

# 3D打印结合PMMA骨水泥髓内支撑技术在老年肱骨近端骨质疏松性骨折中的应用

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**【摘要】目的** 探讨3D打印技术结合聚甲基丙烯酸甲酯(PMMA)骨水泥髓内支撑辅助锁定钢板治疗肱骨近端Neer二、三、四部分骨质疏松性骨折的应用效果。**方法** 回顾性分析2017年9月至2020年5月北部战区总医院收治的33例肱骨近端Neer二、三、四部分骨质疏松性骨折。男5例,女28例,平均年龄(68.4±2.5)岁。按Neer分型,二部分骨折3例,三部分骨折21例,四部分骨折9例。术前收集患者双侧肱骨三维重建CT扫描数据通过Mimics Research 20.0软件进行模拟复位及镜像比对,获得骨折复位后骨缺损范围并以此设计髓内支撑假体模具。通过3D打印技术打印髓内支撑假体模具,术中应用模具制作PMMA骨水泥髓内支撑假体。将该假体植入肱骨近端髓腔内,支撑肱骨头骨折块,辅助锁定钢板进行骨折的复位和固定,术后即刻行肱骨近端正侧位X线评估骨折复位质量,术后定期复查,观察骨折愈合及并发症情况,测量并记录肱骨近端颈干角、肱骨头高度变化情况;术后1年通过Constant-Murley肩关节功能评分、VAS疼痛评分。**结果** 33例患者均获得随访,随访时间(13.2±1.5)月。Neer二部分骨折中,健侧、术前及术后1年颈干角比较,差异有统计学意义( $F=39.038, P<0.05$ ),两两比较中发现健侧颈干角( $145.33\pm1.52^\circ$ )与术前颈干角( $102.00\pm11.13^\circ$ )比较,差异有统计学意义( $P<0.05$ ),与术后1年颈干角( $145.67\pm2.52^\circ$ )比较,差异无统计学意义。Neer三部分骨折中,健侧、术前及术后1年颈干角比较,差异有统计学意义( $F=13.957, P<0.05$ ),两两比较中发现健侧颈干角( $145.86\pm3.18^\circ$ )与术前颈干角( $173.90\pm35.33^\circ$ )比较,差异有统计学意义( $P<0.05$ ),与术后1年颈干角( $143.81\pm4.19^\circ$ )对比,差异无统计学意义。Neer四部分骨折中,健侧、术前及术后1年颈干角比较,差异有统计学意义( $F=89.297, P<0.05$ ),两两比较中健侧颈干角( $146.44\pm3.74^\circ$ )与术前颈干角( $96.22\pm14.09^\circ$ )比较,差异有统计学意义( $P<0.05$ ),与术后1年颈干角( $141.11\pm3.96^\circ$ )比较,差异无统计学意义。Neer二、三、四部分骨折中,术中肱骨头高度与术后1年肱骨头高度比较,差异无统计学意义。Neer二部分骨折中,肱骨头高度差异平均为( $0.70\pm0.18$ )mm,Neer三部分骨折中,肱骨头高度差异平均为( $1.12\pm0.24$ )mm,Neer四部分骨折中肱骨头高度差异平均为( $1.92\pm0.21$ )mm。术中与术后1年肱骨头高度比较,差异无统计学意义。术后1年三维重建CT显示所有患者均已获得骨折愈合。Constant-Murley肩关节功能评分中,二部分骨折患者为( $78.42\pm4.31$ )分,三部分骨折患者为( $74.34\pm3.82$ )分,四部分骨折患者为( $69.31\pm3.43$ )分,VAS疼痛评分中二部分骨折患者为( $1.53\pm0.81$ )分,三部分骨折患者为( $2.12\pm0.63$ )分,四部分骨折患者为( $3.14\pm1.22$ )分。**结论** 应用3D打印结合PMMA骨水泥髓内支撑技术辅助锁定钢板治疗老年肱骨近端Neer二、三、四部分骨质疏松性骨折,可以增强骨折固定的稳定性,有效保持术后颈干角、肱骨头高度,获得较好的临床结果。

