Biomechanical comparison of osteosynthesis with poly-L-lactic acid and titanium screw in intracapsular condylar fracture fixation: An experimental study

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Abstract

Background and Aims: The aim of this study was to compare the biomechanical stability of poly-L-lactic acid and titanium screws in the fixation of intracapsular condylar fractures, in 10 polyurethane hemimandibles.

Materials and Methods: Artificial intracapsular fractures were created with a steel disk and electronic micromotor. The first group was fixed with 15 mm long self-tapping 2.0 mm system titanium screws and the second group was fixed with 15 mm long 2.4 mm bioresorbable screws. Linear loads of 25, 50, 75, 100 N was applied in anteroposterior direction to the hemimandibles and the data were transmitted directly from the load cell to a computer that shows emergent results of material characteristics under same forces as a graphic containing force and displacement.

Results: The results show that there were no significant differences between the two methods, with 25 N of loading. (P > 0,05) The difference became significant with a higher value of loading.

Conclusion: The results suggest that treatment with a single resorbable screw is not functionally stable as a single titanium screw.

Key words: Intracapsular condylar fractures, osteosynthesis, screw fixation

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Introduction

Fractures of the mandibular condylar process are common fractures affecting the mandible and maxillofacial region.[1] Intracapsular condylar fractures account for 22–36% of all adult mandibular condylar fractures and frequently occur as a result of facial trauma.[2,3] A sagittal mandibular condylar fracture presents as a fracture line that begins from the lateral pole of the condylar surface to the medial side of the condylar neck. This type of fracture is also called a type B intracapsular condylar fracture.[4,5] Intracapsular condylar fractures are the most controversial fractures regarding management.[3,6] Due to the complex anatomical and biomechanical relations of the intracapsular condylar fractures, they are technically challenging to reduce and fix without causing injury to the facial nerve, bleeding, and scarring.[7] Thus, most surgeons choose conservative treatment.[6] However, nonsurgical treatments cannot correctly reposition the dislocated fragment of fracture and restore the normal length of the mandibular ramus.[4]

To overcome the shortcomings of conservative treatment, various surgical techniques using metallic or bioresorbable materials have been developed to treat intracapsular fractures of the mandibular condyle.[7-10] In the literature bicortical screws,[3] microplates,[11] a single titanium screw or pins,[12] two resorbable screws[7] and resorbable pins[10] have

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been used for the surgical reduction of the intracapsular condylar fractures. Despite the fact that both of the metallic and resorbable fixation devices have advantages and are frequently used in the surgical reduction of the intracapsular fractures, to our knowledge there have been no published study that compare the biomechanical efficacy of these two techniques in the literature.

The purpose of the present study on the synthetic mandible replicas was to evaluate the biomechanical behavior of two different types of osteosynthesis that are used in the operative treatment of intracapsular condylar fractures.

Materials and Methods

Ten synthetic polyurethane human mandible replicas are having a medullar and a cortical portion (Synbone CF 8596, Malans, Switzerland) were used to carry out the study. Polyurethane mandibles were used to achieve homogeneity between the experimental subjects. Ten polyurethane hemimandibles were randomly divided into two groups ($n = 5$). Each hemimandible was sectioned with acrylic guide to simulate same fracture line homogeneity. All osteotomies were performed on a standard basis, as follows. The superior border of the osteotomy was set 4 mm inferior to the most concave distal point of the mandibular condyle. A parallel drawing to mandibular ramus axle was performed, and osteotomy continued at 80° for this drawing, ascending from the X point [Figure 1]. Sectioning was performed with a steel disk and electronic micromotor. After sectioning, the first group was fixed with 15 mm long self-tapping 2.0 mm system titanium screws (Titanium Implant System, Ankara, Turkey), and the second group was fixed with 15 mm long 2.4 mm bioresorbable screws (Lactasorb, Biomet, Florida, USA) [Figures 2-4].

