COMFORT AND ANTIFUNGAL PROPERTIES OF ORTHOTIC MATERIALS USED IN FOOTWEAR

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An orthotic material could be defined as an externally applied device, which modifies the function by supporting or controlling a body part. Shoe orthoses are devices placed inside a shoe to accommodate anatomical abnormalities, to relieve pressure at a specific site or to alter the transmission of forces during gait. They work by applying force in a controlled manner and maybe accommodative or corrective devices. Besides, previous reviews have revealed that foot orthotics can prevent some lower limb overuse injuries, particularly femoral stress fractures and shin splints. These reviews highlight that further research in this area is still required, particularly in the form of wear comfort and antimicrobial properties of orthoses. Up to now, according to our knowledge there has been no reported research on these characteristic properties of orthoses materials in footwear. For this purpose, antifungal activity with *Aspergillus niger*, air permeability and water vapour permeability properties of five different orthotic materials were investigated in the present study. The results demonstrated that foot orthotic samples fulfilled the wear hygiene properties and could be used as safe antifungal materials for foot orthoses.

Keywords: orthoses, footwear, wear hygiene, antifungal

INTRODUCTION

Shoe inserts and/or orthoses are generally used to improve comfort, daily performance and/or to prevent the feet from the injuries (Nigg *et al.*, 1997). Shoe orthoses are also described as the devices placed inside the wear material to accommodate anatomical abnormalities, to relieve pressure or to alter the transmission of forces (Kurup *et al.*, 2011). Besides, foot inserts and orthoses have a great potential to prevent lower extremity ailments, including ankle or knee pain or, more specifically, plantar fasciitis, posterior tibial syndrome, Achilles tendonitis, patellar femoral pain syndrome, or osteoarthritis (Mündermann *et al*. 2001; Collins *et al*. 2007; Landorf and Keenan 2007; Murley *et al*. 2009).

In addition, requirement of comfort for shoe inserts and orthotics is crucial, however, limited information is available in the literatures about the effect of orthotic materials on footwear comfort (Mündermann *et al.*, 2001), particularly in the form of antimicrobial properties and comfort behaviors of orthoses. According to our knowledge, there has been no reported research on the antifungal and comfort properties in terms of air and water vapor permeability of orthotic materials in footwear.

In this study, antifungal activity with *Aspergillus niger* and comfort properties in terms of air permeability and water vapour permeability of orthotic materials such as dyatec, plastazote, thermoformable cork and 2 types of pedilin (2mm and 10mm) were investigated whether the materials could be used as an antifungal shoe device by providing a footwear comfort during gait.

MATERIAL AND METHOD

Material

In the present study, dyatec, plastazote, thermoformable cork, and 2 types of pedilin (2mm and 10mm) were investigated as orthotic materials. All chemicals used in the study were of analytical grade and purchased from Merck, Germany.

Methods

Antifungal Activity

The antifungal activity was performed in accordance with ASTM D 4576-86: 1996 Standard Test Method. The orthoses samples were cut into pieces having the surface of 1 inch^2 and the assays were done in duplicates with *Aspergillus niger* test organism. The test samples were placed in the center of Petri vessels and later the growth medium (*potato dextrose agar*-PDA), was filled up to the upper level of the samples. The Petri vessels were incubated for two weeks at the temperature of 26-30°C. Later, at 3, 7 and 14 days the Petri vessels were checked and evaluated visually according to the assessment as given below. In addition, the samples in Petri dishes were also photographed.

Table 1. Assessment of antifungal activity

0	mould absent on the surface of sample
0.5	less than 12% of sample surface is covered with micelle
1	25% of sample surface is covered with micelle
2	50% of sample surface is covered with micelle
3	75% of sample surface is covered with micelle
4	100% of sample surface is covered with micelle

Air Permeability

Orthotic samples were classified and conditioned for minimum 48 hours in an acclimatized room having a temperature of 20 ± 2°C and a relative humidity of 65% ± 5. The air permeability values of the samples were determined by means of a Devotrans branded air permeability measuring device. Measurements were performed by determining in m^3 the amount of air that flows for 5 minutes under 200 Pa and 500 Pa pressure with a ring of 100 cm^2; the results were expressed in cm^3/cm^2.s. The test was repeated at 3 different points of the samples and the mean values were calculated (Kanli *et al*., 2010).

Water Vapor Permeability

The water vapor permeability was performed in accordance with TS EN ISO 14268 (2004) standard.

RESULTS AND DISCUSSION

High air permeability and water vapor permeability properties are known as the most important requirements for foot comfort and hygiene of the materials for the medical devices and shoes.