**【关键词】** 骨质疏松症; 肱骨近端骨折; 聚甲基丙烯酸甲酯; 内侧支撑; 3D打印

**Application of 3D printing technology combined with PMMA bone cement intramedullary support in the treatment of senile proximal humeral osteoporotic fractures** Jin Wantong<sup>1,2</sup>, Xue Haipeng<sup>1</sup>, Zhou Dapeng<sup>1</sup>, Liu Bing<sup>1</sup>, Ji Zhengang<sup>1</sup>, Ma Xiangyu<sup>1</sup>, Yang Chao<sup>1</sup>, Zhang Hao<sup>1</sup>, Han Ning<sup>1</sup>, Zong Yuning<sup>1</sup>, Zhang Yonghao<sup>1</sup>, Ma Zefang<sup>1</sup>. <sup>1</sup>Postgraduate training base of northern theater General Hospital of Jinzhou Medical University, Jinzhou Medical University, JinZhou121001, China; <sup>2</sup>Department of orthopedics, General Hospi-

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**【Abstract】 Objective** To investigate the application effect of 3D printing technology combined with PMMA (polymethylmethacrylate) bone cement intramedullary support assisted locking plate in the treatment of proximal humeral Neer II, III and IV osteoporotic fractures. **Methods** From September 2017 to may 2020, 33 cases of proximal humeral neer II, III and IV osteoporotic fractures were retrospectively analyzed. There were 5 males and 28 females, with an average age of  $(68.4 \pm 2.5)$  years. According to neer classification, there were 3 cases of two-part fracture, 21 cases of three part fracture and 9 cases of four part fracture. The CT scanning data of three-dimensional reconstruction of bilateral humerus were collected before operation, and the simulated reduction and mirror image comparison were carried out through mimics research 20.0 software to obtain the bone defect range after fracture reduction, and then the intramedullary support prosthesis mold was designed. The mold of intramedullary support prosthesis was printed by 3D printing technology, and the mold was used to make PMMA bone cement intramedullary support prosthesis during operation. The prosthesis was implanted into the medullary cavity of the proximal humerus to support the fracture block of the humeral head, and the locking plate was used to reduce and fix the fracture. Immediately after the operation, the proximal humerus positive and lateral X-ray was performed to evaluate the quality of fracture reduction. After the operation, regular reexamination was performed to observe the fracture healing and complications, and the changes of the proximal humeral neck shaft angle and the height of the humeral head were measured and recorded; One year after operation, it passed the constant Murley shoulder function score and VAS pain score. In neer's four part fracture, there was significant difference between the healthy side of the neck shaft angle  $(146.44 \pm 3.74)^\circ$  and the preoperative neck shaft angle  $(96.22 \pm 14.09)^\circ$  ( $P < 0.05$ ), but there was no significant difference between the healthy side of the neck shaft angle and the postoperative neck shaft angle  $(141.11 \pm 3.96)^\circ$  one year later. **Results** All 33 patients were followed up for  $(13.2 \pm 1.5)$  months. In neer's two-part fracture, there was a statistically significant difference in the cervical trunk angle of the healthy side, before operation and one year after operation ( $F=39.038$ ,  $P < 0.05$ ). In the two-part comparison, it was found that there was a statistically significant difference between the cervical trunk angle of the healthy side  $(145.33 \pm 1.52)^\circ$  and the preoperative cervical trunk angle  $(102.00 \pm 11.13)^\circ$  ( $P < 0.05$ ), and there was no statistically significant difference between the cervical trunk angle of the healthy side  $(145.67 \pm 2.52)^\circ$  and the postoperative cervical trunk angle of one year. In neer's three part fractures, there was a statistically significant difference in the angle of the neck trunk on the healthy side, before operation and one year after operation ( $F=13.957$ ,  $P < 0.05$ ). It was found that there was a statistically significant difference in the angle of the neck trunk on the healthy side  $(145.86 \pm 3.18)^\circ$ , compared with the angle of the neck trunk before operation  $(173.90 \pm 35.33)^\circ$  ( $P < 0.05$ ), and there was no statistically significant difference in the angle of the neck trunk one year after operation  $(143.81 \pm 4.19)^\circ$ . In neer's four part fractures, there was a statistically significant difference in the cervical trunk angle between the healthy side, before operation and one year after operation ( $F=89.297$ ,  $P < 0.05$ ). There was a statistically significant difference in the cervical trunk angle between the healthy side  $(146.44 \pm 3.74)^\circ$  and the preoperative cervical trunk angle  $(96.22 \pm 14.09)^\circ$  ( $P < 0.05$ ), and there was no statistically significant difference between the healthy side and the postoperative cervical trunk angle one year after operation  $(141.11 \pm 3.96)^\circ$ . In neer's second, third and fourth part fractures, there was no significant difference between the height of humeral head during operation and that one year after operation. In neer two-part fracture, the average height difference of humeral head is  $(0.70 \pm 0.18)$  mm, in neer three part fracture, the average height difference of humeral head is  $(1.12 \pm 0.24)$  mm, and in neer four part fracture, the average height difference of humeral head is  $(1.92 \pm 0.21)$  mm. There was no significant difference in the height of humeral head between intraoperative and 1 year after operation. One year after operation, three-dimensional reconstruction CT showed that all patients had achieved fracture healing. In the constant Murley shoulder function score, patients with two-part fractures scored  $(78.42 \pm 4.31)$ , patients with three-part fractures scored  $(74.34 \pm 3.82)$ , patients with four part fractures scored  $(69.31 \pm 3.43)$ , patients with two-part fractures scored  $(1.53 \pm 0.81)$ , patients with three part fractures scored  $(2.12 \pm 0.63)$ , and patients with four part fractures scored  $(3.14 \pm 1.22)$ . **Conclusion** Using 3D printing combined with PMMA bone cement

