THE BIOMECHANICAL ANALYSIS FOR BIODEGRADABLE PURE MAGNESIUM BONE SCREWS UNDER THREE POINT BENDING AND TORSIONAL TEST

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Abstract

Recently, magnesium and its alloys have been used as the raw material of degradable implants. In the orthopedic implant group, it is used in the production of medical tools due to its close modulus of elasticity and mechanical behavior suitable for bone tissue. In addition, magnesium is completely biodegradable both in biocompatible and living organisms. The purpose of using a degradable implant within the living organism is both to perform biomedical functions. It has become even more attractive to use the biodegradable magnesium screws due to the use of the temporary (non-biodegradable) implant in the living organism, the need for a secondary surgical operation to remove it from the body, and the increased risk of complications for the patient. However, the degradation times of magnesium screws; It is difficult to control the biological environment, the age and gender of the patients and the implant geometry Determination of the degradation stage is important for mechanical performance due to loss of mass and volume in the implant. Furthermore, loss of adhesion performance due to deterioration of bone screws weakens the mechanical properties of the implant system.

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Considering this feature of magnesium screws, pure magnesium screws of different origin were kept in phosphate buffer solution (pH = 7.4) for 1 day, 1,4,12 and 26 weeks. Then, three-point bending and torsion tests were performed according to ASTM F2502-11 standard to examine the mechanical properties of the screws. In the mechanical tests applied for both groups, when the three-point bending test and force-displacement curves were examined, it was observed that the mechanical properties of the 26th week decreased by about half compared to the 1st day. In the same way, when the torsion-torsion angle curves were examined in the torsion test, it was observed that the mechanical properties of the 26th week decreased for both groups.

Keywords: Pure Magnesium, Biodegradation, Bone Screws, Three-Point Bending Test, Torsion Test.

1. Introduction

Biomaterials, which are of great importance in repairs and changes as a result of damage to human hard tissue, are widely used in orthopedics, bone and dentistry [1-4]. The number of patients with bone diseases caused by causes such as trauma, tumor and inflammation is increasing day by day. With this increase, the number of patients who need both bone treatment and replacement increases in parallel [5]. For these reasons, research is ongoing to produce bone tissue materials and new materials.

Bone therapy materials are divided into two groups as bioinert and biodegradable implants according to their degradation performance [6]. Bioinert implants show superior success in bone fixation. The patient remains in his body forever. However, in cases where it needs to be removed from the body, a secondary surgical operation is required, which means an increase in pain and pain for the patient. For this reason, interest in biodegradable implants is increasing according to their original characteristics [7,8 Biodegradable implants; biocompatibility and nontoxicity of degradation products, appropriate mechanical properties and close-to-bone mechanical properties, should comply with criteria such as bone degradation rate in the healing process. For these reasons, magnesium and its alloys are preferred due to their close mechanical properties and high biocompatibility [9].

Mechanical performance is an important factor for magnesium and its alloys. In addition, since their resistance to corrosion is very low, the degradation that occurs in the body without healing leads to mechanical losses. The mechanical properties of biodegradable magnesium alloy implants depend not only on their original mechanical properties but also on the common surface strength of the tissues to which they are implanted and the liquid environment to which they are exposed [9-11].

For this reason, the purpose of this study is to investigate the mechanical properties of two different types of pure magnesium bone screws in PBS solution by subjecting them for 1 day, 1-4-12 and 26 weeks, and by torsion and three-point bending tests. In addition, surgery was mainly aimed at delaying or preventing arthroplasty for young adult patients.

2. Experimental

2.1 Preparing Solutions

Bone screws were kept in PBS for a certain time for mechanical tests. PBS was prepared with a combination of 8g & / L NaCl, 0.2g / L KCl, 1.44 g / L Na_2HPO_4 and 0.25 g / L KH_2PO_4. The temperature of the solution was kept at 37 ºC and the prepared PBS pH value was adjusted to be 7.4 [11].

