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Design and Preparation of Novel Anti-adhesion Polyvinyl Alcohol Foam Nasal Matrix for PM 2.5 Protecting and Hemostasis Treatments *via* a Combined Procedure of Precision Machining and Super Clean Air-foaming

Ching-Cheng Huang[1,2,3,*], Meng-Jen Yang[1], Huan Zhou[4] and Lei Yang[4]

[1]PARSD Biomedical Material Research Center, Jiangsu, China
[2]Department of Biomedical Engineering, Ming Chuan University, Taoyuan, China
[3]Institute of Medical Device, Jiangsu University of Technology, Jiangsu, China
[4]Center for Health Science and Engineering, Hebei University of Technology, Tianjin, China
[*]Corresponding author

***Abstract*—A patient with nasal hemorrhage would usually insert wadding composed of blood sucking material easily available at home, such as toilet paper, cotton, or gauze, into the nostril. The wadding tends to split under draw force, and is difficult for extraction from the nostril after blood sucking or generates adhesion with inner wall of the nasal cavity in hemostasis process, such that secondary injury occurs for nasal cavity during extraction. The most common problem occurs in that such wadding cannot press the bleeding site inside the nasal cavity of the patient in compliance with nasal cavity shape effectively, so that there is limited effect in mitigating intranasal bleeding symptom. Preclinical evaluation of new polyvinyl alcohol foam (PVAF) nasal matrix could be established by determining morphology, water permeability, macroporosity, and compression property.**

Keywords—PVA; foam; matrix

I. INTRODUCTION

In usual, a patient with nasal hemorrhage would usually insert wadding composed of blood sucking material easily available at home. The wadding tends to split under draw force, and is difficult for extraction from the nostril after blood sucking or generates adhesion with inner wall of the nasal cavity in hemostasis process, such that secondary injury occurs for nasal cavity during extraction. The most common problem occurs in that such wadding cannot press the bleeding site inside the nasal cavity of the patient in compliance with nasal cavity shape effectively, so that there is limited effect in mitigating intranasal bleeding symptom. In this report, we propose a series of novel techniques and medical devices for epistaxis treatments. The novel design of the medical device could be developed and applied for new microscopic surgical procedures instead of the traditional surgical procedures. For the design of new medical devices, selections of materials or suitable materials for biomedical applications such as polymethacrylate, polyester, polynorbornene, and polymeric resins could be substantially considered and employed [1–6]. Also, the surface modification technology could be considered to change the surface microenvironment of materials for specific need [7-8]. Furthermore, the biological and clinical evaluations of materials and medical devices by using polyvinyl alcohol(PVA) foam must be considered for the application and design[9-13]. Preclinical evaluation of new polyvinyl alcohol foam (PVAF) nasal matrix could be established by determining morphology, water permeability, macroporosity, and compression property. New anti-adhesion extra thin polyvinyl alcohol foam dressings derived from a super clean air-foaming process were designed for epistaxis treatments. Preclinical evaluation of new designed anti-adhesion polyvinyl alcohol foam nasal matrixs could be established by determining water morphology, water permeability, thickness, macroporosity, mechanical property of resulting samples.

II. EXPERIMENTAL

A. Materials

A novel anti-adhesion nasal medical device for epistaxis treatments was designed via a super clean air-foaming process. The medical grade Cenefom PVA materials were employed in this work(PARSD Pham. Tech. Co.). This hemostatic anti-adhesion nasal medical device has a pallet and an inflatable pillar, the pallet has a patented holder used for patient to hold to enter nasal cavity quickly, and the inflatable pillar has a head exposed with a pressing surface for pressing a bleeding site inside a nasal cavity of a patient to stop and absorb bleeding. Easy plug epistaxis maybe the best nosebleeds solution for first aid and home use as showed in Figure I. The anti-adhesion material was important for the clinic application of epistaxis treatment. Polyvinyl alcohol (PVA) foam dressing could be considered as a good anti-adhesion material for epistaxis treatment. An anti-adhesion foam nasal matrix with good mechanical property would be a potential medical device for

epistaxis treatment. anti-adhesion foam nasal matrix.

B. *Mechanical Property*

Mechanical property of the resulting foam nasal matrix was determined.