intramedullary support technology to assist locking plate in the treatment of elderly proximal humeral neck II, III and IV osteoporotic fractures can enhance the stability of fracture fixation, effectively maintain the postoperative neck shaft angle and humeral head height, and obtain better clinical results.

**【Key words】** Osteoporosis; Proximal humerus; Polymethylmethacrylate; Medial support; 3D printing

随着人口老龄化和骨质疏松症患者增多,肱骨近端骨折的数量显著增加<sup>[1]</sup>。肱骨近端骨折占所有成人骨折的5%至6%<sup>[2]</sup>,超过70%的肱骨近端骨折患者年龄在60岁以上,其中四分之一是女性,从40岁开始,肱骨近端骨折的发病率开始呈指数增长<sup>[3]</sup>。肱骨近端骨折是老年患者第三常见的骨折之一<sup>[4]</sup>,大多数为骨质疏松性骨折且为粉碎性骨折,严重的破坏了肱骨头血运,传统钢板治疗骨质疏松性肱骨近端骨折造成极大困难,获得满意复位固定和最终骨愈合的难度增大,术后并发症发生率高<sup>[5]</sup>。

目前我国老年患者肱骨近端骨质疏松性骨折患者日益增多,骨科对老年患者肱骨骨质疏松性骨折患者治疗与康复的关注也必然增多。虽然临床上治疗肱骨近端骨折的手术技术越来越多,然而仍没有一种治疗技术被证明是治疗骨质疏松性肱骨近端骨折的最佳选择<sup>[6-7]</sup>。即使有锁定钢板的引入,肱骨近端骨折的治疗得到一定改善,固定更容易维持。但在治疗骨质疏松性骨折时,关于钢板螺钉松动、内翻对线不良、螺钉断裂和螺钉穿透关节的并发症仍然时有报道<sup>[5,8]</sup>。

基于锁定钢板治疗骨质疏松性肱骨近端骨折时术后并发症发生率高,本文回顾性分析2017年9月至2020年5月我院收治的33例使用3D打印技术结合聚甲基丙烯酸甲酯(polymethyl methacrylate, PMMA)骨水泥髓内支撑辅助锁定钢板进行治疗的患者,目的为探讨3D打印技术结合PMMA骨水泥髓内支撑辅助锁定钢板治疗肱骨近端Neer二、三、四部分骨质疏松性骨折的应用效果。

## 资料和方法

### 一、纳入及排除标准

纳入标准:(1)采用3D打印技术结合PMMA骨水泥髓内支撑辅助Philos锁定钢板治疗的新鲜肱骨近端骨折(伤后时间<2w);(2)年龄>65岁者且骨密度检查T值低于-2.5;(3)单侧肱骨近端骨折;(4)Neer二部分骨折合并内侧柱严重缺失、Neer三、四