Both types of bone screws were immersed in PBS (phosphate buffered solution / saline) with Ph 7.4 and kept for 1 day, 1-4-12 and 26 weeks. After waiting at different times, the bone screws removed from the solution were cleaned with ethanol and dried in the oven. Bone screws were measured weekly using pH calibrated pH meters. Bone screws (without process) are shown in Figure 1 before they are kept in PBS solution.

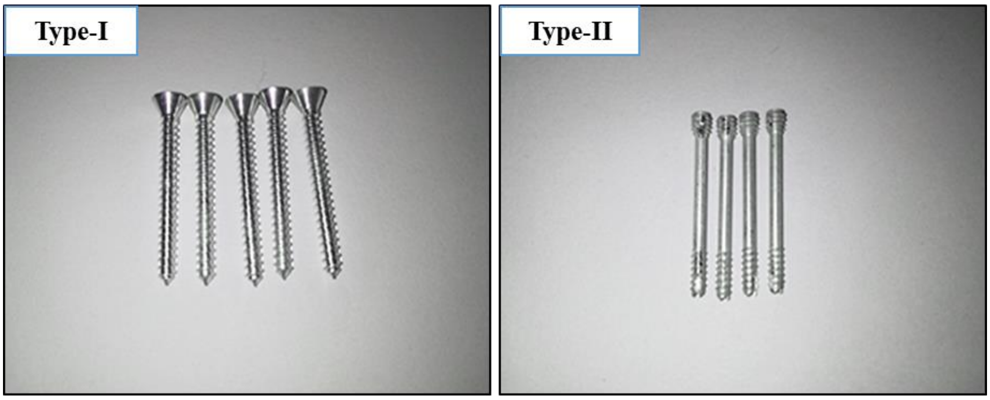


Fig.1. Unprocessed pure magnesium bone screws

After waiting for 1 day, 1-4-12 and 26 weeks in PBS, the appearance of different types of magnesium bone screws is given in Figure 2 [11].

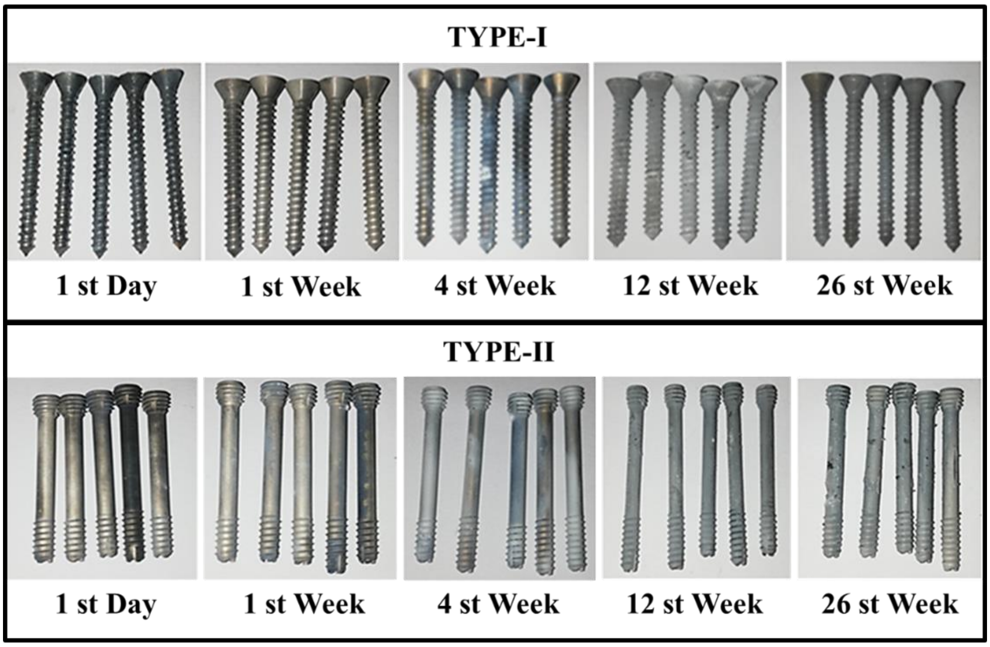


Fig. 2 Different types of magnesium bone screws kept in PBS for different periods

