Nano Silver Over Extracellular Matrix of Wound & Its Numerical Model

Oindri Ray

Asst.Professor,Department of Electronics & Communication Engineering, Meghnad saha Institute of Technology.

Kolkata,West Bengal,India

Sudhin Ray

IPGME&R S.S.K.M Hospital

Kolkata,West Bengal ,India

Abhishek Adhya

Researcher ,IPGME&R,S.S.K.M Hospital

Kolkata ,West Bengal ,India

Bijay Kr.Majumdar

Professor & Head ,Department of Plastic surgery ,S.S.K.M Hospital

Kolkata ,West Bengal ,India

Abstract— **Wound healing is a complicated process. Infections are major constraints of mortality and morbidity in burn patient. It is seen the healing rate is much faster if nano silver particle in between 1-100nm in diameter are used .The nano sized particle are very effective and reactive because of their high surface area[13].Nano silver particle in order of 20 nm is used as a wound healer to fight against microbes over wound. After application of nano silver the surface of wound is analyzed by numerical modeling using surface morphology according to its relevant chemical and biological parameters.**

Keywords— NanoSilver,Numerical wound model;Surface-morphology;Numerical Solution.

I.INTRODUCTION

Wound can be categorized by the differences of its chemical and biological parameters Wound is a deformation of cells which can be designed by extracellular matrix model. This Extracellular model demonstrates the traction forces in between the cluster wise cell to cell regeneration. The Finite element analysis model is used to design and categorized those types of wound .This approach gives a numerical prominent solution over cell regeneration after burn after application of nanosilver.

II.NANO SILVER & ITS STANDARDIZATION

A simple chemical reduction method is used for production of nano silver .Different concentration of aqueous solution of silver nitrate; glucose and organic base are mixed to set the reactor. In this preparation controlled reaction parameters like P^H, temperature, rate of reaction is closely monitored.

III.EXTRACELLULAR MATRIX BASED WOUND MODEL

To assess the condition of wound and rate of healing post application of nanosilver, a numerical model is introduced relation the all chemical parameters[1,2,7] .These parameters are used as observation factors[12,13]. Firstly the fibroblasts are generally which are prone to migrate into the wound region and crating a force in between extracellular matrix zone. Secondly Fibroblasts are carried out by myofibroblasts and results into the formation of cellular adhesion .Thirdly the collagen is monitored as it behaves as one of the structural component of extracellular matrix. Collagen component is modeled using finite element model. Finally a wound generation factor is taken under observation to study the improvement of burn wound area.
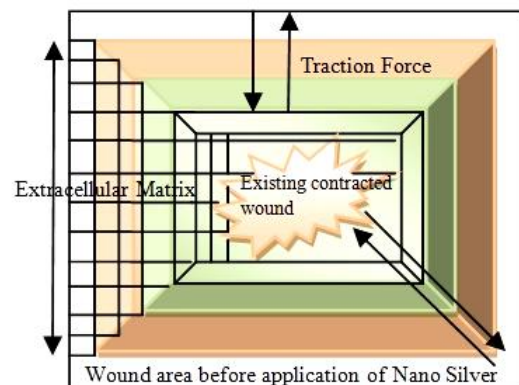

Fig.1.Proposed Extracellular matrix model of Wound

All these parameters are structured by numerical equation[3,5]. Using MATLAB all those morphological surfaces are modeled to establish the effectiveness of nano particle over burn wound.

Fibroblasts Model (F):

These cells are very mobile cells, and tending to attach with the wound surface area[8]. The flux produced by these fibroblasts cells can be modeled as

$$J_F = -D_F.\nabla_F + \frac{a_F}{Z_n.(b_F + C_F)^2}.F.(\nabla_c + \nabla_n) + F.\frac{\partial x}{\partial t} + Z_F$$

(1)

Where J_F is the volumetric flux produced by the fibroblasts tissues. D_F stands for the diffusion rate relating fibroblasts tissues. ∇_F stands for partial derivative vector operator for fibroblasts tissue.a_F is the initial chemo tactic sensitive function rate .b_F is the Chemo tactic sensitive response. c_F is the maximum rate of fibroblasts migration over the fibroblasts density and ∂X is the displacement vector. ∇_c is the chemical concentration of wound. ∇_n is the chemical concentration of nano silver.Z_F is the Time dependent negative divergence constant and F stands for fibroblasts density in undamaged tissue.Z_n is the convergence factor of nano silver.

$$Z_F = \nabla.\vec{A(r)} = \underset{\Delta V \to 0}{Lim} \oiint_S \frac{\vec{A(r)}.dS}{\Delta V} \qquad (2)$$

S stands for existing wound surface area having volume ΔV at a point r and dS points inward from the wound surface and A(r)is converging.

