Investigation of Mechanical Properties of Silicate Doped Synthetic Flexible Biomaterial
Silikat Katkılı Sentetik Fleksible Biyomalzemenin Mekanik Özelliklerinin İncelenmesi

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Abstract—**Biomaterials play an active role in tissue regeneration and are widely used in the treatment of tissue transplantation applications for the repair of damaged hard tissue, bone cancer, bone loss due to skeletal trauma and infection, bone fractures and congenital deformities of the facial and skull bones. Since autografts and allografts have many disadvantages, there is a need for synthetic bone grafts and biomaterials. Many bioceramic materials such as β-tricalcium phosphate (β-TCP) and calcium sulfate are widely used in bone formation. Since β-TCP-based bone grafts are used in the form of granules, silicate reinforced flexible strips are used in orthopedic surgery, oral and maxillofacial surgery. The aim of this study is to examine the mechanical properties of silicate-doped flexible biomaterials, taking into account their biocompatibility and their positive effects on tissue regeneration. In order to achieve the stated purpose, the methods planned to be followed, tensile tests will be applied for the mechanical properties of the scanning electron microscope (SEM) image for its morphology. In this study, it was found that silicate-doped flexible biomaterials have a homogeneous and porous structure. In addition, the obtained mechanical test results and the functionality of the silicate-doped flexible biomaterial during bone regeneration according to the ISO (International Organization for Standardization) 5833 and ASTM (American Society for Testing and Materials) D638 standard have been demonstrated.**

Keywords—biomaterial; β-TCP; osteoconductive; tensile test; silica.

Özetçe—**Biyomalzemeler doku rejenerasyonunu sağlamada aktif rol almaktadır ve hasarlı sert dokunun onarımına yönelik doku nakli uygulamaları, kemik kanseri, iskelet travması ve enfeksiyonuna bağlı kemik kayıpları, kemik kırıkları ve yüz ve kafatası kemiklerinin doğuştan gelen deformitelerinin tedavisinde yaygın olarak kullanılmaktadır. Otogreft ve allogreftlerin birçok dezavantaja sahip olması sebebiyle sentetik kemik greft ve biyomalzemelere ihtiyaç doğmuştur. β-trikalsiyum fosfat (β-TCP) ve kalsiyum sülfat gibi birçok biyoseramik materyal kemik oluşumunda yaygın olarak kullanılmaktadır. β-TCP bazlı kemik greftlerinin granül formunda kullanılması sebebiyle ortopedik cerrahi, oral ve maksillofasiyal cerrahide silikat katkılı esnek şeritler kullanılmaktadır. Bu çalışmanın amacı, silikat katkılı fleksible biyomalzemelerin biyouyumluluğunu ve doku rejenerasyonu üzerindeki olumlu etkilerini dikkate alarak, mekanik özelliklerinin incelenmesi amaçlanmaktadır. Belirtilen amacı gerçekleştirmek için izlenmesi planlanan yöntemler, morfolojisi için taramalı elektron mikroskop (SEM) görüntüsü mekanik özellikleri için çekme testleri uygulanacaktır. Bu çalışmada silikat katkılı esnek biyomalzemelerin homojen ve porlu yapıya sahip olduğu bulunmuştur. Ayrıca elde edilen mekanik test sonuçları ve ISO (Uluslararası Standartlar Organizasyonu) 5833 ve ASTM (Uluslararası Amerikan Test ve Materyalleri Topluluğu) D638 standartına göre silikat katkılı fleksible biyomalzemenin kemik rejenerasyonu boyunca işlevselliğini ortaya koymuştur.**

Anahtar Kelimeler—biyomalzeme; β-TCP; osteokondüktif; çekme testi; silika.

I. Introduction

Nowadays, tissue transplantation applications for the repair of damaged hard tissue are widely used in the treatment of bone cancer, bone loss due to skeletal trauma and infection, bone fractures and congenital deformities of the facial and skull bones. Although autografts have appropriate standards, the interest in synthetic bone grafts produced by tissue engineering techniques is increasing day by day due to limiting factors such as damage to the tissue taken area and limited graft availability [1], and the risk of immune system response in allografts [2]. Many bioceramic materials, including β-tricalcium phosphate (β-TCP) and calcium sulfate, are commonly used as bone replacers in both block and granule form.On the other hand, β-TCP, another biocompatible ceramic, has become the most preferred graft material in recent years due to its high osteo-compatibility and mechanical strength [3].