部分骨折;(5)患者术后随访资料完整,随访时间在12个月以上。

排除标准:(1)开放性骨折、病理性骨折;(2)合并精神、免疫、血液系统疾病者;(3)合并骨代谢疾病;(4)上肢手术史或肿瘤病史。

### 二、一般资料

回顾性收集2017年9月至2020年5月就诊于北部战区总医院的肱骨近端Neer二、三、四部分骨折患者资料。其中接受了3D打印技术结合PMMA骨水泥髓内支撑辅助锁定钢板治疗的患者36例。3例患者因随访中断原因被排除。最终符合纳入排除标准的患者33例。其中男性5例,女性28例,平均年龄68.4岁(55~87岁),按Neer分型,二部分骨折3例,三部分骨折21例,四部分骨折9例。

本研究已经通过中国人民解放军北部战区总医院伦理委员会批准【(2019)72号】入选患者均对此手术知情同意并签署知情同意书。

### 三、术前准备

完善双侧肱骨正侧位X线及三维重建CT检查,应用岱嘉A-SiteV4.0软件测得健侧肱骨近端颈干角及患侧术前肱骨近端骨折颈干角。

### 四、PMMA骨水泥占位器模具制定

应用螺旋CT扫描双侧肱骨,扫描后导出DICOM格式数据,将双侧肱骨扫描数据导入Mimics Research20.0软件,进行重建3D模型,将健侧肱骨3D模型镜像,与患侧肱骨3D模型与健侧肱骨3D模型镜像对比,根据骨缺损范围,制定PMMA骨水泥占位器模型,将患侧肱骨3D模型数据与骨水泥占位器模型数据导入3D打印机中以光固化树脂材料为原料制作3D打印患侧肱骨模型及骨水泥占位器模具,将占位器置入患侧肱骨近端骨缺损中,检验是否匹配,匹配后根据骨水泥占位器模型制作骨水泥占位器模具并给予灭菌待用(图1~10)。

