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POLİESTER MONOFİLAMENTTEN ÜRETİLMİŞ BİYOMEDİKAL TEKSTİL İÇİN YÜZEY İŞLEMİ

SURFACE TREATMENT OF BIOMEDICAL TEXTILE MADE OF POLYESTER MONOFILAMENT

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ABSTRACT: Foreign Body Reaction is a critical issue to be addressed when polyethylene terephthalate textile implants are considered in the medical field to treat pathologies involving hernia repair, or heart valve replacement. The natural porosity of textile materials tends to induce exaggerated tissue ingrowth which may prevent the implants from remaining flexible. One hypothesized way to limit the Foreign Body Reaction process is to increase the material surface roughness. Supercritical jet particle projection is a technique that provides enough velocity to particles in order to generate plastic deformation on the impacted surface. The aim of this study is to investigate the influence of micro particles laden supercritical nitrogen jet projection parameters like jet static pressure, standoff distance and particle size on the roughness of polyethylene terephthalate fabric surfaces. Results bring out that particles projected by supercritical nitrogen jet generate craters on the surface of monofilament as well as monofilament fabric, allowing topographical modifications at the yarn scale. Thus, this treatment increased the roughness of the monofilament fabric from 0.78 µm to 1.22 µm. Regarding the strength of the textile material, it is only slightly modified with the treatment process, as the tenacity of the yarns decreases by only 10%. In this work, it is revealed that the obtained structures tend to limit the adhesion and slow down the proliferation of human fibroblasts. The results obtained in this work show that it is possible to create a roughness on a polyethylene terephthalate fabric using the nitrogen jet technology.

Key words: Biomedical textile, polyester monofilament, surface treatment, supercritical nitrogen jet

POLİESTER MONOFİLAMENTTEN ÜRETİLMİŞ BİYOMEDİKAL TEKSTİL İÇİN YÜZEY İŞLEMİ

ÖZ: Yabancı Cisim Reaksiyonu, polietilen terefitalat tekstil implantlarının tıp alanında fıtık onarımı veya kalp kapağı değişimi içeren patolojilerin tedavisi için düşünüldüğünde ele alınması gereken kritik bir konudur. Tekstil malzemelerinin doğal gözenekliliği, implantların esnek kalmasını engelleyebilecek abartılı doku iç büyümesini tetikleme eğilimindedir. Yabancı Cisim Reaksiyonu sürecini sınırlandırmanın varsayılan bir yolu, malzeme yüzey pürüzlülüğünü artırmaktır. Süperkritik jet parçacık projeksiyonu, etkilenen yüzey üzerinde plastik deformasyon oluşturmak için parçacıklara yeterli hız sağlayan bir tekniktir. Bu çalışmanın amacı, jet statik basıncı, uzaklık mesafesi ve parçacık boyutu gibi mikro parçacık yüklü süperkritik nitrojen jet projeksiyon parametrelerinin polietilen terefitalat kumaş yüzeylerinin pürüzlülüğü üzerindeki etkisini araştırmaktır. Sonuçlar, süperkritik nitrojen jeti tarafından yansıtılan parçacıkların, monofilamentin yanı sıra monofilament kumaşın yüzeyinde kraterler oluşturduğunu ve iplik ölçeğinde topografik modifikasyonlara izin verdiğini ortaya koymaktadır. Böylece, bu işlem monofilament kumaşın pürüzlülüğünü 0,78 µm'den 1,22 µm'ye yükseltmiştir. Tekstil malzemesinin mukavemeti dikkate alındığında, ipliklerin mukavemeti sadece %10 azaldığından, yüzey işlemi ile sadece biraz değiştirilebildiği görülmüştür. Bu çalışmada, elde edilen yapıların insan fibroblastlarının adezyonunu sınırlama ve çoğalmasını yavaşlatma eğiliminde olduğu ortaya konulmuştur. Bu çalışmada elde edilen sonuçlar, nitrojen jet teknolojisi kullanılarak bir polietilen tereftalat kumaş üzerinde pürüz oluşturmanın mümkün olduğunu göstermektedir.

Anahtar Kelimeler: Biyomedikal tekstil, poliester monofilament, yüzey işlemi, süper kritik nitrojen jet.

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1. INTRODUCTION

The essential requirement of a material to be used as biomaterials is its ability to receive an appropriate host response. This response depends on how similar the implant behaves as compared to the real organ. Such requirement is commonly termed as biocompatibility. Biomaterials with a low level of biocompatibility readily induce different infections within the patients. Control of the degree of biocompatibility is still a challenge to overcome within the health care industry as these polymers very often do not possess the surface properties needed for various applications [1].