C. *Macroporosities*

The resulting anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix samples with different macroporosities were determined by using OM(Olympus BX53M).

D. *Water Permeability*

The water permeability of the resulting anti-adhesion extra thin polyvinyl alcohol foam dressings could be determined by following ASTM D4491(standard test methods for water permeability).

E. *Compression Property*

The electronic pull-pressure gauge was employed for characterization of the nasal matrix for epistaxis treatments with a compressed module, which could provide compression effect on the bleeding point of nasal cavity.

FIGURE I. PHOTO OF THE RESULTING FOAM NASAL MATRIX

III. RESULTS AND DISCUSSION

Super clean air-foaming process was employed in the preparation of novel nasal matrix to obtain a kind of fully open cell structure, which could provide extra short saturated swelling time for epistaxis treatments.

A. *Macroporosities*

The morphology of open cell structure could be observed by using optical microscope (OM). The anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix with macroporosity in the range of 424μm~482 μm was observed as showed in Figure II. Furthermore, average diameter of 475 μm could be obtained in the macroporosity of nasal matrix.

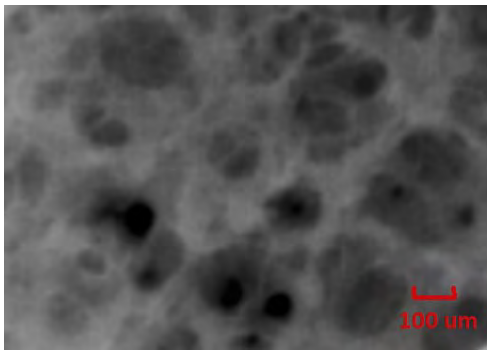

FIGURE II. PHOTO OF THE RESULTING NASAL MATRIX FOR EPISTAXIS TREATMENTS

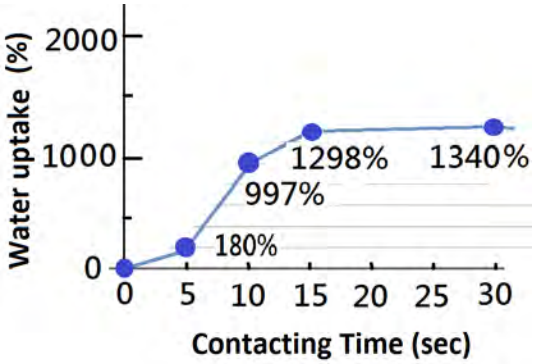

FIGURE III. WATER UPTAKE OF NOVEL NASAL MEDICAL DEVICE FOR EPISTAXIS TREATMENTS FROM INITIAL STAGE

B. *Water Uptake*

Super clean air-foaming process was employed in the preparation of novel nasal matrix to obtain a kind of fully open cell structure, which could provide extra short saturated swelling time for epistaxis treatments The nasal matrix contains a compressed module for epistaxis treatments. Before epistaxis treatment, the compressed module is dry which could be defined as an initial stage. After epistaxis treatment, the compressed module is wet because of the blood. The wetting PVAF nasal matrix could be defined as a saturated stage and expanded volume of the compressed module could be observed. The expanded volume in the saturated stage is eight times larger than volume of the compressed module in the initial stage. It spends a saturated swelling time of 5-15 sec from the initial stage to the saturated stage(Figure III). Remarkable increasing water uptake of the resulting nasal medical device was observed from initial stage of 0% .to saturated stage of ca.1300%(Figure IV).

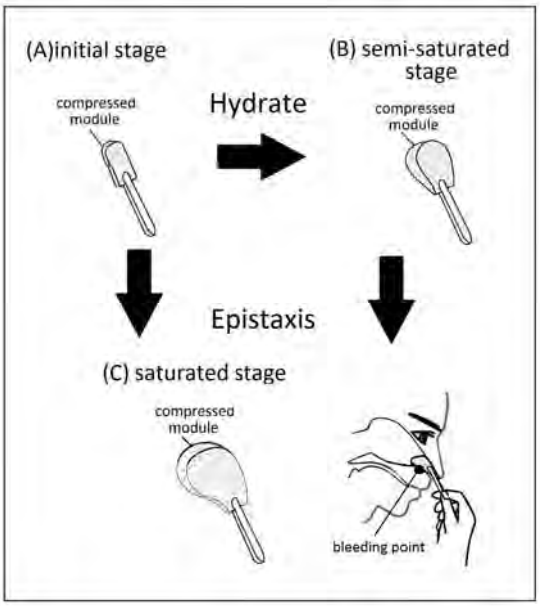

FIGURE IV. SCHEME 1 NOVEL NASAL MEDICAL DEVICE FOR EPISTAXIS TREATMENTS (A)INITIAL STAGE, (B) SEMI-SATURATED STAGE AND (C) SEMISATURATED STAGE