Although granule form is the most widely used form of β-TCP- based bone grafts in dental, maxillofacial and orthopedic surgery, filling epiphysis defects in sinus elevation and alveolar crest augmentation and orthopedic surgery, anterior intersomatic fusion and filling of epiphyseal bone spaces during compression of the tibia plate, especially in oral and maxillofacial surgery. Silicate-added flexible strips of different sizes can be used in operations [4, 5].

In our current literature analysis evaluations made at the beginning of 2019, there has been an increase in interest in β-TCP-based synthetic grafts in recent years due to the high bioactivity of silicate (SiO2) addition. Recent studies have shown that silicate has a critical effect on bone formation relative to its rapid apatite formation ability [5, 6]. These studies demonstrated that silicate-reinforced grafts can promote the formation of HAp in vitro, and also that the small silicate content is better for promoting bone regeneration in vivo compared to β-TCP. Silicate-reinforced grafts also showed greater bone fusion in clinical spinal fusion surgery compared to smooth β-TCP [7].

The aim of this study is to examine the mechanical properties of the prepared silicate added flexible biomaterials according to ISO 5833 and ISO 13175-3 test standards.

II. Materials & Methods

A. Preparation of β-TCP

In order to achieve the Ca/P : 1.5 ratio, appropriate amount of calcium nitrate and ammonium phosphate are placed in deionized water and mixed with a mechanical mixer. After the chemicals are put into the water, an appropriate amount of ammonium hydroxide (ammonia) is added to the mixture and mixed. After mixing, filtration is done. After filtration, the filtrant is dried in an oven for two days. a final process, calcination is done and β-TCP is formed.

B. Preparation of Silicate Doped Synthetic Flexible Biomaterial

Due to procedure, PCL (Poly L-lactide/Caprolactone Copolymer) is dissolved in chloroform at stirrer and the temperature 20 °C. It's called PCL solution. Afterthat, β-TCP, porogen and SiO2 within determined amount are mix in PCL solution. To create pore structure, removed sucrose in distilled water for 3 days.

C. SEM Image for Silicate Doped Synthetic Flexible Biomaterial

The morphology of synthetic silicate doped flexible biomaterial was observed using a scanning electron microscope (SEM) (Carl Zeiss 300VP, Germany) operated at 5 kV. A thin layer of gold was coated on the surface of the synthetic silicate doped flexible biomaterial by using an automatic sputter coater (Emitech K550X) to reduce the extent of sample arcing during SEM observation.

D. Silicate Doped Synthetic Flexible Biomaterial Tensile Test

Tensile test was performed by using a universal testing machine having a 500 N load cell (Shimadzu AGS-X Model, Japan) [8]. The tensile test of the silicate doped synthetic flexible biomaterial was carried out according to the ASTM D638 standard, and the crosshead speed was selected to be 50 mm/min. The test was repeated at least three times to check for repeatability.

III. Result

As can be seen from the Fig. 1, it has been observed that the obtained products have a porous pore structure. SEM observations showed that the homogeneity and fiber size of silicate doped synthetic flexible biomaterial were also similar.

According to Table I, the mechanical test results of silicate doped synthetic flexible biomaterials are consistent with each other and are approximately 3.64 MPa. ISO 5833 standarts indicate that bone graft substitutes over 2 MPa mechanical strength are functional throughout bone remodelling and regeneration process [9, 10].

Tensile Test	Test Results	
	Test Standard	Tensile Strength (MPa)
Sample 1	ASTM D638 - ISO 5833 – ISO 13175-3	3.5 ± 0.31
Sample 2	ASTM D638 - ISO 5833 – ISO 13175-3	3.72 ± 0.3
Sample 3	ASTM D638 - ISO 5833 – ISO 13175-3	3.70 ± 0.1

Table I: Tensile test results.

IV. Conclusion

According to the results obtained, consistent results were obtained according to ASTM D638 and ISO 5833. In addition, as can be seen from the SEM images, a porous structure was obtained and it will be helpful in our next study. In the future of the study we aim to prepare peptite and silicate integrated flex biomaterial and investigate the antibacterial activity of designed biomaterials against E. coli and S. aureus bacteria and evaluate the biofilm forming potency of prepared biomaterial in in order to understand the impact of the treatment for antibiofilm applications decrease the potential of bacteria to form biofilm.

