

3D打印技术辅助重建髋臼骨缺损的临床研究进展

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摘要

全髋关节置换术中髋臼骨的缺损对于骨科医师是巨大的挑战。既往的髋臼骨缺损重建技术都有一定的缺点, 然而随着3D打印技术的快速发展, 该技术在关节外科中的应用也得到了飞速的发展。3D打印在髋臼骨缺损中的应用包括3D打印解剖模型和3D打印定制假体等。根据国内外研究者的中长期随访结果来看, 该技术明显的提高的手术的精确性和假体的稳定性, 术后患者的活动度和生活质量也得到了明显的改善。同时3D打印技术同样也面临着一些挑战和问题, 但是随着研究的推进、临床病例的积累和新的材料的应用, 3D打印技术在髋臼骨缺损的应用一定会得到迅速的发展。

关键词

髋关节置换术, 髋臼骨缺损, 3D打印技术

Clinical Research Progress on 3D Printing Technology Assisted Reconstruction of Acetabular Bone Defects

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Abstract

The acetabular bone defect during total hip joint replacement is a great challenge for orthopedic

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surgeons. Previous techniques for reconstructing acetabular bone defects have certain drawbacks, but with the rapid development of 3D printing technology, its application in joint surgery has also been rapidly developed. The application of 3D printing in acetabular bone defects includes 3D printed anatomical models and 3D printed customized prostheses. According to the long-term follow-up results of domestic and foreign researchers, this technology has significantly improved the accuracy of surgery and the stability of the prosthesis, as well as the postoperative mobility and quality of life of patients. At the same time, 3D printing technology also faces some challenges and problems. However, with the advancement of research, the accumulation of clinical cases, and the application of new materials, the application of 3D printing technology in acetabular bone defects will definitely develop rapidly.

Keywords

Hip Joint Replacement, Acetabular Bone Defect, 3D Printing Technology

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1. 引言

自全髋关节置换术问世以来, 以其超高的患者满意度、功能恢复结果及植入物寿命被广泛认为是骨科最成功的外科手术[1]。随着人口老龄化的加剧, 据估计, 到 2030 年在美国初级全髋关节置换术的需求将增长 174%, 每年共进行 57.2 万例手术, 而这又会增加髋关节翻修的需求, 预计到 2030 年, 髋关节翻修手术的数量将增加 137% [2]。进行髋关节翻修手术的患者通常年龄比较大且伴随有骨质疏松, 整体身体状况相对较差, 所以, 大半进行髋关节翻修术的患者都伴随有髋臼侧骨缺损, 这对于骨科手术医生来说是一种挑战[3] [4] [5] [6]。

1984 年 8 月 8 日, Charles W “Chuck” 因为一个可以印刷 3D 物体的立体平板印刷设备向美国申请获得专利[7]。随后的 30 年里, 3D 打印技术作为一种通过连续“打印”材料层来复制计算机模型形状的机械过程, 已经被许多行业采用。3D 打印机的实用性在制造业中得到了极大的认可, 据报道, 世界前 100 公司中有近 70% 的公司投资于 3D 打印机领域[8]。在外科领域, 手术室内和手术室外也开始使用 3D 打印技术加强术前规划手术方案, 开展应用的主要有颌面外科、心胸外科、骨科等专业。在关节外科领域, 3D 打印技术的应用为髋关节置换术髋臼骨缺损的重建带来了新的选择。

2. 常规髋臼骨缺损重建方法的不足点

髋臼侧骨缺损的重建方法主要有 Jumbo 杯, 结构性植骨, 打压植骨, 杯笼结构, 多杯结构, 抗突出笼架, 定制三翼假体和多孔金属垫块等[4] [6] [9] [10] [11]。然而各个重建方法都有其优点和缺点。