Myofibroblasts Model(M):

These cells are motile cells .The volumetric flux filed surface is generated by myofibroblasts can be designed by the Myofibroblasts model of the contracted wound. If Jm is the produced flux field by myofibroblasts tissue then

$$Jm = \pm Dm.\nabla m + M.\frac{\partial X}{\partial t} + Zm \qquad (3)$$

Dm is the diffusion rate of myofibroblasts tissue. ∇m Stands for partial derivative vector operator for myofibroblasts logistic growth rate. M stands for density of myofibroblasts for integrated damaged and undamaged tissue. ∂X is the displacement vector. Zm is time dependent convergence constant.

*Collagen Model(K):*Type I collagen is primary structural component of extracellular matrix. The mesh structure is formed by using finite element structure.

$$Jk = Dk.\nabla k + K.\frac{\partial X}{\partial t} + Zk \qquad (4)$$

Jk is the flux produced by collagen.D_K is the diffusion rate of collagen. ∇k is the partial derivative vector operator of collagen for the collagen degradation rate per unit cell. K is collagen production rate. ∂X is the displacement vector and Zk is the time dependent divergence constant. Different types of sample wound are taken. And the above physical and biological parameters are comparatively studied by before and after application of nano silver.

Wound regeneration Factor(p):

Wound is considered as deformation[4,6]. When we observe wound first we integrate secondly differentiate the observation .This approach is similar to the finite element model if we consider wound as a deformed structure. After application od nano silver what are the feasible changes of structure is achieved is established by the Wound regeneration factor.If we consider that the P is the wound regeneration factor for structural basis

$$p = \pm Dn.\nabla p + Cp\frac{\partial x}{\partial t} + Zc + Zn_1$$

(5)

Dn is the diffusion rate of nanosilver within the structure of wound. ∇p is the fibroblasts differentiation rate.Cp is the fibroblasts differentiation factor considering dermis regeneration.. Zc is the time dependent divergence constant produced by fibroblasts integrated with myofibroblasts and collagen..Zn_1 is the nano silver active surface area.. ∂x is the displacement vector which shows the tissue growth.

IV.RESULT

The result can be categorized in two different sections[11]. First one is to categorize and establish the characteristics of nano particle and the second phase is to determine the Surface of wound's parameter those are used as wound healing parameter in above section. Those above equation are simulated through matlab and the pattern of the surface is generated. Prepared nano particle is monitored using UV-Vis absorption spectroscopy. This absorption spectroscopy reveals silver nano particle characteristics by exhibiting typical surface Plasmon absorption maxima at 418-320 nm from the UV spectrum. Mie Light scattering theory and experimental results shows that diameter of silver nano particle in order of 50 nm, Energy dispersive spectroscopy and Transmission electron microscopy are used to standardize the prepared silver nano particle.
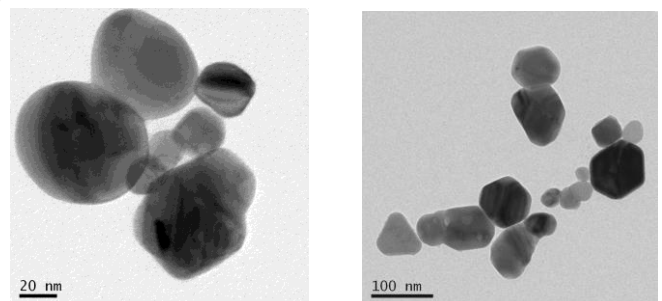

Fig.2. Transmission Electron Microscopic Image Of Prepared Nano silver
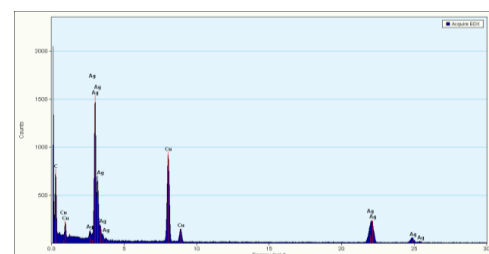