Consequently, their surface needs to be refined to the microstructure level to obtain better performance in biomedical applications in terms of biocompatibility [2-3]. Various chemical and physical methods for modification of the polymer surfaces have been developed and are currently being studied, including chemical and plasma treatment, ion implantation, and UV-irradiation. Yet no surface modification technique is unanimously accepted since these methods are often associated with undesirable side effects. One of them is the degradation of the internal bulk of the material. Biomaterials have very precise requirements that derive from the mechanical performance of the bulk properties. These provisions can be categorized informally into three main groups including mechanical performance, mechanical durability, and physical properties. In total hip replacement surgeries for example, the biomaterial used for constructing a prosthetic implant must be mechanically strong and rigid.

In case of valve replacement, the leaflet of valve must be flexible and tough; otherwise, it will cause hindrance in blood flow. Textile synthetic vascular graft material requires very specific modulus properties in order to behave like real vascular soft tissue when implanted within the body such that the walls of the artery or vein pulsate in a similar manner to real tissue [4]. In that latter application fibrous constructions would provide a good combination of strength and flexibility. However, textiles are characterized by specific roughness features due to the yarn crossing in their construction. It has been shown in the literature that fibroblast tissue in-growth depends on the characteristics of the textile pores of a surface and on the topography of the yarns involved in the textile construction. Vaesken et al. [5] studied the interaction between various textiles in vivo in heart valve position and concluded that pore size and yarn diameter are the most critical parameters, which control the tissue ingrowth.

In this work, the potential of a novel mechanical surface treatment is investigated, which could be particularly suited for textile biomaterials. It consists in spraying on the surface to be treated a cold and dry flow of solid particles embedded within a high-speed nitrogen jet (N2), which itself does not interact with the material surface. The main goal is to provide experimental data about the behavior of polyethylene terephthalate (PET) textile material with respect to the N2 processing conditions. We investigate how the mechanical properties are modified through the process and if they remain compatible with expected performances. Moreover, the interaction pattern of a Supercritical N2 (ScN2) jet treated woven surface with fibroblasts is also studied in vitro.

2. MATERIAL AND METHODS

The textile samples used in this study are PET monofilament fabric. This fabric (surface density 70 g/m^2 and thickness150 µm) is woven (plain weave) from threads made from continuous PET monofilaments (10.8 tex) and is supplied by Sefar Fyltis (Lyon, FRANCE).

The surface treatment technology used in this work consists of spraying onto the surface to be treated solid particles embedded within a dense High-Speed Supercritical Nitrogen Jet HSNJ [6]. The surface modification tests were carried out on Monofilament fabric textile. Samples were treated with a Supercritical nitrogen jet charged with glass particles (with a size range from 45-53 µm). Two parameters were varied in the study: (1) the pressure (300 and 500 bars), (2) the stand-off distance (700, 600, 500, 400, 300 mm…until the breaking). Samples were treated with a supercritical nitrogen jet and characterized for material modification assessment. Different types of analysis were carried out on the samples: SEM analysis, mechanical tests, roughness measurement and biological analysis.

3. RESULTS AND DISCUSSION

From the fabric surface SEM images analysis, significant visual difference could be observed between the initial state and after surface modification using a Supercritical nitrogen jet charged with glass particles. These images clearly showed a difference in their local surface morphology of filaments. It can be clearly observed that the surfaces of the untreated filament are relatively smooth with a cylindrical shape. However, the surfaces of the monofilament treated appeared rough with impact craters or with a presence of fibrils on the surface of filament. For several configurations at a pressure 500 bars (SoD < 400 mm), the filament surfaces are shredded with certainly a loss for material.

We found that larger particles induce larger crater diameters. Moreover, increasing the static jet pressure from 300 to 500 bars further allows increase in the crater diameter. For a pressure of 500 bars, the standoff distance must be greater than 300 mm in order to obtain significant roughness values without breaking the PET monofilament fabrics.

The surface analysis by optical profilometer confirmed for both materials the modifications related to the fabric surfaces topography already observed at SEM level. The results show that the mean surface roughness increases with the pressure and the standoff distance regardless of the fabric. It is observed that the treatment increased the roughness of the monofilament fabric from 0.78 µm to 1.22 µm.

The tensile strength properties were studied for treated and untreated fabrics. The results show a slight reduction in ultimate strength and ultimate strain of the fabric after treatment. Maximal reductions of 15% of strain at P=300 bar and 14% of strain at P=500 bars, were obtained respectively in samples with SoD= 300mm and SoD= 400mm. This quantitative result confirms the observations made at a macroscopic level, which showed accentuated fibrils for the configuration P=500 bars and SoD 400.