### 五、指标测量

颈干角及肱骨头高度测量方法:沿肱骨头孟肱关节面上缘与下缘边界绘制线AB,通过肱骨头中心垂直于关节面绘制线C。D线平行于肱骨干,CD



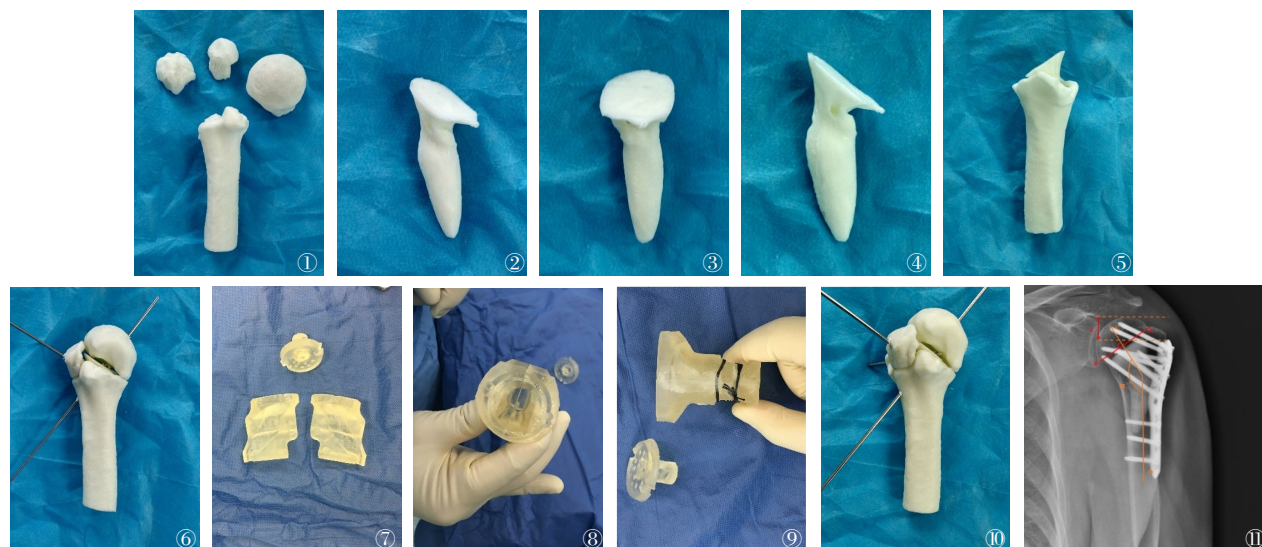


图1~4 根据患者三维重建CT数据打印患侧肱骨模型及髓内支撑占位器模型 图5~7 将髓内支撑占位器模型置入髓腔内,肱骨近端骨折复位克氏针固定,检测髓内支撑占位器与骨折断端匹配,复位良好 图8~10 骨水泥髓内支撑占位器模具 图11 沿肱骨头盂肱关节面上缘与下缘边界绘制线AB,通过肱骨头中心垂直于关节面绘制线C。D线平行于肱骨干,CD线交汇的颈骨干角度为 $\alpha$ 角。沿肱骨头和钢板的上缘绘制两条线(由黄色水平虚线表示),这两条线之间的距离(E)是肱骨头的高度

线交汇的颈骨干角度为 $\alpha$ 角。沿肱骨头和钢板的上缘绘制两条线(由黄色水平虚线表示),这两条线之间的距离(E)代表肱骨头的高度。(图11)每侧颈干角及肱骨头高度测量均由同一位有经验的临床医生测量,每侧颈干角测量3次,取其平均值。

#### 六、手术方法

麻醉满意后,患者取仰卧位,肩部垫高,常规消毒、铺巾,贴皮肤保护膜。从喙突尖开始作一纵行切口,沿三角肌与胸大肌间沟向下至肱骨外侧面三角肌的止点,逐层切开皮肤、皮下组织、仔细分离并保护头静脉,辨明三角肌胸大肌间沟,沿此肌间沟分

离,将头静脉与胸大肌一起牵向内侧。分离肌间隙至三角肌止于三角肌粗隆的止点处。沿胸大肌止点外侧纵行切开骨膜,显露肱骨近端骨折断端。清理骨折断端血肿及软组织,显露大小结节、冈上肌与冈下肌、肩胛下肌止点,将缝线穿过上述止点备用。将加入单体后的PMMA骨水泥注入灭菌的模具,制作骨水泥占位器(图12~17),将固化后的PMMA骨水泥占位器插入肱骨髓腔内(图18),近端支撑肱骨头,远端插入骨折远端的髓腔,支撑肱骨内侧柱。透视下手法复位骨折,使肱骨近端内侧皮质复位。提拉缝线,促进肱骨大小结节复位。使用克氏针临时