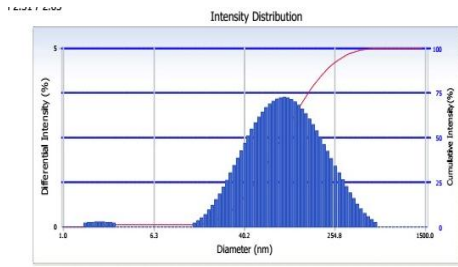Fig.3. Energy Dispersive spectroscopy of Nano silver

Fig.4. Differential Intensity distribution depending on diameter of nano particle

Table I

Distribution Result of prepared nano sliver, which is applied over burn wound

Distribution Result		
Peak	Diameter(nm)	Std.Dev
1	2.1	0.4
2	118.4	91.4
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
Average	117.0	91.7
Residual 7.398e-003 (0K)		

(a)   (b)

Fig.5. (a)3D surface visualization model -considering normalized wound factor(Y axis) ,Diffusion rate(X axis) and time (Z axis)visualization considering the parameter of Table II Presenting Fibroblasts structure And (b) Myofibroblasts Wound Model relating Table III

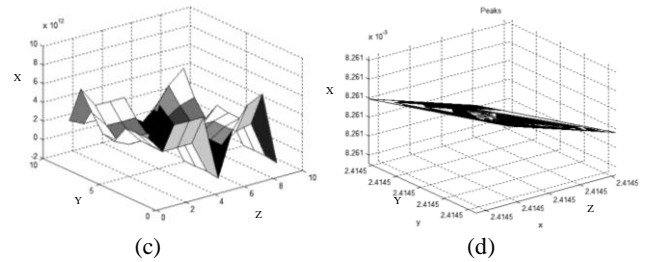(c)   (d)

Fig.6. (c)3D visualization considering normalized wound factor(Y axis) ,Diffusion rate(X axis) and time (Z axis) of collagen cluster model of wound relating the parameter of Table IV & (d) . Integrated Wound regeneration factor model relating Table V.
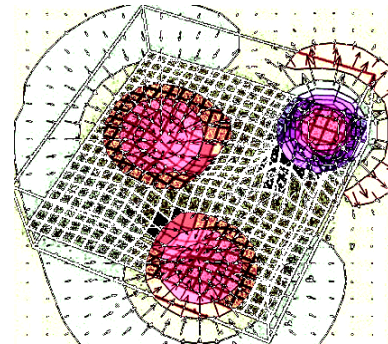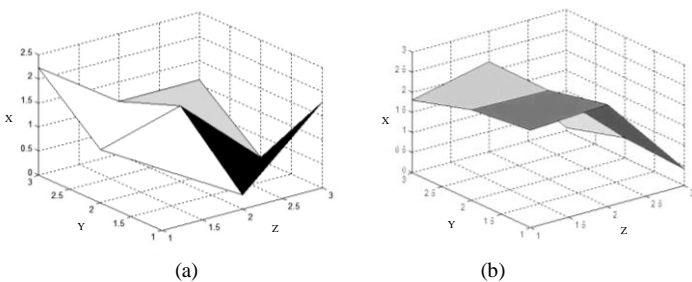

Fig.7 Extra cellular Matrix model of wound by finite element method defining traction forces with respect to convergence and divergence along with nano silver.   Stands for traction force due to converging field & stands for traction force due to divergence of extracellular matrix.

Table II

List of model Parameters related to the fibroblasts model

List of Model Parameters of proposed model Parameter	Description	Value
D_F	Diffusion rate relating fibroblasts tissues	2×10^{-2} cm^2/day
a_F	Initial chemo tactic sensitive function rate	4×10^{-10}g/cm day
Z_n	Convergence factor of nano silver	0.345 day^{-1}
b_f	Chemo tactic sensitive response	3×10^{-9}g/cm^3
C_F	Maximum rate of fibroblasts migration over the fibroblasts density	10^{-8} g/cm^3
F	Fibroblasts density in undamaged tissue	10^4cells/cm^3
∇c	Chemical concentration of wound	10^{-9}g/cm^3
Z_F	Time dependent negative divergence constant	1.1×10^{-2}day^{-1}
∇n	Chemical concentration of nano silver	3×10^{-9} g/cm

Table III

List of model Parameters related to the Myofibroblasts model

List of Model Parameters of proposed model Parameter	Description	Value
Dm	Diffusion rate of myofibroblasts tissue	2×10^{-2} cm^2
∇m	Partial derivative vector operator for myofibroblasts logistic growth rate.	0.345 day^{-1}
M	Density of myofibroblasts for integrated damaged and undamaged tissue	10^4 cells/cm^3
X	Distance from the wound centre	2cm
Zm	Time-dependent convergence constant.	2