Table 2. Air and water vapor permeability results of the orthotic materials

Materials	Air Permeability ($cm^3/cm^2.s$)	Water Vapor Permeability ($mg/cm^2.h$)
Cork	0.007	228.53
Plastazote	0.017	753.05
Pedilin (2 mm)	0.027	984.34
Pedilin (10 mm)	0.013	313.87
Dyatec	8.600	35135.98

The air and water vapor permeability test results of orthotic materials are shown in Table 2. Dyatec provided the highest water vapor and air permeability values such as 35135.98 $mg/cm^2.h$ and 8.600 $cm^3/cm^2.s$ respectively. Permeability values of the other orthoses were found quite lower than the Dyatec. However, comparable air permeability results were obtained from the cork, plastazote and pedilin materials. In contrast to air permeability results, water vapor permeability of the orthotic materials was determined quite satisfactory. Although low air permeability lead to a negative impact in terms of the air transfer in the footwear and resulted an uncomfortable feeling, pedilin (2mm) and plastazote could be differed due to their high water vapor permeability values. Milasiene (2003) indicated that the decrease in the water vapor permeability depends on the reduced porosity of the materials and the air permeability values of the materials could be directly affected from the same factors of water vapor permeability (Milasiene *et al*., 2003).

In addition to orthotic materials, the same samples were covered with goat lining leather and also analyzed for the determination of their antifungal activity. The antifungal activity test results and their photos were given in Table 3 and 4 respectively.

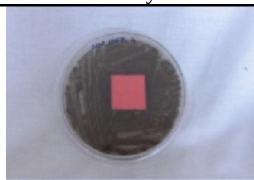
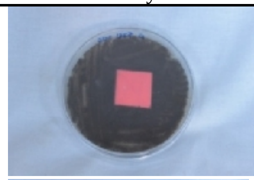
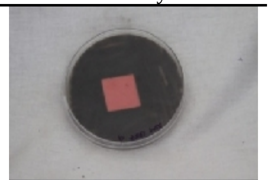
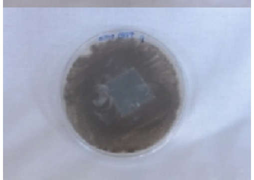
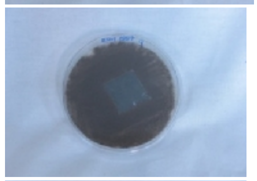
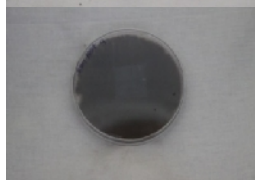
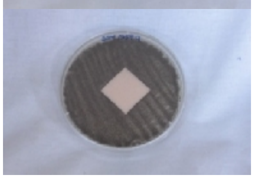
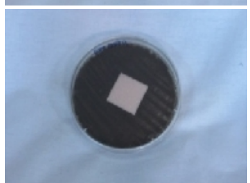
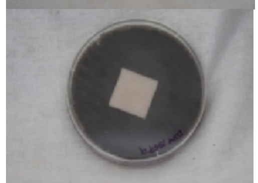
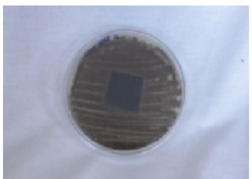
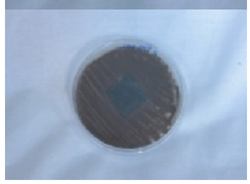
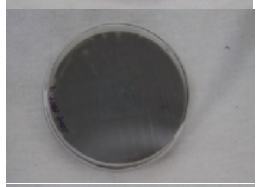
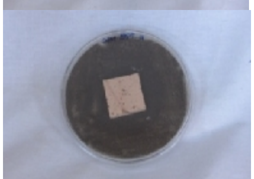
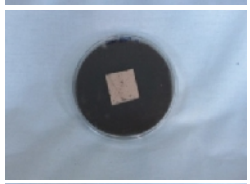
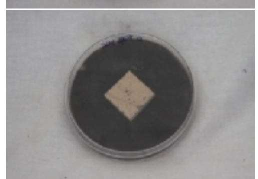
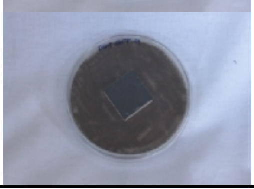
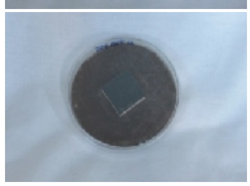
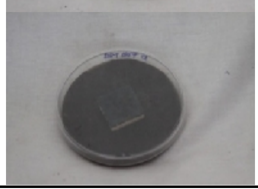
Table 3. Antifungal activity test results of the orthoses materials

