Optimization of Manufacturing Parameters on Microneedles created by resin-based 3D Printing

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Background: Microneedles (MNs) are a viable method for overcoming the Stratum Corneum (SC), the main barrier to delivery of therapeutics through the skin. The micron sized needles are able to penetrate the outermost layer of the skin, and deliver drug without reaching the dermal nerves, therefore, allowing for pain free delivery into the systemic circulation. Commonly, polymeric MNs are manufactured through the micromoulding technique, which can be time consuming and require multiple fabrication steps. To explore different geometries of needles, new moulds would have to be created for each new design, which can be costly. 3D printing (3dP) is an emerging technology with increased interest, due to its ability to create objects of different geometries and designs in a short period. Computer Aided Design (CAD) is used to design the 3D prints, which can then be processed and sent directly to the printer. This allows for easy modification of designs, as files can be easily accessed online and altered, without the need for creating new moulds. In this study, three different resin-based printers are explored, for the first time, in order to compare their ability to print sharp MNs of both solid and hollow designs.

Methods: MN arrays were created, with a 15x15x0.5mm base plate and 1x1mm needles in both Conical (Co) and Pyramidal (Py) shapes, in solid design and with a 0.25x0.25mm bore. Designs were printed using Stereolithography (SLA), UV Liquid Crystal Display (LCD) and Digital Light Processing (DLP) techniques. Needle height, base diameter and tip size were assessed to evaluate which printing technique produced the sharpest needles, closest to design geometry. Printed MNs were imaged using SEM and optical light microscopy. Different printing angles ranging from 0° - 90° were explored in order to identify which angle of printing produced MNs closest to the design geometry. Parafilm M insertion tests were performed to assess the insertion capabilities of printed MN arrays as well as mechanical strength testing of arrays using Texture Analyser.

Results: DLP printing produced MNs with needle heights closest to design geometry and smallest tip size for both Py and Co needles. When printing Hollow MNs using the resin-based 3D printing systems, only the DLP printing produced needles with visible bores. Printing capabilities of DLP process was assessed, by printing needles of 800, 600, 400 and 200 µm. DLP was successfully able to produce solid MNs down to 400 µm in size at 0.025 mm resolution. MNs were able to penetrate 4 layers at a force of 32N, 3 layers at a force of 20N in both Py and Co MN arrays. When a force of 10N was applied, Py MNs were able to penetrate 2 layers or Parafilm M, Co needles also resulted in 2 layers being penetrated with some holes being present in the third layer of Parafilm M. Insertion depth was also dependent on the spacing between needles on the base plate. 5x5 needle arrangement on a 15x15mm baseplate, had better insertion capabilities than a 7x7 needle arrangement on the same sized base plate. When needles were printed at varying angles ranging from 0° to 90° from the base plate, 45° angle produced MN arrays with optimal needle geometries. After mechanical testing of the MN arrays, 20 min cure time was found to be optimal for mechanical strength of Hollow MN arrays.

Conclusions: Hollow MNs were successfully created using the DLP technique, with optimal printing parameters identified. This study proves potential for a faster fabrication method of Hollow MNs with the potential for personalized drug delivery system in future.