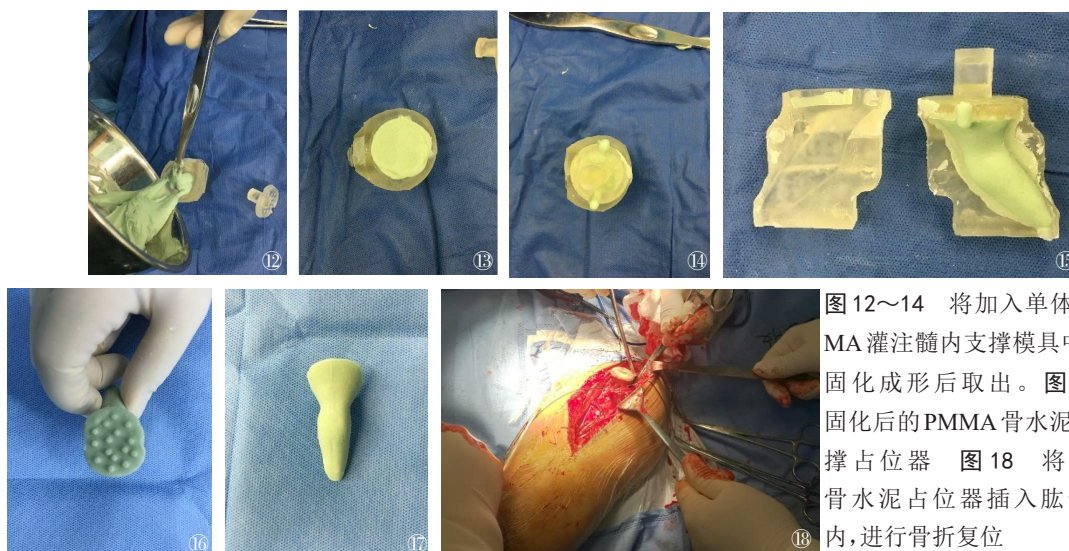


图12~14 将加入单体的PMMA灌注髓内支撑模具中,待其固化成形后取出。图15~17 固化后的PMMA骨水泥髓内支撑占位器 图18 将PMMA骨水泥占位器插入肱骨髓腔内,进行骨折复位

