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Modelling Microneedle Assisted Micro-particle Delivery

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In a recent work, microneedle assisted micro-particle delivery has been shown to allow a percentage of micro-particles penetrate through the pierced holes which achieve the purpose of improved penetration depth¹⁻³ for micro-particle accelerators, e.g., gene guns. In order to further understand the process of microneedle assisted micro-particle delivery, a mathematical model³ is developed and reported in this paper. The model mimics the acceleration, separation and deceleration stages of the operation of an experimental rig aimed at delivering micro-particles into tissues. The model is used to simulate the particle velocity and the trajectories of micro-particles while they penetrate into the target. The model mimics the deceleration stage to predict the linear trajectories of micro-particles which randomly select the initial positions in the deceleration stage and fired into the target. Some typical results are shown in Fig.1. As can be seen, the velocity of the micro-particle is represented by the coloured particle trajectory. It is found that the velocity variation is negligible before they reach the target, and it decreased immediately after the injection. About 25% of micro-particles penetrate through the pierced holes. In addition, the micro-particle penetration is analyzed in relation to the operating pressure, MN length, particle size and density. The results suggest that the penetration depth was increased from an increase in operating pressure, MN length, particle size and density. In addition, the model results match well with the experimental results for the penetration depth of micro-particles. From the results, MN length presents a significant effect on micro-particle penetration due to the presence of the pierced holes causes a surge in penetration distance.

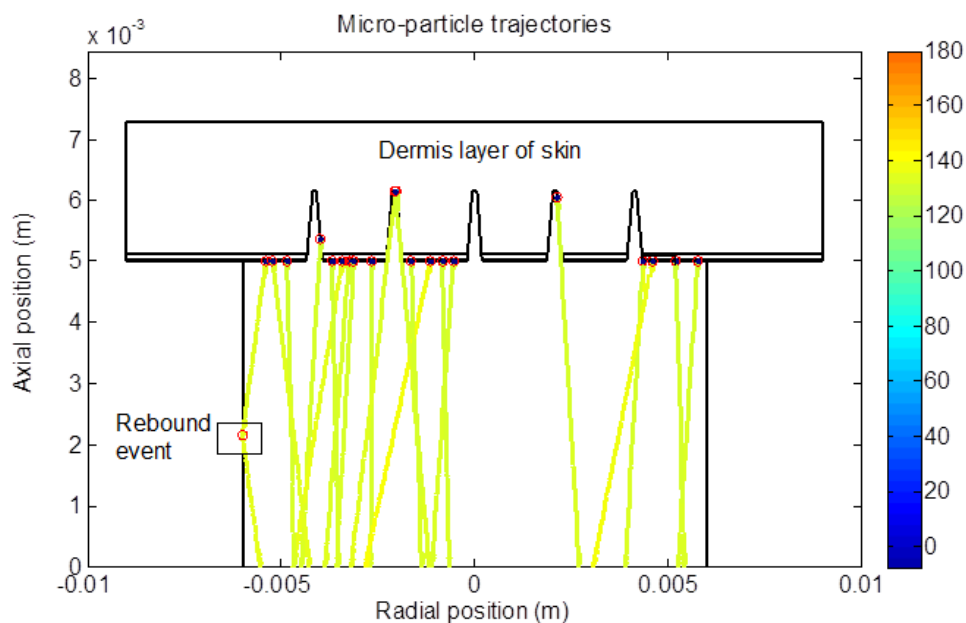


Fig. 1: The trajectories of the micro-particles in the deceleration stage

Reference:

1. Zhang D.W., Das D.B., Rielly C.D. (2013). An experimental study of microneedle assisted micro-particle delivery, *Journal of Pharmaceutical Sciences*, 102(10): 3632-3644, DOI: 10.1002/jps.23665. (2013).
2. Zhang D.W., Das D.B., Rielly C.D. (2014). Microneedle assisted micro-particle delivery from gene guns: Experiments using skin-mimicking agarose gel. *Journal of Pharmaceutical Sciences*, 103(2): 613-627, DOI: 10.1002/jps.23835.
3. Zhang D.W., Das D.B., Rielly C.D. (2014). Potential of microneedle assisted micro-particle delivery by gene guns: A review. *Drug Delivery*, DOI: 10.3109/10717544.2013.864345 (in press).
4. Zhang D.W., Das D.B., Rielly C.D (2014). Microneedle assisted micro-particle delivery by gene gun: Experiments and modelling on the effects of particle characteristics. *Drug delivery* (accepted), DOI: 10.3109/10717544.2014.887158 (in press).