Finally, the biological assessment confirms that the roughness induced on the fabric yarn surface tends to effectively slow down the growth of human fibroblasts, which is in accordance with what was expected.

In the frame of this study an average 4 µm crater depth was obtained on the 100 µm diameter fiber woven textile construction. This value allowed to limit the cell adhesion as can be observed from Figure 4.

As part of this work, an average 4 µm crater depth was obtained on the 100 µm diameter fiber woven textile construction. This value allowed to limit the cell adhesion. Actually, the roughness value obtained here is in the range of what is expected on a polymer surface in order to limit the proliferation of fibroblasts according to literature [7].

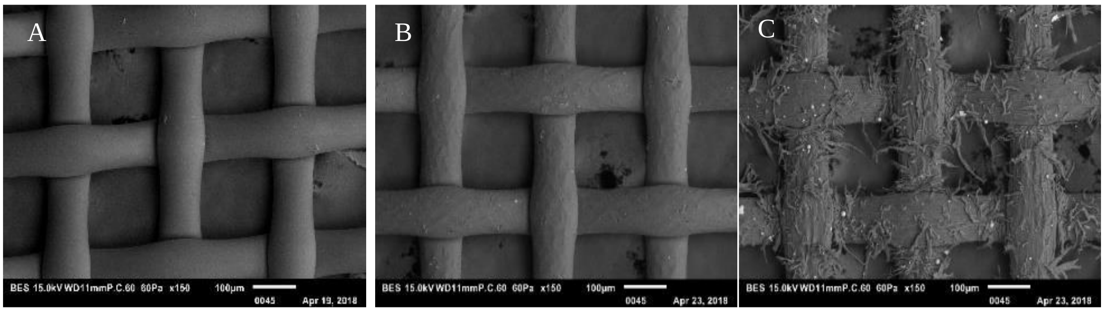

Figure 1. SEM Photographs of Monofilament PET fabric samples, 100µm at P: 500 Bar; A: Untreated, B: SoD 500mm, C: SoD 400mm

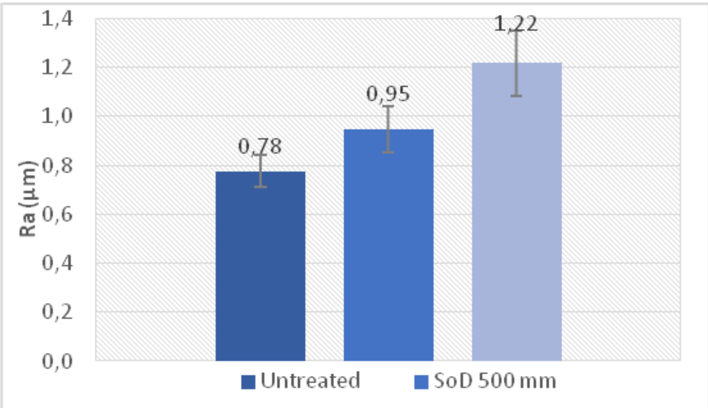

Figure 2. Surface roughness topography of fabric samples untreated and treated at P: 500 bars

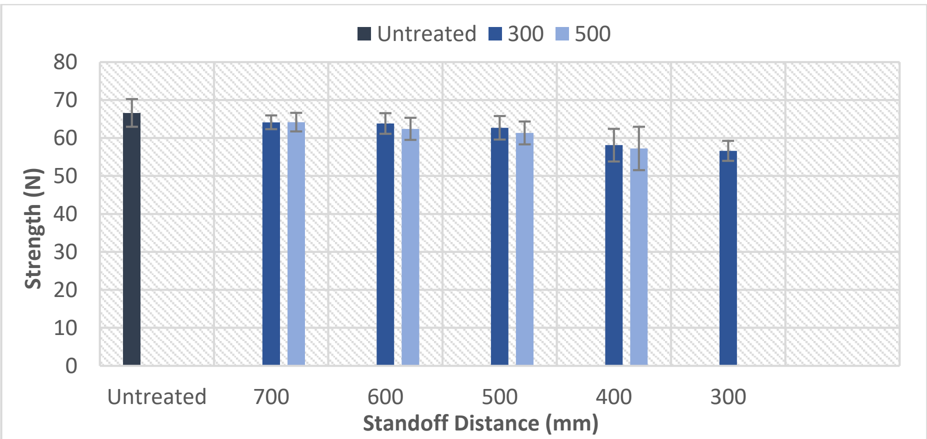

Figure 3. Strength evolution of textile fabric.