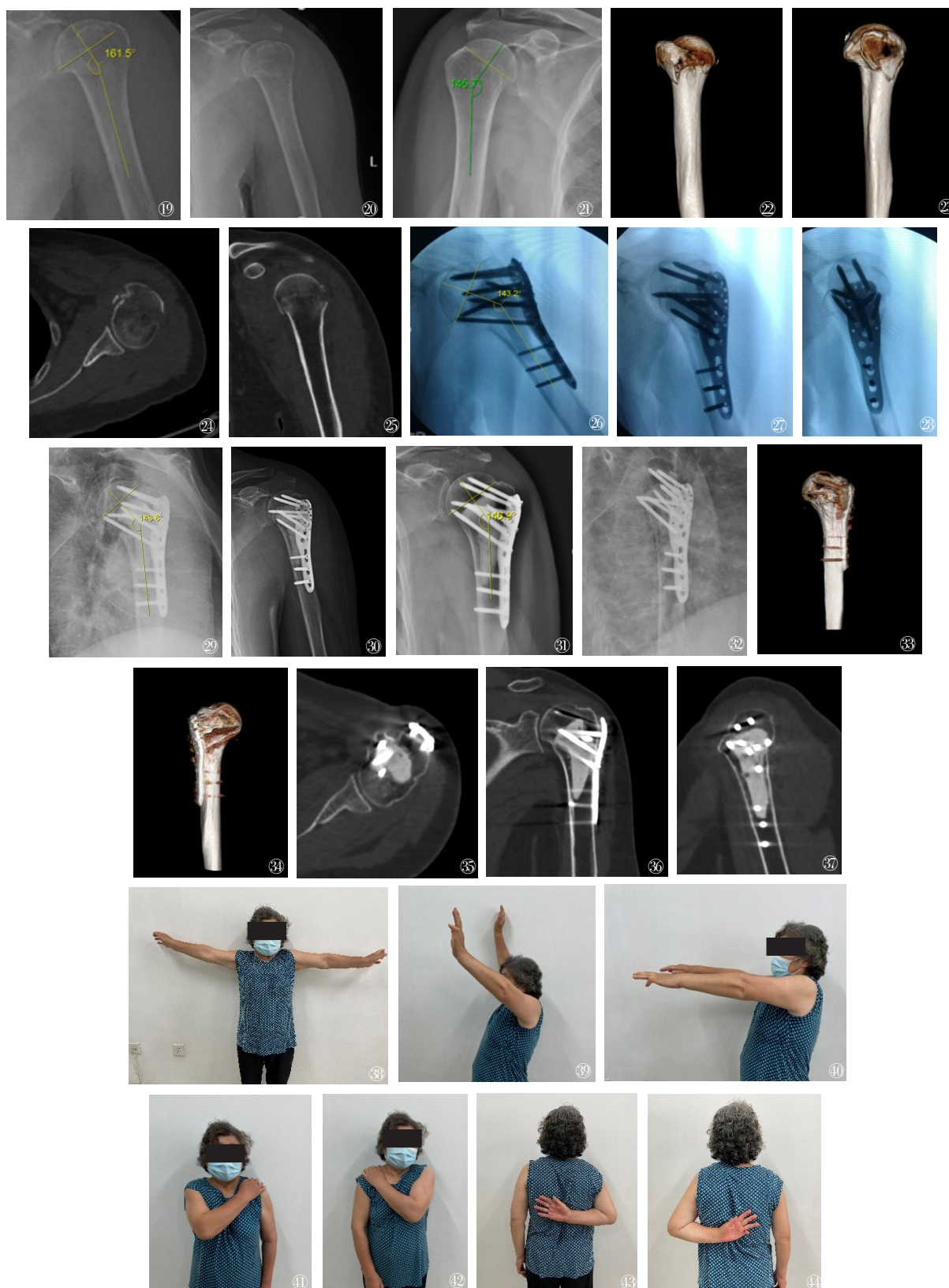


图19~44 女性,65岁,摔伤致左肱骨近端粉碎性骨折,按Neer分型为肱骨近端三部分骨折。图19~21 术前患侧肱骨X线并测量其颈干角为 $161.5^{\circ}$ ;健侧肱骨X线,并测量其颈干角为 $145.7^{\circ}$ ;图22~25 患侧术前三维重建CT;图26~28 术中C臂机透视情况,并测量骨折复位且置入骨水泥占位器后颈干角为 $143.2^{\circ}$ ;图29~30 术后1个月X线。测量其颈干角为 $143.8^{\circ}$ ;图31~32 术后1年患侧肱骨X线并测得颈干角为 $146.9^{\circ}$ ;图33~37 术后1年患侧肱骨CT,提示骨折获得骨性愈合;图38~44 术后1年随访患者上肢功能满意



固定。安装Philos接骨板(大博公司)。探查肱二头肌腱长头腱无卡压、肩袖有无撕裂。设计螺钉分布和数量,依次打入螺钉。将缝合于冈上肌和冈下肌、肩胛下肌缝线通过接骨板孔穿入,收紧打结。再次透视,确认盂肱关节对位良好,肱骨近端骨折对位对线良好,接骨板高度及螺钉长度合适。彻底冲洗,查无活动出血,逐层缝合,关闭伤口,置橡胶引流管1根,无菌敷料包扎。

#### 七、围术期处理及术后康复

术后常规给予氟比洛芬酯注射液100 mg静脉输液2/日×3天、注射用七叶皂苷钠15 mg×3天,静脉输液2/日消肿等对症治疗。术后当日嘱患者适当活动患侧肘关节、手及各指。术后第2日可在家属看护下下床活动。术后第3日查看术区引流量及患者术区情况并拔除引流管。所有患者术后2周进行门诊复诊并接受相应的康复训练指导。术后2周患侧肩关节进行适度的钟摆样活动;术后3周患侧肩关节开始适度内收、内旋等活动;术后4周门诊复查,行影像学检查示在骨折端形成连续性骨痂后开始主动活动。

#### 八、疗效评估与随访

所有患者分别于术后1个月、3个月、6个月、12个月通过电话及门诊复查等方法进行随访。每次复查患者均拍摄患侧肩关节正侧位X线,术后1年行患侧肩关节三维重建CT检查,术后12个月随访时评估Constant-Murley肩关节功能评分、VAS疼痛评分。

评估颈干角丢失程度(术后颈干角恢复到 $120^{\circ} \sim 150^{\circ}$ 视为解剖复位, $< 120^{\circ}$ 或 $> 150^{\circ}$ 则被视为内固定失效发生内翻或外翻畸形,颈干角丢失即内翻角度( $^{\circ}$ )=术后第1次复查时颈干角-末次随访时颈干角<sup>[11]</sup>。

评估肱骨头高度丢失程度(肱骨头高度降低超过5 mm视为内固定结构失效)、肱骨头高度丢失(mm)=术后第1次肱骨头高度×放大比率-末次随访时肱骨头高度×放大比率(以锁定钢板长度为标准)<sup>[11]</sup>。

#### 九、统计学处理

采用SPSS 21.0软件(SPSS公司美国)对数据

进行统计学处理,计量资料经独立样本正态性检验,符合正态分布肱骨颈干角、肱骨头高度、Constant-Murley肩关节功能评分、VAS疼痛评分,均以 $\bar{x} \pm s$ 来表示,术前颈干角、术后1年颈干角及健侧颈干角资料采用单因素方差分析,两两比较采用LSD-*t*检验,术中肱骨头高度与术后1年肱骨头高度对比采用独立样本*t*检验, $P < 0.05$ 为差异有统计学意义。