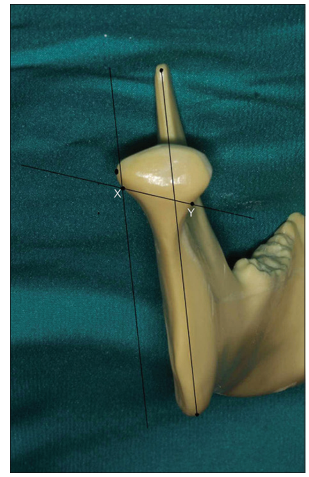


Figure 1: Schematic drawing of the fracture line

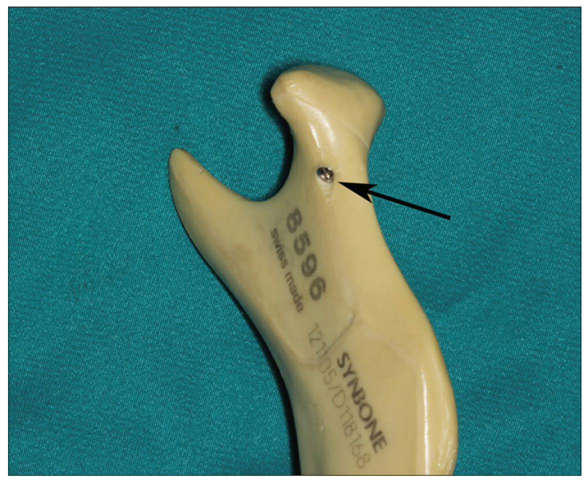


Figure 2: Fixation of the fracture by a single titanium screw

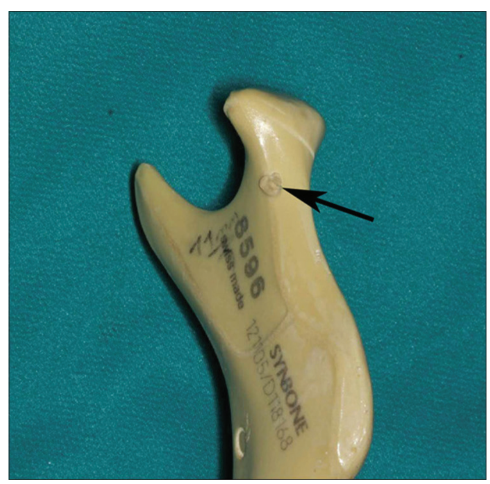


Figure 3: Fixation of the fracture by a single resorbable screw

A specially produced biomechanical fixation appliance, which can be fixed to servo hydraulic test device (Shimadzu AG-IS 100 kN; Kyoto, Japan), was used to immobilize the hemimandibles under force [Figure 5]. This appliance contains two vertical parts: One of them is taller than the other to fix the anterior part of the hemimandible, and the shorter one is to fix the hemimandile from the ramus side. Each hemimandibles was fixed turn by turn from the same point in the testing machine, and the condylar axle was made parallel to the ground plane. Before the application of loading, 10 Newton (N) of preload were applied for standardization.

All testing was performed on a servo hydraulic testing machine (Shimadzu AG-IS 100 kN; Kyoto, Japan). The data were transmitted directly from the load cell to a computer that shows emergent results of material characteristics under same forces as a graphic containing force and displacement (Trapezium2i version 2.15, Kyoto, JAPAN). Loads of 25, 50, 75 and 100 N was applied to the hemimandibles and the data of displacement under linear loads were measured. The statistical analysis performed through parametric testing using the statistical package SPSS version 15.0 (SPSS, Inc.,