Materials	3rd day	7th day	14th day
Dyatec	0	0	0
Dyatec with Leather	0	0.5	1
Plastazote	0	0	0
Plastazote with Leather	0-0.5	0.5-1	2
Cork	0	0	0
Cork with Leather	0	0.5	1
Pedilin (10 mm)	0	0	0
Pedilin with Leather (10 mm)	0	0.5	1
Pedilin (2 mm)	0	0	0-0.5
Pedilin with Leather (2 mm)	0	0.5	1
Leather	0-0.5	1	2-3

The 14th day results of antifungal activity with *Aspergillus niger* showed that there was no fungal growth on Dyatec, Plastazote, Cork, and Pedilin (10 mm) samples (Table

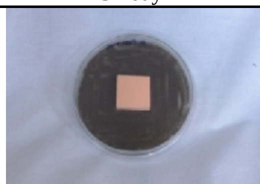
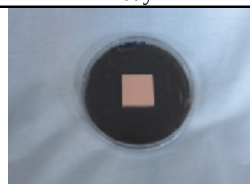
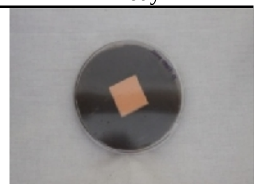
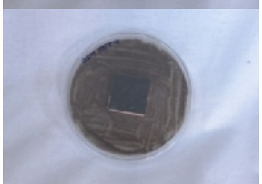
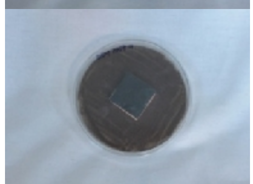
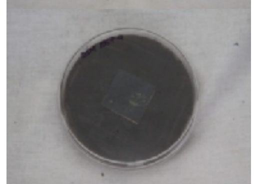
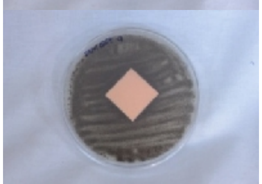
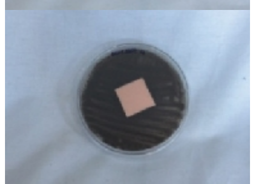
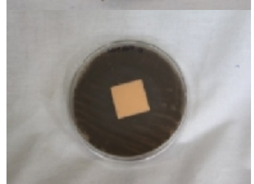
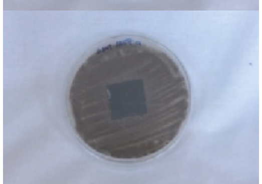
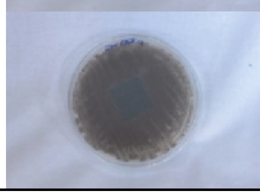
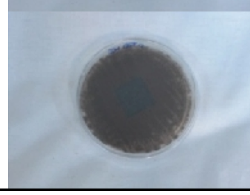
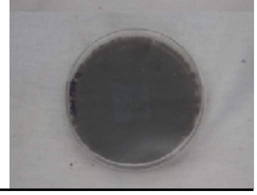
4), although the surface of Pedilin (2 mm) samples were covered with the organism micelles nearly in proportion of 12%.

Table 4. Final appearance of orthoses for the antifungal activity

	Aspergillus niger 3rd day	7th day	14th day
Dyatec			
Dyatec with leather			
Plastazote			
Plastazote with leather			
Cork			
Cork with Leather			

The results of orthotic samples covered with goat lining leather were found worse than the orthoses without lining leather. The lining leather was covered with *Aspergillus niger* nearly 65% of its area at the last assessment day. The reason of lower antifungal properties of the samples covered with leather was the lower antifungal property of the leather. The lowest antifungal effect was determined from Plastazote with leather samples.

Table 5. Final appearance of materials for the antifungal activity

	Aspergillus niger 3rd day	7th day	14th day
Pedilin (10 mm)			
Pedilin with leather (10 mm)			
Pedilin (2 mm)			
Pedilin with leather (2 mm)			
Leather			

CONCLUSION

In this study, antifungal activity with *Aspergillus niger*, air permeability and water vapor permeability properties of five different orthotic materials were investigated and following conclusions have been drawn; a) Orthoses could be characterized as antifungal materials; b) Only pedilin (2 mm) samples were covered with micelles of the organism in low proportions; c) Dyatec, Plastazote, Cork, and Pedilin (10 mm) demonstrated their safely usage as antifungal orthoses due to their effective antifungal properties against *Aspergillus niger*; d) Dyatec had the highest air and water vapor permeability results among the orthoses.

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