Author Contributions

Ihsan Coskun is the lead author of the study, and he did the statistical studies and the setup of the experimental setup. Ozan Karaman carried out the daily recording of the data.

Acknowledgements

We would like to thank Bonegraft Biomaterials Company for providing products and financial support.

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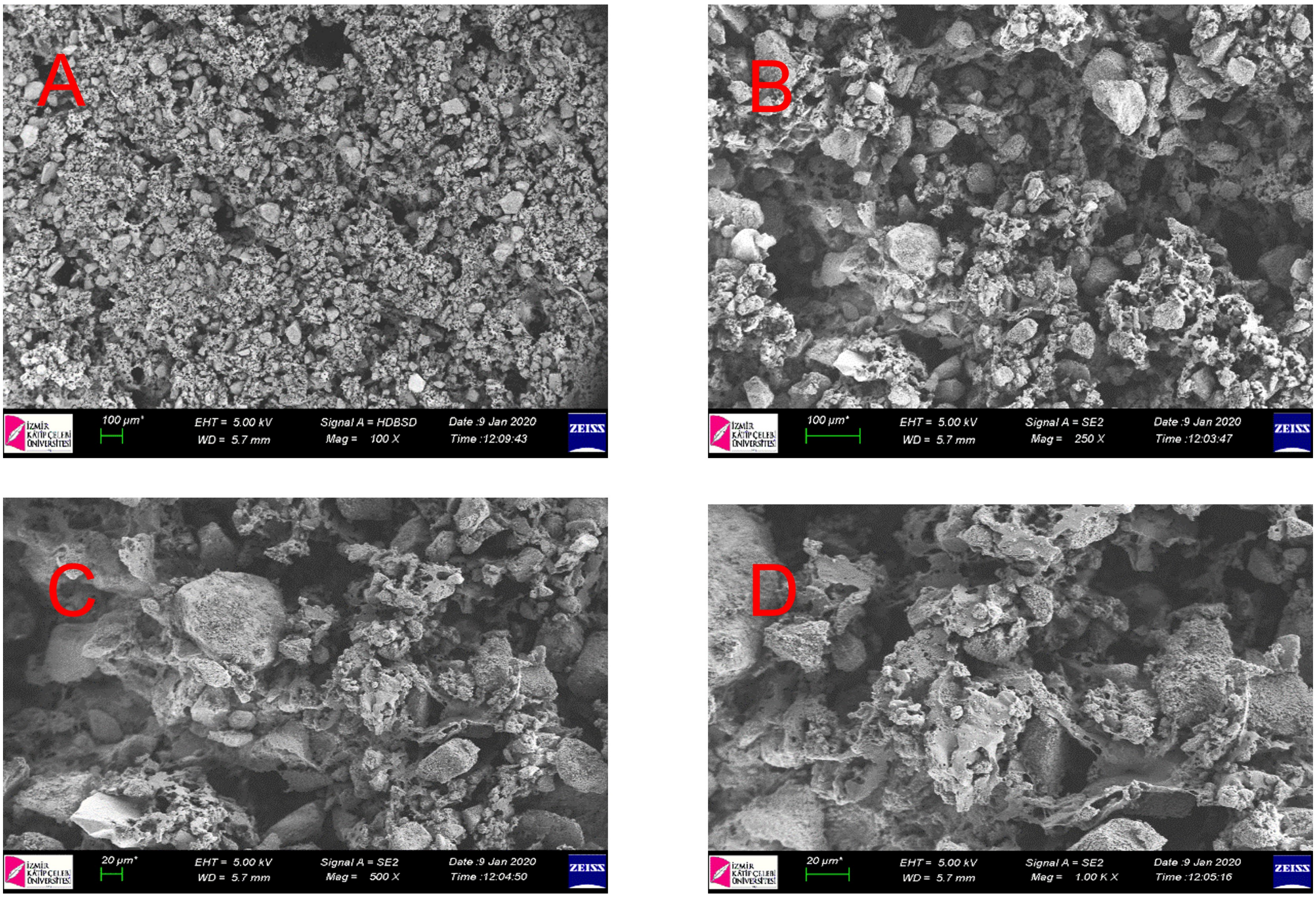

Figure 1: SEM Image for flexible biomaterial (A: Magnification 100X, B: Magnification 250X, C: Magnification 500X, D: Magnification 1.0KX)

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