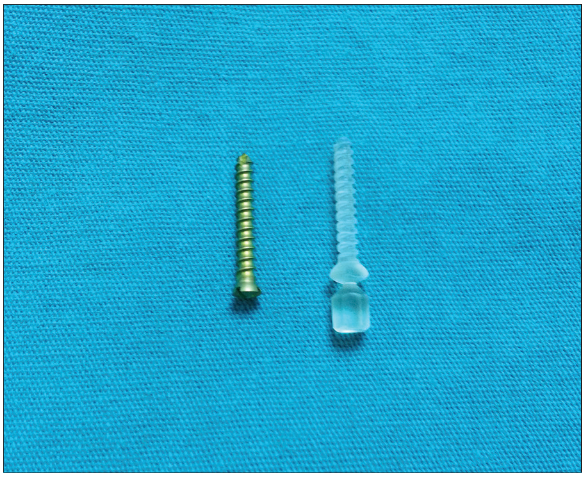


Figure 4: Titanium and PLLA screws

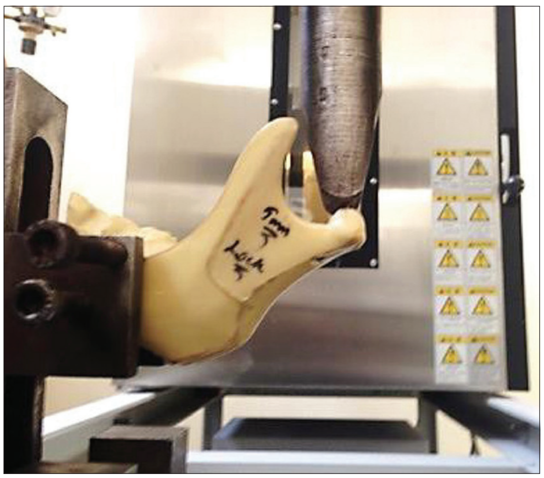
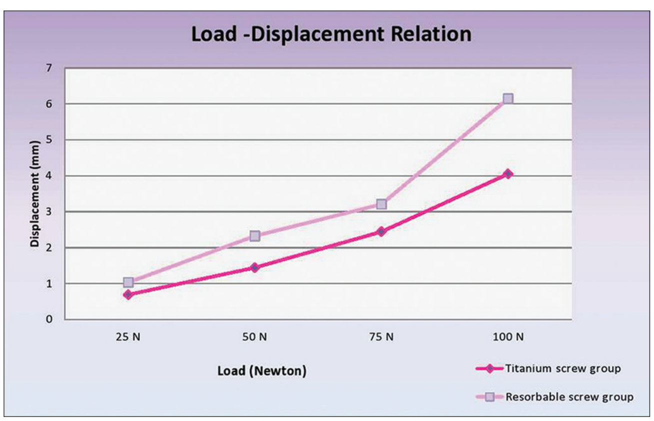


Figure 5: Application of the forces in the testing machine



Graph 1: Load-displacement relation of groups

Chicago, IL, USA). The comparison between groups was analyzed with the independent-samples *t*-test and $P < 0.05$ considered significant.

Results

The results show that there were no significant differences between the two methods while 25 N of loading ($P > 0.05$). The difference became significant with a higher value of loading. It is clear that there are significant differences between the two groups in the loading forces 50, 75 and 100 N. *P* values and mean displacement for forces are shown in Table 1 and Graph 1.

Table 1: Displacement of screws against loading

Force (*N*)	Displacement (mm) Titanium screw group	Resorbable screw group	*P*
25	0.690	1.030	0.096
50	1.442	2.322	0.030
75	2.442	3.206	0.021
100	4.050	6.140	0.008

Discussion

Mandibular condyle fractures are among the most frequently encountered injuries for patients who suffer from facial trauma.[13] The fixation of these fractures is performed in a confined space and the greater part of the condylar heads consist of thin and friable cancellous bone.[1,14] In recent years, screw osteosynthesis has been preferred in the fixation of the condylar process because it requires much less space compared with plate fixation to apply the screws, as well as provide relatively good stability with minimal incisions.[15,16] Compared with the miniplate methods, screw osteosynthesis is a less complicated operation that reduces operative time and articular scarification.[15] Different combinations of screw osteosynthesis have been previously published to explore the type and number of screws that can provide the best stability.[7,14,17] In 1998, Kermer *et al.*[18] used two miniscrews for the internal fixation of the mandibular intracapsular fractures. Oki *et al.*[14] presented a modified technique of the Rasse *et al.* and used two bioabsorbable screws for the anatomical restoration of the fracture. Meng *et al.*,[4] who also used two lateral screws for the internal fixation of the intracapsular fracture, reported that two lateral screws for bicortical osteosynthesis resist the lateral dislodging forces and prevent the proximal rotation of the fragments. Based on the biomechanical simulations they performed Neff *et al.*[19] reported that osteosynthesis with one lag screw is insufficient in providing the rotational stability. Nevertheless, the satisfactory results of Yang *et al.*[1] and Luo *et al.*[3] have been achieved by the use of a single bicortical screw.