C. Compression Property

Compression property of the nasal matrix with a compressed module was determined by using the electronic pull-pressure gauge, which could provide compression effect on the bleeding point of nasal cavity as showed in Scheme 1. The absolute hardness of PVAF nasal matrix could be characterized by determining the reaction force of the compressed module when different indentations of 2, 4, and 6 mm were achieved. The corresponding results of $2.94*10^{-2}$, $5.26*10^{-2}$, and $8.21*10^{-2}$ N/cm^2 were observed. The compression will be increased with the indentations of the compressed module. The relative low compressions ($2.83*10^{-2}$, $5.09*10^{-2}$, and $8.15*10^{-2}$ N/cm^2) of the PVAF nasal matrix' compressed module with saturated water capacity were observed in the various indentations of 2mm, 4 mm, and 6mm.

D. Elongation Property

The resulting anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix showed good elongation property such as PVAF nasal matrix in saturated stage with 665% of elongation rate.(Table I).

TABLE I. MECHANICAL PROPERTY OF ANTI-ADHESION POLYVINYL ALCOHOL (PVA) FOAM NASAL MATRIX

	Elongation at Break (%)	Tensile Strength (kPa)
PVAF Nasal Matrix in initial stage	48.7	1044.4
PVAF Nasal Matrix in saturated stage	665.2	421.7

E. Mold-inhibiting Property

Mold-inhibiting property of the resulting PVAF nasal matrix was determined by using mould test. At the same time, the other related medical devices by using PVAF such as sample 1, sample 2, and sample 3 were determined for comparison. After 4 days, the resulting PVAF nasal matrix was still clear and the other medical devices were covered with mold as showed in Figure V.

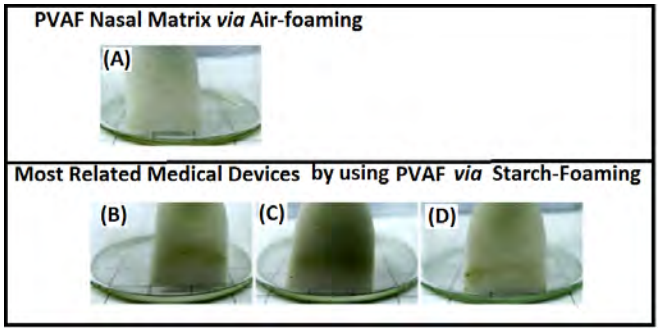

FIGURE V. MOULD TEST OF THE RESULTING PVAF NASAL MATRIX (A) AND THE OTHER RELATED MEDICAL DEVICES BY USING PVAF SUCH AS SAMPLE 1(B), SAMPLE 2(C), AND SAMPLE 3(D)

F. Clinic Application for Epistaxis Treatments

The resulting anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix with good anti-adhesion property could be employed to solve the adhesion problems for epistaxis treatments as showed in Figure III. The anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix could be a kind of contact dressings to provide good anti-adhesion property, water permeability, and mechanical property. It could be a powerful medical device for epistaxis treatments. Of course, the other clinic application also could be considered because of their excellent properties. For example, the semi-saturated stage of the resulting anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix could be a good PM2.5-protecting medical device because of a safe, low tissue damage, anti-adhesion, super clean, and mold-inhibiting properties.

IV. CONCLUSIONS

In this study, a kind of new anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix with macroporosity in the range of 424μm~482 μm was obtained. The resulting anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix showed good elongation property such as PVAF nasal matrix in saturated stage with 665% of elongation rate. The resulting anti-adhesion polyvinyl alcohol (PVA) foam nasal matrix could provide a powerful potential in the clinic application of epistaxis treatments and enhance the range of clinic application of epistaxis treatments.

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