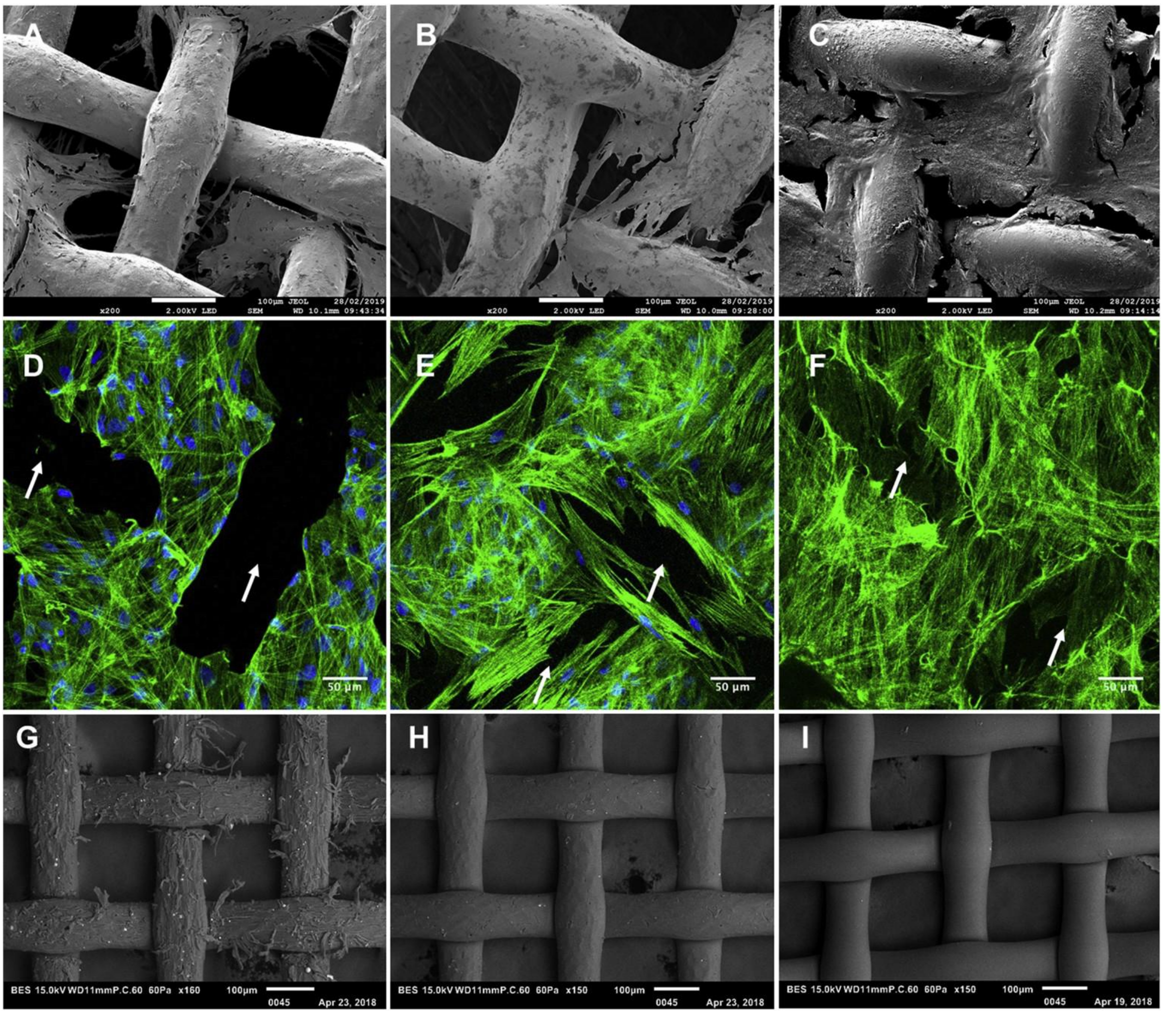

Figure 4. Fibroblast morphology P500 SoD 400 (A, D), P500 SoD 500 (B, E) and untreated (C, F) fabrics. A–C: SEM views after 15 days of culture (scale bar 100 µm). D–F: Laser scanning confocal microscopy views of cytoskeleton labeled fibroblasts after 15 days of culture (scale bar 50 µm). G–I: Before seeding.

4. CONCLUSION

In this study, the potential of a novel treatment surface is investigated. The research focused on the influence of microparticles laden supercritical N2 jet projection parameters on the roughness of PET fabric surfaces. Results bring out that particles projected by the jet N2 SC generate craters on the surface of monofilament fabric, allowing topographical modifications at the yarn scale. The obtained roughness helps slow down fibroblasts proliferation.

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