Force placed on mandibular condyle in virtually all directions and planes of space and it is difficult to replicate all of the complex interactions of the mandibular condyle.[13] In the biomechanical study carried out on polyurethane mandible by Gealh *et al.*[20] force was applied in anteroposterior and mediolateral directions, and peak displacements were evaluated. In 2009, Pilling *et al.*[21] compared the stability of ten different osteosynthesis techniques of condylar base fractures on minipig mandible. Force was applied in four directions: Lateral to medial, anterior to distal, distal to anterior, and medial to lateral. Their results concluded that the least promising result was the placement of a single resorbable plate, which did not withstand the applied physiological maximum forces. Schneider *et al*.[16] compared the shear forces that resorbable pins and titanium screws could resist in the fixation of diacapitular fractures of the mandibular condyle. Their results demonstrated that resorbable pins resisted a mean shear force of 310 N, whereas a titanium screw resisted 918 N. We applied linear loads in the anteroposteior direction to explore the biomechanical behavior of titanium and poly-L-lactic acid (PLLA) screws on polyurethane hemimandibles. Forces of 25, 50, 75, 100 N applied both resorbable and titanium screws. The load versus displacement relation indicates that at the loading over 25 N resorbable screws showed significant displacement when compared with titanium screws.

Synthetic polyurethane hemimandibles were used in this study due to their standardized size, anatomical shape, density, hardness, the elasticity coefficient, and similarity to the human mandible.[20] In biomechanichal tests, according to Hegtvedt *et al*.,[22] the fixation material should be applied to a substrate with similar characteristics to the material that the fixation system will be applied *in vivo*. The synthetic polyurethane hemimandibles have been created from the impression of actual human cadaver mandibles and in all dimensions and proportions exactly match the human anatomy.[13] These provide a more uniform and consistent sampling than cadaver bone. Furthermore, they have a porous inner core designed to replicate cancellous bone and dense outer core, which is intended to represent cortical bone.[13]

Metallic fixation devices have been used for the internal fracture fixation.[23] Although the repositioning of fractured fragments was successful, metallic devices tend to cause atrophy of the bone by stress-shielding, increase the risk of secondary infections, and can cause disturbances in growth.[7,14,23] Necessity of second surgery in the metallic devices also cause additional trauma in the fracture region.[10,16] Despite the biocompatibility of titanium, many authors recommend removal for different reasons, such as metallosis, corrosion, thermal dysaesthesia, difficulties with future radiological diagnosis, malpositioning, and the migration of osteosynthesis material, particularly in craniofacial surgery.[12,23] On the other hand, bioresorbable osteosynthesis devices offer numerous advantages over metallic implants and recently systems using bioresorbable devices have been accepted as suitable tools for osteosynthesis.[14] Bioresorbable materials disappear gradually and therefore, obviate the need for removal.[24] The bending moduli of bioresorbable materials are close to that of bone and will enhance stress protection when bone support is no longer required.[23,24] The most commonly used bioresorbable material, PLLA, is slowly degraded in the human body and physical stress is gradually transferred to the healing bone. It is believed that this property of PLLA screws prevents osteoporosis which is one of the main disadvantages of titanium fixation systems.[23] Although, some *in vitro* studies have reported the biomechanical stability of resorbable pins and osteosynthesis with resorbable screws,[7,12,16,25] Pilling *et al*.[21] mentioned that resorbable screws exert lower retention forces than titanium ones, which result in a less stable fixation. In addition, besides their poor mechanical stability, biodegradable screws also have the number of limiting factors, such as difficult handling properties and time-consuming fixation.[25]

Conclusion

The results of the present study showed that the internal fixation of intracapsular fractures of the mandibular condyle with a titanium screw has more functionally stable results than resorbable screws. Absorbable screws, which offer numerous advantages, are not strong enough for the fixation in higher loading values. This discourages the use of resorbable screws in heavily load areas. We, therefore, consider that titanium screws can be used more safely in the fixation of intracapsular fractures and suggested intermaxillary fixation in cases where resorbable screws are used.

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