Perspective

An engineering perspective on 3D printed personalized scaffolds for tracheal suspension technique

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Abstract: 3D printing is a large family of many distinct technologies covering a wide range of topics. From an engineering point of view, there should be considerations for selection of design, material, and process when using 3D printing for surgical technique innovation such as personalized scaffolds. Moreover, cost should also be considered if there are equally effective alternatives to the innovation. Furthermore, engineering considerations and options should be clearly communicated and readily available to surgeons for advancement in future.

Keywords: 3D printing; additive manufacturing; 4D printing; tissue engineering; trachea

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3D printing (formally known as additive manufacturing) is a group of technologies that rely on the interaction of mass and energy to manufacture a complex 3D object layer by layer (1). Compared to conventional subtractive and formative manufacturing processes, 3D printing is most suitable for making products characteristic with high complexity, high value, high customization but low volume (as low as one piece). In the medical setting, 3D printings are mostly used for making surgical guides, anatomical models and custom implants (2). 3D printing has also been extensively used in tissue engineering and regenerative medicine as an enabling tool to fabricate customized biodegradable scaffolds with controlled architecture (3-8).

Recently, a 3D printed polycaprolactone (PCL) scaffold is used unconventionally as a new surgical technique to treat a malfunctioned segment of trachea (9). In this study, instead of inserting a luminal stent to expand the collapsed trachea from the internal, the authors implanted 3D printed C-shaped tubular scaffold around the collapsed segment to suspend it from the external. The collapsed segment is attached to the scaffold by using 4–0 Polyglactin (Ethicon, Somerville, USA) sutures. An artificial pleural patch was wrapped around the scaffold to alleviate abrasion to other organs. The patient was discharged from the hospital in 2 weeks after the surgery. In the follow up of first 3 months, the patient had a remarkable improvement in breathing and physical strength, and the cavity of the suspended trachea remained the same.

This is not the first study on tracheal suspension in human, but this is the first report on using a 3D-extruded PCL scaffold in an adult patient (a 46-year-old female). Previously reported cases are limited to the use of laser-sintered PCL scaffolds in paediatric patients (10,11). In 3D printing, 3D extrusion is formally known Fused Deposition Modelling (FDM), which is simple, versatile and cheap compared to laser sintering process. Other medical material such as PEEK can also be printed by FDM (12). Therefore, this study provides complementary information to prior studies at least with regard to the variety of 3D printing techniques. In fact, there are over 50 different commercial 3D printing systems available in the market (1). Their potentials for medical applications have not been fully unveiled.

This study is interesting though, from an engineering point of view, there are still a few unanswered questions. Firstly, the collapsed trachea is suspended to the scaffold by using bioresorbable sutures without any other fasteners. The bioresorbable sutures are likely to degrade and loosen over one month. However, the follow up study shows that the suspended trachea remained widely open and did not detach from the scaffold or re-collapse anywhere. It is worth finding out what are the forces that suspend the collapsed trachea to the scaffold even after the sutures have degraded. This observation has not been clearly explained in detail.

If it is because the tracheal tissue penetrates into the pores of PCL scaffold and integrates with PCL material, it would signify the importance of scaffold design, in particular the pores. However, it is not clear in this study why a series of solid C rings were chosen for the scaffold design, especially when alternative designs could also be 3D printed, such as a porous tubular structure (13). Although it is difficult to predict which design will lead to the best outcome, at least there is more than one design option for tracheal suspension technique.

Secondly, it is not clear what would the fate of the treated trachea be after the PCL scaffold has completely degraded. If the trachea still remains adequately open, PCL must be involved in the healing or regeneration of the malfunctioned trachea. Then the mechanism responsible for it becomes interesting.

If the treated trachea is at the risk of an ultimate re-collapse after PCL degradation, then why not using 3D printed biocompatible metals (e.g., titanium alloy) with a lightweight design at the beginning? Selective laser melting (SLM) and electron beam melting (EBM) are two established 3D printing methods for fabricating complex lightweight titanium alloys (14). Unfortunately, follow up data more than the degradation time of PCL are not available. It remains elusive whether biodegradable polymeric scaffolds are better than biocompatible metals. Considering that there is also 3D printed biocompatible but non-degradable polymer (e.g., PEEK), the materials suitable for tracheal suspension technique should never be limited to PCL.

In fact, in the case of paediatric patients, PCL is used as a 4D printed material rather than 3D printed material. 4D printing refers to the shape change of a 3D printed material over time when given some stimulus (15). PCL degrades over time and the strength decays, which allows accommodating the growth of a child. Therefore PCL may be more suitable for pediatric patients. However, in an adult patient, it is debatable if PCL is still the best option. Nonetheless, PCL is a tested and perhaps a safer option in tracheal suspension so far.

Thirdly, 3D printed medical devices have advantages such as personalization and speed, but the advantage on cost effectiveness is not conclusive yet (2). In this study, whether there is any cost advantage for using the 3D printed PCL scaffold over conventional methods is not revealed. However, since the 3D printing technique used in this study is FDM, which is less expensive compared to SLS in previous studies, the increased cost may be balanced by the advantages.

In conclusion, 3D printing is gaining more and more acceptance in surgical practices, including innovation of new surgical technique. If more engineering considerations and options can be clearly communicated and readily available to doctors and surgeons, more interesting advances in this direction should be seen in future.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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