2.2 Mechanical Tests

Torsion and bending of three points of magnesium bone screws were performed. Said tests were made according to ASTM F2502-11 standards. The tests were carried out in dry environment and at room temperature. Torsion test 5 rad / min. and three-point bending test 5 mm / min. was made at the speed. The tests were carried out for two types of bone screws that were kept in PBS for different periods of time. Torsion and three point bending test devices are given in Figure 3.

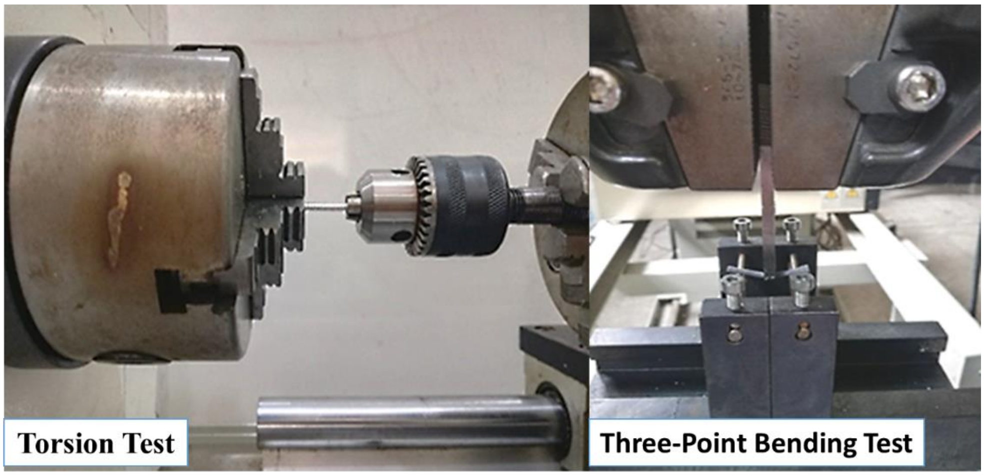
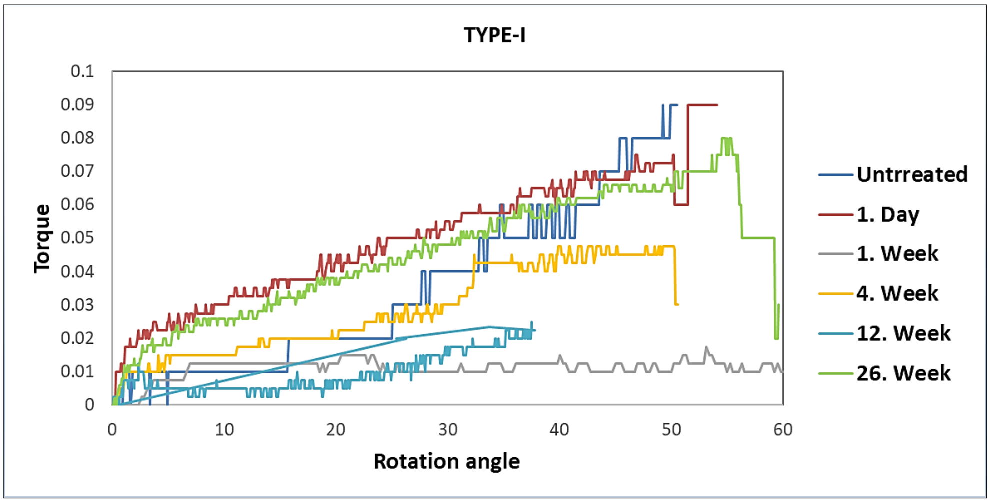


