Inkjet-printed alumina pattern for improvement of the activity of Periodontal Ligament Cells

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Statement of Purpose: The topography such as micro-, submicro- and nano-scale roughness on the biomaterials has been reported to significantly influence cell behavior.[1-3] In-vitro studies on micropatterns at the range of micro-scale roughness have shown that it is possible to promote directed cell behavior. Variation in surface morphology, such as micropattern size, depth, and spacing within a micropatterns, have also been found to influence the movement and density of cells. In studies of micropatterns using various methods, inkjet printing is a commonly used technique for controlling the deposition of solutions of functional materials in a specific location on a substrate. However, there have been only a few reports on the effects of morphology created using the inkjet printing process on the activity of osteoblastic cells. In this study, the effect of the Al_2O_3 micropattern formed using inkjet printing on the activity of cells was investigated. The spacing between the Al_2O_3 micropatterns was controlled to measure from 50 μm to 550 μm. By analyzing the surface characteristics and alkaline phosphatase (ALP) activity for each specimen, the relationship between the Al_2O_3 micropattern created by inkjet-printing and the activity of Periodontal Ligament Cells (PLCs) was examined.

Methods: Al_2O_3 ink for inkjet-printing was prepared by dispersing Al_2O_3 nanoparticles (D_{50}=20 nm) in a co-solvent of D.I.water (25 vol%) and ethylene glycol (75 vol%). The content of Al_2O_3 nanoparticles in the ink was fixed at 6 vol% of the co-solvent and the dispersant content was fixed at 3 wt% of the Al_2O_3 nanoparticles. In order to disperse Al_2O_3 nanoparticles in the ink, they were mixed by ball-milling for 48 hr at room temperature, followed by high speed mixing at 8000 rpm for 2 hr using a homogenizer. The formulated Al_2O_3 ink was then filtered through a 5 μm nylon mesh. An Al_2O_3 plate was used as the substrate. The Al_2O_3 line pattern on the Al_2O_3 substrate was created using droplets of Al_2O_3 solution in a jetting device. An omni 500 inkjet printing unit (Unijet, Korea) equipped with a cartridge (DMC-11610, Fujifilm Dimatix, Inc., USA) with an orifice diameter of 21 μm was used to print the Al_2O_3 micropatterns on the substrates with spacings from 50 μm to 550 μm. Both untreated Al_2O_3-substrates and substrates fully coated with Al_2O_3 were used as controls (AP and AC). After the printing of the Al_2O_3 ink onto Al_2O_3 substrates, the inkjet-printed substrates were heated for 1 hr at 1200°C in air at a heating rate of 5°C/min.

Results: Fig. 1 shows surface images of an Al_2O_3 micropattern on an Al_2O_3 substrate as a function of spacing size. The Al_2O_3 micropattern created using inkjet-printing consist of smooth lines with width of approximately 60 ± 2 μm. Fig 2-(a) shows the results of the ALP activities for the Al_2O_3 inkjet-printed substrates after 14 days of cell growth. PLCs grown on AP35, AP45 and AP50 surfaces had a greater ALP activity than those on any other surface ($p<0.05$). In addition, the ALP activity of the AP35 specimen was increased by over 200% compared to the AS specimen.

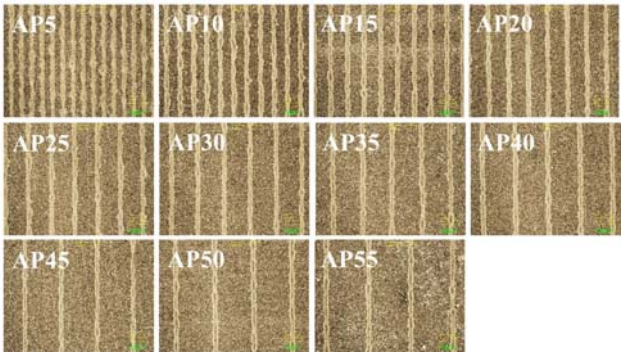

Figure 1. FE-SEM image of each sample printed by inkjetting alumina ink.

Fig 2-(b) shows the cell CLSM image of the non-patterned and patterned surface. The adsorbed cell numbers of patterned surface was higher than that of the non-patterned surface and the cell shape of patterned surface was more widely varied.

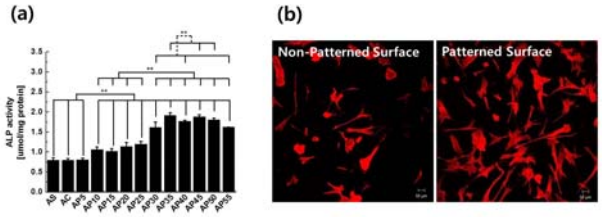

Figure 2. ALP activity after 14 days of cell culture for each sample (a) and cell CLSM image of non-patterned and patterned surfaces (b)

Conclusions: The Al_2O_3 micropattern fabricated by inkjet printing controlled spacing between micropatterns. Micropatterned surfaces with a spacing of over 300 μm have a positive effect on cell activity. This research demonstrated that cell activity can be improved just by variation of surface morphology using an inkjet printing process.

References:

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