髋臼骨缺损最初是通过异体结构性植骨来解决的, 然而其松动率和迁移率高达 70% [10]。打压植骨技术也因为骨吸收引起的较高失败率而受到一定的限制[12]。Battaro 等人[13]发现, 加压植骨和金属网的组合应该被应用于非包含性骨缺损, 其在包含性骨缺损的临床效果并不好。抗突出笼架结合骨水泥型髋臼假体的中远期随访结果并不理想[14] [15]。杯笼技术在放置髋臼杯时为了能容纳笼架结构, 外展角不得不偏大一些, 并且坐骨侧翼结构在坐骨骨缺损病例当中放置有相当大的难度[16] [17]。另外, 有研究表明 Jumbo 杯虽然能提供更高的骨 - 假体覆盖面, 但其会增加股骨头旋转中心的高度, 从而导致下肢长度差

异增加,影响假体稳定性及患者步态[18][19]。

3. 3D 打印技术在髌臼骨缺损重建中的应用现状

近些年来,随着 3D 打印技术的快速发展和推广,如今,3D 打印技术可以用来创建结构模型和医疗植入物,从而显著帮助外科医生更精确地规划和实行手术[20]。3D 打印技术在髌臼骨缺损重建中的应用主要有个性化定制解剖模型,术前模拟手术和个性化定制假体。

3.1. 个性化定制解剖模型

使用 3D 打印技术打印一个实际大小的骨盆模型,外科医生可以充分了解解剖异常,并制定一个更完整的手术计划[20][21][22]。髌关节翻修手术中,在广泛骨质缺损的复杂情况下,使用 X 光片和传统 CT 扫描的传统规划可能不够准确的反应患者真实的情况,而根据患者 CT 扫描结果制造的 3D 打印模型可以更好地了解术前的解剖学问题,最小化术中问题[23]。Jiang 等人[24]的一项包含 41 个研究、948 例患者的系统评价结果显示,3D 打印定制模型在术前规划中的使用能够帮助缩短术中透视时间、降低出血量和缩短手术时间。另外,3D 打印定制模型通过严格的消毒后在手术台上帮助外科医生分析解剖特征,为手术顺利进行提供重要参考,取得良好的效果[25][26][27]。

如果根据 3D 打印模型规划的手术方案进行手术,则术中遇到的问题理论上都是可以预测的而且做好充分准备的,从而进一步减少术中预期外的事件的发生、缩短整体手术时间。

3.2. 术前模拟手术

髌关节翻修手术中,在广泛骨质缺损的复杂情况下,使用 X 光片和传统 CT 扫描的传统规划可能不够准确的反应患者真实的情况,而根据患者 CT 扫描结果制造的 3D 打印模型可以更好地了解术前的解剖学问题,最小化术中问题[23]。如果根据 3D 打印模型规划的手术方案进行手术,则术中遇到的问题理论上都是可以预测的而且做好充分准备的,从而进一步减少术中预期外的事件的发生、缩短整体手术时间。Zerr 等[28]研究发现,在行髌关节翻修手术时,可以借助 3D 打印技术在术前打印出患髌的 3D 解剖模型,借助模型可以让医生们进行术前演练,并测量计算出臼杯的大小,还可以确定螺钉的安装方向,最终使患者的手术是时间得到了缩短。Hughes 等[29]使用 3D 打印的解剖模型进行术前模拟手术,认为螺钉置入轨道的模拟能提高螺钉置入精确度,从而减少术中神经血管损伤的发生;而螺钉位置的模拟手术则可以帮助术者更好地利用残留的骨量,提高假体的稳定性。

3.3. 个性化定制假体

3D 打印个性化假体则是使用患者特定的医学图像创建的,定制假体可以与患者局部残留的骨量的解剖结构实现完美匹配,提高手术精确度[20][30]。同时,对于上下支柱都失去支撑的巨大缺损病例来说,没有现成的普通假体能提供满意的效果,而这时候 3D 打印定制假体是唯一的选择[31]。Dall'ava 等人[32]将病人分为 3D 打印定制髌臼假体组和普通髌臼假体组,随访检测假体表面骨长入组织学情况,结果显示 3D 打印定制髌臼假体组骨长入率优于普通假体组。假体的孔隙率和孔隙大小是髌臼假体的骨整合的重要影响因素之一,而 3D 打印技术则外形与普通假体一样的情况下可以能够更好的调整这些参数,让 3D 打印定制髌臼假体孔隙更加符合骨长入的条件[33]。Wyatt 等人[34]系统回顾了包含 243 例 Paprosky III 型髌臼骨缺损和骨盆不连续的患者应用 3D 打印定制髌臼假体的 7 项研究,结果显示 3D 打印定制髌臼假体的机械性失败的可能性较低。

