·专家笔谈·

儿童骨科 3D 打印技术的临床实践

沈先涛

3D 打印技术于三十多年前首次在国内引进,当时被视为无法获得的、昂贵的和未来的技术,临床应用很有限[1-3]。近年来,3D 打印技术被广泛应用于外科手术中,其在小儿骨科的应用也得到越来越多的认可,在小儿骨科临床实践中发挥着重要作用。

一、概述

3D 打印技术将计算机生成的 3D 图像转换为物理模型,也被称为快速原型技术或增材制造技术[4]。是一项将材料结合在一起(通常是层层叠加的),以三维模型数据来制作物品的工艺。通常,3D 模型的制作可以基于来自 CT 或 MRI 图像的 DICOM 格式数据,生成格式为 STL 的 3D 模型。

打印机通过一系列液体、粉末或片材材料(例如塑料/聚合物和金属)的一系列横截面层来建立模型,最终形状是在层连接时形成的[4]。这个过程可以用来创建个体化材料,并且可能较传统的植入物制作更具成本效益[5]。3D 打印可以创建任何复杂的形状,并可将固体和多孔部分进行组合,以提供最佳的强度和性能[4]。许多不同的材料都可被运用,包括塑料、聚合物、玻璃、陶瓷、金属和生物材料[4,6-8]。

二、用于医学教育

3D 打印模型可用于教育患者及家属、医学生、临床医生。三维模型可以在复杂病例的讨论和患者知情同意过程中发挥重要作用。该模型有助于使患者和家属了解疾病的复杂性和严重性,进而了解治疗的过程。3D 模型相较于影像学资料更为直观,对空间想象力的要求更低,可以帮助医学生和经验不足的临床医生提高对疾病的认识和缩短学习曲线[9,10]。

三、用于手术规划

目前 3D 打印技术主要在复杂类型的骨折、肢体畸形、肌肉骨骼肿瘤等领域中广泛应用。临床上常用的 X 线、CT 扫描、MRI 仅是二维图像,对于一些复杂骨折而言,缺乏三维立体感的医师很难对其进行诊断、分型及制定治疗方案。3D 打印技术的应用为临床医师提供了复杂类型骨折的视觉和触觉辅助[11]。该模型可以根据需要进行消毒和手术中使用[12,13]。3D 模型的术前评估可以使医生预测手术中的困难,选择最佳的手术方式和特定的手术器械。倪磊等[14]将 3D 打印技术应用于小儿骨科中的复杂 Pilon 骨折,认为具有定位精准、组织损伤小、固定稳妥等优点,同时也大大缩短了手术时间。

此外,有学者利用 3D 打印模型来协助治疗复杂的脊柱侧凸、Perthes 病和 Blount 病[12,15]。他们将这些模型用于协助术前规划、与患者沟通、手术过程中作为参考,以提高手术安全性和缩短手术时间。

临床医生可以通过模型来研究畸形情况并用计算机模拟手术,包括理想的截骨部位和确切的植骨位置。高斌等[16]应用 3D 打印技术确定儿童复杂扁平足手术中截骨的部位和范围。3D 打印技术还可以生产夹具,并使其适用于内置截骨导向器的预钻孔[17]。有报道 3D 技术已被用于复杂上肢[18-25]和下肢截骨病例[17,26,27]。这些文献支持 3D 打印技术将复杂手术简单化,并有增强手术者达到手术目标的信心。当然,这仍需要进行常规术前规划与使用 3D 打印进行术前规划的对比研究[28]。计算机辅助设计和定制的 3D 打印导板也被用于椎弓根螺钉置入术,关节成形术和肌肉骨骼肿瘤切除术[29-32]。

四、用于定制植入物

3D 打印技术使定制植入物成为可能[33]。当患者不适合标准范围的植入物或疾病需要特定植入物时,这项技术可用于定制患者个性化植入物。运用 DICOM 图像在计算机上创建解剖模型,然后根据患者的解剖学特点定制植入物。

Imanishi 等[34]利用 3D 打印技术为跟骨肿瘤患者定制了具有软组织附件的跟骨植入物。虽然定制植入物在某些情况下非常有用,但仍需与每位患者及家属仔细沟通。

与现阶段的传统技术相比,关于 3D 打印技术定制植入物的许多优点尚未得到证实,3D 打印技术

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作者单位:华中科技大学同济医学院附属武汉儿童医院骨科(湖北省武汉市,430016),Email:xiantaoshen9815@aliyun.com

与传统技术相比，也缺乏长期随访的研究报道[35-37]。

五、用于定制外固定器和矫形器

目前已有使用 3D 打印技术定制外固定器来协助骨折复位[38]。他们提出，这种技术可以结合压力调节、骨愈合因素以及纳米技术来促进骨折的愈合。

六、展望

3D 技术在小儿骨科中的应用可以分成两大类。一类涵盖该工艺的工业应用，包括制作复杂的模型、修复体、生物支架和纳米技术等[39]。第二类是日常临床应用，可用于教育和手术规划。

在现阶段，3D 打印技术在小儿骨科的工业应用与高额成本相关，这项技术是否可纳入日常实践仍受到当前制造成本以及其简化手术并最终改善手术结果等方面的影响。日常临床使用 3D 打印来进行教育培训和手术规划已经非常普遍。近来随着免费软件的推出，3D 打印的成本大幅降低。除了小儿骨科临床试验较少之外，主要的缺点是准备图像和打印模型需要很长时间。

生物组织 3D 打印已经被提出一段时间，并且动物模型也证明了其可行性[8,40-42]。该技术能够打印细胞或将细胞载入 3D 支架以植入体内。例如肝组织的再生[43]，可定制血管，皮肤，骨和软骨[39]，以及包含有治疗因子或纳米颗粒传递系统的支架[39]。但严格的伦理监管限制了其广泛的临床应用[44]。同时，实验室的发现运用到患者仍然需要更高质量的试验研究[45]。

当前对 3D 细胞打印的挑战包括工程组织的长期稳定性和血管化[46,47]。由于生物打印机需要复杂的计算机技术支持，因此无法在实验室外打印细胞。然而，这项技术有能力改变目前选择很有限的肌肉骨骼疾病的治疗方法。

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