Table IV

List of model Parameters related to the Collagen model

List of Model Parameters of proposed model Parameter	Description	Value
Dk	Diffusion rate of collagen	5×10^{-2} cm^2/day
∇K	Partial derivative vector operator of collagen for the collagen degradation rate per unit cell	7.5×10^{-5} cm^3/cell
K	Collagen production rate	6.53×10^{-10} g^3/cm^6 cell day
Z_K	Time-dependent divergence constant,considering undamaged skin poisson's ratio	0.3
X	Displacement from the wound centre to define displacement vector	1.1cm

Table V

List of model Parameters related to the Wound regeneration factor model

List of Model Parameters of proposed model Parameter	Description	Value
D_n	Diffusion rate of nanosilver within the structure of wound.	3×10^{-2} cm^2/day
∇p	fibroblasts differentiation rate	0.891 day^{-1}
Z_{n1}	Nano silver active surface area	2800cm^2/g
C_p	Fibroblasts differentiation factor considering dermis regeneration.	10^{-8} N/cm-g
Z_c	Time dependent divergence constant produced by fibroblasts integrated with myofibroblasts & collagen..	10^4 cells/cm^3

DISCUSSION

Wound healing is a complicated process .Wound size reduction is a major issue to form the exact structure of the wound. The chemical properties along with physical properties of a burn wound can be considered as a subjective clinical study of major burn. In this work the mathematical model along with the surface of wound has been modeled, by which the convergence of wound and divergence of Extracellular matrix can be defined through the flux and density distribution. Traction forces, the itching effect at the time of cure of wound can be sensed by this structural model.

REFERENCES

[1] CAMPBELL, S. L., CHANCELIER, J.-P., AND NIKOUKHAH, R. *Modeling and simulation Scilab/Scicos*, 1st ed. Springer Verlag, 2005.

[2] CAMPBELL, S. L., MOORE, E., NAKASHIGE,R., ZHONG, Y., AND ZOCHLING, R. Constraint preserving integrators for unstructured higher index idaes. *Zeitschrift fuer Angewandte Mathematik und Mechanik (ZAMM) 76* (1996), 83.86.

[3] NAJAFI, M., NIKOUKHAH, R., STEER, S., AND FURIC, S. New features and new challenges in modeling and simulation in scicos. *IEEE conference on control application, Toronto, Canada* (2005).

[4] PETZOLD, L. R. Order results for implicit rungekutta method applied to differential algebraicsystems. *SIAM. J. Numer. Anal. 23* (1986), 837.852.

[5] Elmlund, D., Elmlund, H., 2012. SIMPLE: software for ab initio reconstruction of heterogeneous single-particles. J. Struct. Biol. 180, 420–427.

[6] Zienkiewicz,O.C., Taylor,R.L,2000b. the Finite Element Method.Solid Mechanics,Vol2.Butterworth-Heinemann,Oxford.

[7] Sherratt,J.A.,Sage,E.H.,Murray,J.D.,1993,Chemical Control of eukarytic cell movement:a new model ,journal of Theoretical Biology 162(1),23-40

[8] Ghosh ,k pan,Z., Guan,E,.ge,s.,Liu,Y.,Nakamura,T.,Ren,X-D Rafailovich.,M.,Clark,R.A.F.,2007,Cell adaptation to a physiologicallyreievant ECM mimic with different viscoelasticproperties,Biomaterials 28,671-679

[9]   Lee,S.J 2000,cytokine delivery and tissue engineering ,Yonsei Medical Journal,41. 704-719

[10]   Single particle 3D reconstruction for 2D crystal image of membrane proteins. Sebastian Scherer ,Marcel Arheit,JuliaKowal,Xiangyan Zeng,Henning Stahlberg.25 October 2013

[11]   Gupta A,Mayness M,Silver S.effects of halides on plasmid mediated silver resistance in Escherichia coli.Appl Environ Microbial 1998;64.5042-5

[12]   W. J. Tam, and L. Zhang, "3D-TV content generation: 2D-to-3D conversion," in Proc. ICME, pp. 1869-1872, 2006

[13]   Nanofluids and Their Properties Gianluca Puliti, Samuel Paolucci and Mihir Sen ,*Appl. Mech. Rev.* 64(3), 030803 (Mar 30, 2012) (23 pages) doi:10.1115/1.4005492 History: Received June 21, 2011; Revised November 25, 2011