1890.

22. Nap, R.C., Meij, B.P., Hazewinkel, H.A.W.: Fractures of the mandible and maxilla in the dog and cat. Tijdschr. Diergeneesk, 1994; 119: 456-462.

23. Nunamaker, D.M.: Fractures and dislocations of the mandible. In: Small Animal Orthopedics (eds: Newton CD, Nunamaker CM), JB Lippincott Co, Philadelphia, 1985; 297-305.

24. Montavon, P.M., Pohler, O.E.M., Olmstead, M.L., Wendelburg, K.L.: The mini instrument and implant set and its clinical application. Vet. Comp. Orthopaed., 1988; 1: 44-51.

25. Boudrieau, R., Kudisch, M.: Miniplate fixation for repair of mandibular and maxilary fractures in 15 dogs and 3 cats. Vet. Surgery, 1996; 25: 277-291.

26. Summer-Smith, G., Dingwall, J.S.: The plating of mandibular fractures in the dog. Vet. Rec., 1971; 88: 595-598.

27. Dulisch, M.L.: Skull and Mandibular Fractures. In: Textbook of Small Animal Surgery (ed: Slatter DH), WB Saunders Co, Philadelphia, 1985; 2286-2295.

28. Norsworthy, G.D., Miller, D.C.: Mandibular fracture repair using an acrylic splint. Canine Pract., 1977; 4: 36-39.

29. Kern, D.A., Smith, M.M., Grant, W., Rockhill, A.D.: Evaluation of bending strength of five interdental fixation apparatuses applied to canine mandibles. Am. J. Vet. Res., 1993; 54: 1177-1181.

30. Smith, M.M., Kern, D.A.: Skull trauma and mandibular fractures. Vet. Clin. N. Am.-Small, 1995; 25: 1127-1149.

31. Aron, D.N.: Acrylic pin splint external skeletal fixators for mandibular fractures. In: Current Techniques in Small Animal Surgery (ed: Bojrab MJ), 4th Ed, Williams & Wilkins Co, Baltimore, 1998; 980-984.

32. Brinker, W.O., Flo, G.L.: Principles and application of external skeletal fixation. Vet. Clin. N. Am.-Small, 1975; 5: 197-208.

33. Roush, J.K., Wilson, J.W.: Healing of mandibular body osteotomies after plate and intramedullary pin fixation. Vet. Surgery, 1989; 18: 190-196.

34. Lantz, G.C.: Interarcade wiring as a method of fixation for selected mandibular injuries. J. Am. Anim. Hosp. Assoc., 1981; 17: 599-602.

35. Wallace, J., Kapatkin, A., Manfra Maretta, S.: Composite fixation of mandibular fractures and luxations. Vet. Surgery, 1992; 21: 409-412.

36. Bennett, J.W., Kapatkin, A.S., Manfra Maretta, S.: Dental composite for the fixation of mandibular fractures and luxations in 11 cats and 6 dogs. Vet. Surgery, 1994; 23: 190-194.

37. Renegar, W.R.: Axial Skeletal Fractures. In: Canine Orthopedics (ed: Whittck WG), Lea & Febiger, Philadelphia, 1990; 308-327.

38. Kangur, T.T., Tolman, D.E., Jowsey, J.: The use of methylmethacrylate in the fixation of mandibular fractures in dogs. Oral Surg. Med. O, 1976; 41: 578-587.

39. Verstraete, F.J.M., Lighthelm, A.J.: Dental trauma caused by screws in internal fixation of mandibular osteotomies in the dog. Vet. Comp. Orthopaed., 1992; 5: 104-108.

40. DeYoung, D.J., Probst, C.W.: Methods of Internal Fracture Fixation. In: Textbook of Small Animal Surgery (ed: Slatter DH), WB Saunders Co, Philadelphia, 1985; 1949-1972.

41. Boudrieau, R.J., Tidwell, A.S., Ullman, S.L., Gores, B.R.: Correction of mandibular nonunion and malocclusion by plate fixation and autogenous cortical bone grafts in two dogs. J. Am. Vet. Med. Assoc., 1994; 5: 744-750.

42. Cechner, P.E.: Malocclusion in the dog caused by intramedullary pin fixation of mandibular fractures: Two case reports. J. Am. Anim. Hosp. Assoc., 1980; 16: 79-85.

43. Roush, J.K., Howard, P.E., Wilson, J.W.: Normal blood supply to the canine mandible and mandibular teeth. Am. J. Vet. Res., 1989; 50: 904-907.

44. Renegar, W.R., Leeds, E.B., Old, R.B.: The use of the Kirschner-Ehmer splint in clinical orthopedics: Part I- Long bone and mandibular fractures. Comp. Cont. Educ. Pract., 1982; 4: 381-391.

45. Pruß, M.: Klassifikation von Kieferfrakturen Vorkommen und Behandlungsergebnisse bei Hund und Katze, Aus der Klinik für kleine Haustiere der Tierarztlichen Hochschule Hannover, PhD Thesis, 1996.

46. Piermattei, D.I., Greeley, R.G.: An Atlas of Surgical Approaches to the Bones of the Dog and Cat. 2nd Ed, WB Saunders Co, Philadelphia, 1993; 32-39.

47. Lane, J.M., Sandhu, H.S.: Current approaches to experimental bone grafting. Clin. Orthop. Relat. R., 1987; 18: 213-218.

48. Heiple, K.G., Chase, S.W.: Comparative studying of the healing process following different type of bone transplantation. J Bone Joint Surg. Am., 1963; 16A:1593-1616.