Fig. 3 Torsion and three-point bending test settings

Torque and torsion angle graphs obtained for Type-I and Type-II as a result of the torsion test are given in Figure 4 According to the graphics obtained, torsion test results are given in Table 1. According to the untreated sample, torsional strenght decreased as the retention time of Type-I and Type-II bone screws kept in PBS increased. It is seen that the load carrying capacities of the untreated sample decreased in both groups. In the torsion tests performed for the 26th week, it was observed that the torque applied by the untreated sample decreased by half. The corrosion resistance of magnesium is very low and as the waiting time increases in PBS, the magnesium will be corroded and its mechanical strength will decrease.



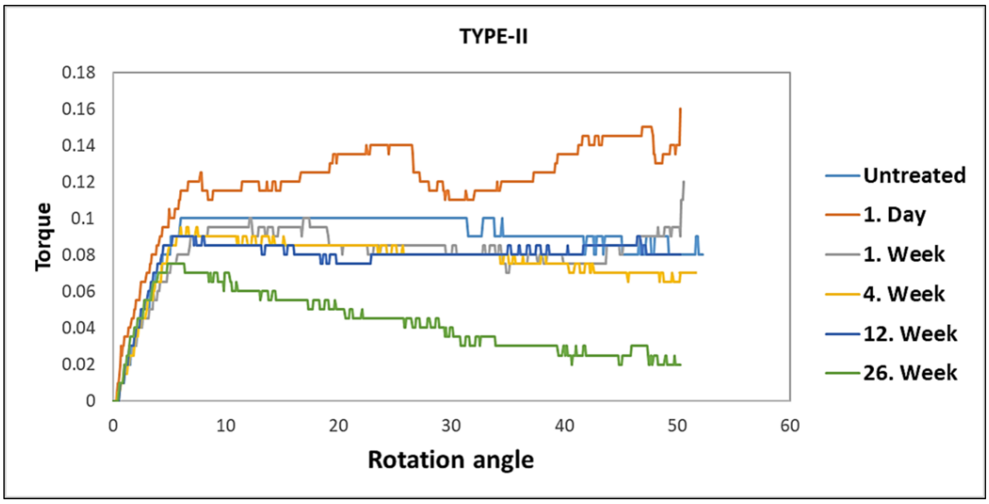


Fig. 4 Torsion graphs for Type-I and Type-II

Table 1. Torsion test results

SCREWS	Torque at yield load (Nm)	Max Torque (Nm)	Number of tested samples
Type-I Untreated	0.050	0.095	5
Type-I 1. Day	0.049	0.090	5
Type-I 1. Week	0.046	0.082	5
Type-I 4. Week	0.044	0.070	5
Type-I 12. Week	0.040	0.060	5
Type-I 26. Week	0.035	0.050	5
Type-II Untreated	0.080	0.110	3
Type-II 1. Day	0.080	0.090	3
Type-II 1. Week	0.075	0.085	3
Type-II 4. Week	0.070	0.080	3
Type-II 12. Week	0.060	0.075	3
Type-II 26. Week	0.060	0.075	3

Force and displacement graphs for bending test from three points are given in Figure 5. In addition, test results are given in Table 2. According to the graphics obtained, it is seen that there is a decrease in both applied force and displacements as the waiting time in PBS increases according to the untreated sample. This is the reason of the decrease in the mechanical properties of magnesium due to corrosion by degradation in PBS with different ion concentration.