此外,多项研究表明[20][29][35][36][37][38][39],3D 打印技术可以辅助提高髌臼骨缺损重建手术精准性和假体稳定性,有助于恢复正常股骨头旋转中心。DeBoer 等人[31]经过长达 10 年长期临床随访结

果提示, 使用 3D 打印定制假体的患者平均髋关节 HHS 评分由术前的 41 分改善到末期随访的 80 分。

3D 打印定制假体在恢复髋关节旋转中心高度、改善髋关节功能和患者生活质量等方面得到了认可, 同时它作为严重的髋臼骨缺损的有效重建方法, 为一些无法使用普通重建方法得到良好的稳定的患者提供了一个新的选择。

4. 3D 打印技术在髋臼骨缺损重建中面临的挑战

虽然, 3D 打印定制假体在严重的髋臼骨缺损中表现突出, 但是有一些研究者仍然质疑它的安全性。Martino [40] 等人的一项 667 例髋关节翻修 meta 分析结果提示, 虽然 3D 打印个性化定制三翼假体在严重的髋臼骨缺损病例中是个有效的重建技术, 但其术后总并发症发生率高于其他髋臼重建技术。Baauw [41] 等人的研究表明, 3D 打印个性化假体虽然在早期疗效上令人满意, 但是假体放置位置不当的发生率依然较高。而假体位置的不当是术后的假体脱位、松动等发生的危险因素。De Martino 等部分研究者[40] [42] [43] [44]表示, 部分 3D 打印定制假体在围术期并发症发生率方面高于其他髋臼骨缺损重建技术。并且, 使用 3D 打印定制化解剖模型做的体外模拟手术与真实手术不同, 模拟手术时骨盆周围缺乏周围软组织, 故并不能做到跟术中遇到的情况完全一样[45]。

目前, 3D 打印定制假体在早中期的小样本、单中心临床试验中展现出了稳定性和良好的骨长入能力, 但是仍然缺乏长期的、大样本的临床随访结果来进一步支持它的稳定性和安全性。

5. 3D 打印技术在髋臼骨缺损重建中的应用前景

3D 打印技术在髋臼骨缺损重建中的应用, 为许多患者带来了良好的关节功能恢复和生活质量的提升, 同时, 关节外科医生面对复杂的髋关节翻修手术多了一个稳定的选项。3D 打印解剖模型和术前模拟手术则更加优化提前制定的手术方案, 优化改善每一颗螺钉的置入方向和深度, 明显提高手术精确度, 为患者安全保驾护航。

面对 3D 打印技术耗费昂贵的问题, 成为了它发展的最大障碍。Zhang 等人[46]认为, 3D 打印所需要的耗材是其价格昂贵的主要原因, 并且按照传统的影像学灰度值结果的 3D 打印解剖模型并不能完全真实的还原患者的残余骨量解剖特征。为了解决这个问题, 多种材料的甚至彩色的材料应用和更可靠更清晰的影像学方法的应用可能是一个有效的解决方案。

Tack 等人[47]研制了一种新型 3D 打印定制假体, 他们对比研究两种假体在耗费方面的优缺点, 发现新型的 3D 打印定制假体在减少耗费方面有很大的潜力。

由于 3D 打印作为新兴的技术, 允许用于临床手术植入物的时间还不够长, 3D 打印定制假体缺乏长期、大样本、多中心的随访结果支持, 所以其并不算是一个完全成熟的技术。故笔者认为, 随着研究的推进、临床病例的积累和新的材料的应用, 3D 打印技术在髋臼骨缺损的应用一定会得到迅速的发展。

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