FIRST TESTS OF EXTRUSION PROCESS USING ARTHROSCOPIC 3D BIOPRINTING HANDHELD TOOLS PROTOTYPES

TOMASZ GAPINSKI[1], KRZYSZTOF LENARTOWICZ[1], PAULINA GALAS[1]*, MAŁGORZATA GONSIOR[1], LEONARDO RICOTTI[2], LORENZO VANNOZZI[2]

[1] VIMEX SP. Z O.O., POLAND
[2] THE BIOROBOTICS INSTITUTE,
SCUOLA SUPERIORE SANT'ANNA, ITALY
*E-MAIL: PGALAS@VIMEX.EU

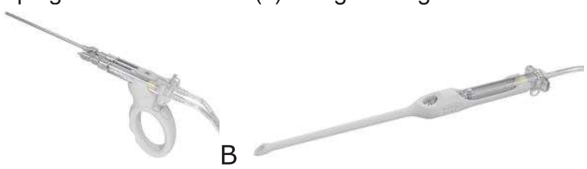
[ENGINEERING OF BIOMATERIALS 158 (2020) 60]

Introduction

Novel nanocomposite responsive materials combined with adipose tissue-derived stem cells (ASCs) and a remotely controllable ultrasound (US) is developed within the H2020 project as the innovative osteoarthritis treatment procedure[1]. The prototype of 3D bioprinting handheld tool[2] was developed as a device which should assist the surgeon in depositing the bio inks during arthroscopy in a well-controlled shape according to the patient's cartilage anatomy. First tests were performed to determine working parameters of extrusion.

Materials and Methods

Hydrogel and ASCs (or ASCc premixed with a hydrogel) delivery – two optional scenarios were considered: single and dual channel tools. Printing resolution for tested materials depends strongly on rheological properties. Suitable extrusion pressure needs to be adjusted and considered for particular extrusion coaxial channel with regard to its length and cross section extrusion area. Five different printing tools have been developed: handheld dual and single channel extruding tool (FIG. 1) – for hydrogel, handheld primer extruding tool and handheld curved spatulas (5º and 20º) to allow spreading or shaping extruded material(s) along cartilage lesions.



A B

FIG. 1. Handheld dual (A) and single (B) channel extrusion tool.

Materials with different density were tested: 0.5% and 1,5% Gellan gum not sterilized and after sterilisation in autoclave, 1.5% Gellan gum + $BaTiO_3$ nanoparticles (1% wt.) not sterilized and after sterilisation in autoclave, collagen from jellyfish – JellaGel, VitroINK 3D (TheWellBioscense: Ref. INK01-2) and VitroINK RGD (TheWellBioscense: Ref. INK02-3).
Pressure value for start of extrusion (kPa) was measured for each material for outer shell (10g) and inner shell (14g) in the dual channel tool. The materials rheological behaviour was observed. Further tests have been done for different needle sizes (gauges) with regard to a liquid material formulation, namely 0.5% Gellan gum (no autoclave). The intention was to observe for which tubing sizes controlled liquid extrusion can be obtained.
Manipulations with the dual and single channel extruding tools in the knee phantom were performed to evaluate the manipulation possibilities and accessibility of particular compartments as well as extrusion conditions.

Results and Discussion

Handheld extruding tools fulfil the following specification: ergonomic and convenient to use; allowing mounting cartridges with materials (biomaterials, primer) – cartridges are visible after mounting to recognize the level of consumed biomaterial.
Extrusion parameters for more dense materials (especially for the outer shell) require pressure values higher than the ones offered by the control unit. The control unit is able to supply the pressure up to 90kPa while VitroINK hydrogels required (for outer shells) 125kPa and 140kPa to initiate the extrusion. Reducing the inner shell diameter to match the desired size for particular material will significantly reduce pressure values for the outer channel thus there is no recommendation to increase the compression values offered by the control unit.
For materials in a liquid form (or less dese gel) for the determined gauges of tubing some uncontrolled extrusion appears after application of minimal value of pressure delivered by the control unit. By decreasing the diameter of the tube a controlled extrusion can be obtained.
The manipulation in the knee phantom has shown that while entering the operating area with a tool, there is a risk that some tissues (e.g., fat, or synovial membrane) might stuck in the tip of the endoscopic tool (FIG. 2).

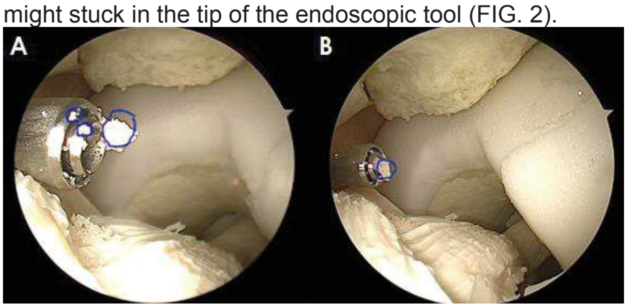


FIG. 2. Possible clogging of tissues at the tip extruding tool.

The possibility to approach the femoral condyle areas from different perspectives and under different angles were tested as well. The tool allows accessing to different parts of the condyle, but the angled approach may not be the most suitable way to extrude biomaterials from the tool. It seems the dual-channel tool may be suitable for perpendicular approach only.

Conclusions

The bioprinting system delivers functionality allowing extrusion of biomaterials. The tubing size of the extruding tool should be adjusted according to the expected density of the biomaterial, which might be: ASC in liquid form and ASC premixed with a hydrogel (in different proportions).
To avoid the problems illustrated in FIG. 2. using arthroscopic cannulas might be recommended. Such approach will reduce the risk of tool passage through tight tissues therefore should be considered in the future.
It is recommended to propose the desired hydrogel material and possible mixing proportions with ASC to perform further tests with different tube sizes and final determination of pressure values. Once the required material is determined this allows also to propose a suitable solution for cross linking strategy.

Acknowledgments

The project leading to the presented results (ADMAIORA) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814413.

References

[1] https://www.admaiora-project.com/
[2] K.Lenartowicz, T.Gapinski *et al.,* Engineering Of Biomaterials 153 (2019) pp. 44