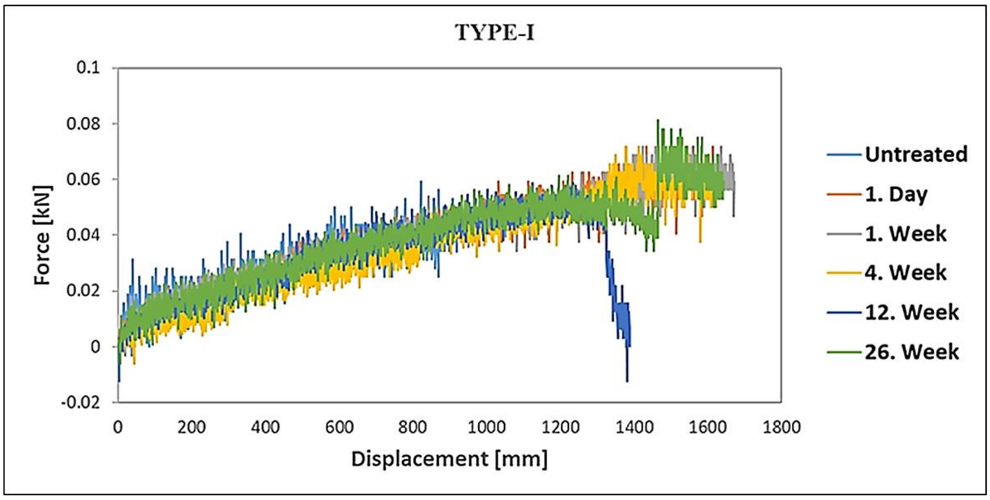


Fig. 5 Three-point bending graphs for Type-I and Type-II

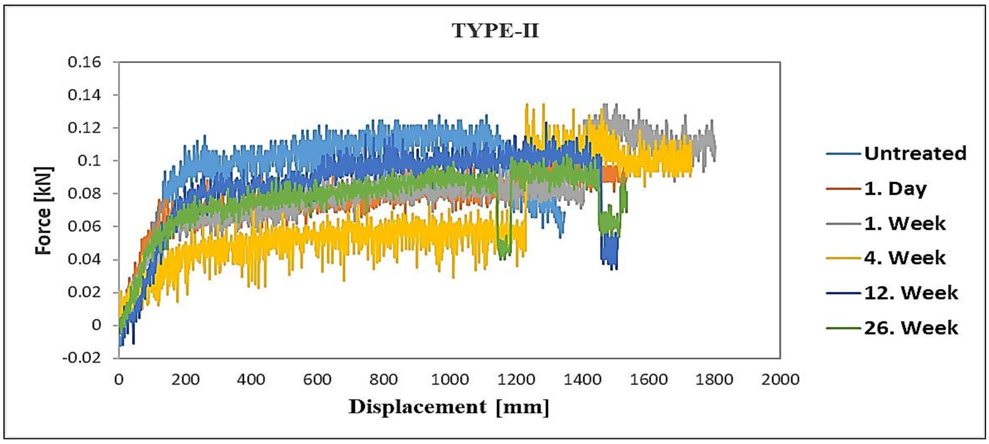


Fig. 5 Three-point bending graphs for Type-I and Type-II

When looking at Type-II with Type-I, Type-II shows more strength shows with the start of the test compared to Type-I. In both groups, it is observed that the 26th week has the lowest strength and the magnesium screw in the Type-II group is based on more force.

Table 2. Three point bending test results

SCREWS	**Yield load (kN)**	**Ultimte load (kN)**	**Number of tested samples**
Type-I Untreated	0.070	0.080	5
Type-I 1. Day	0.060	0.075	5
Type-I 1. Week	0.050	0.065	5
Type-I 4. Week	0.050	0.060	5
Type-I 12. Week	0.040	0.055	5
Type-I 26. Week	0.035	0.050	5
Type-II Untreated	0.080	0.100	3
Type-II 1. Day	0.065	0.090	3
Type-II 1. Week	0.065	0.095	3
Type-II 4. Week	0.060	0.085	3
Type-II 12. Week	0.065	0.080	3
Type-II 26. Week	0.070	0.085	3

3. Conclusion

When the displacement curves for load carrying capacity were examined for both screw groups, it was seen that the load-carrying capacity of the screws taken from the solution at the end of the 26th week decreased approximately by half compared to the 1st day.

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