## 结 果

### 一、一般结果

33例患者均获得完整随访,随访率100%,随访时间12~17个月,平均 $(13.2 \pm 1.5)$ 个月。术后12个月、所有复查三维重建CT显示患者均已获得骨折愈合,无二次手术病例。

### 二、颈干角度数差异变化

Neer二部分骨折中,健侧、术前及术后1年颈干角比较差异有统计学意义( $F=39.038, P < 0.05$ ),两两比较中发现健侧颈干角( $145.33 \pm 1.52$ ) $^{\circ}$ 与术前颈干角( $102.00 \pm 11.13$ ) $^{\circ}$ 比较,差异有统计学意义( $P < 0.05$ ),与术后1年颈干角( $145.67 \pm 2.52$ ) $^{\circ}$ 比较,差异无统计学意义( $P > 0.05$ )。Neer三部分骨折中,健侧、术前及术后1年颈干角比较,差异有统计学意义( $F=13.957, P < 0.05$ ),两两比较中发现健侧颈干角( $145.86 \pm 3.18$ ) $^{\circ}$ 与术前颈干角( $173.90 \pm 35.33$ ) $^{\circ}$ 比较,差异有统计学意义( $P < 0.05$ ),与术后1年颈干角( $143.81 \pm 4.19$ ) $^{\circ}$ 比较,差异无统计学意义( $P > 0.05$ )。Neer四部分骨折中,健侧、术前及术后1年颈干角比较,差异有统计学意义( $F=89.297, P < 0.05$ ),两两比较中健侧颈干角( $146.44 \pm 3.74$ ) $^{\circ}$ 与术前颈干角( $96.22 \pm 14.09$ ) $^{\circ}$ 比较,差异有统计学意义( $P < 0.05$ ),与术后1年颈干角( $141.11 \pm 3.96$ ) $^{\circ}$ 比较,差异无统计学意义( $P > 0.05$ ),见表1。

### 三、肱骨头高度丢失情况

Neer二、三、四部分骨折中,术中肱骨头高度与术后1年肱骨头高度对比无统计学差异。Neer二部

表1 33例患者术前患侧颈干角与健侧颈干角、术后1年患侧颈干角比较( $^{\circ}$ ,  $\bar{x} \pm s$ )

Neer分型	健侧颈干角	术前颈干角	术后1年颈干角	F值	P值
II部分	$145.3 \pm 1.2$	$102.7 \pm 11.3^*$	$145.7 \pm 2.5$	39.038	$< 0.05$
III部分	$145.9 \pm 3.1$	$173.9 \pm 35.3^*$	$143.8 \pm 4.1$	13.957	$< 0.05$
IV部分	$146.4 \pm 3.5$	$96.2 \pm 14.1^*$	$141.1 \pm 3.9$	89.297	$< 0.05$

注:“\*”表示与健侧颈干角比较, $P < 0.05$

表2 33例患者患侧术中肱骨头高度与术后1年肱骨头高度比较(mm,  $\bar{x} \pm s$ )

项目	Ⅱ部分	Ⅲ部分	Ⅳ部分
肱骨头高度-术中( $\bar{X}$ )	16.70±0.37	17.3±0.51	17.83±0.21
肱骨头高度-术后1年( $\bar{Y}$ )	16.00±0.21	16.22±0.32	15.91±0.41
肱骨头高度差异( $ \bar{X}-\bar{Y} $ )	0.70±0.18	1.12±0.24	1.92±0.21
t值	3.780	1.273	1.881
P值	>0.05	>0.05	>0.05

骨折中,肱骨头高度差异平均为(0.70±0.18)mm, Neer三部分骨折中,肱骨头高度差异平均为(1.12±0.24)mm, Neer四部分中肱骨头高度差异平均为(1.92±0.21)mm。见表2。

四、术后1年Constant-Murley 肩关节功能评分与VAS疼痛评分情况

Constant-Murley 肩关节功能评分中,二部分骨折患者为(78.42±4.31)分,三部分骨折患者为(74.34±3.82)分,四部分骨折患者为(69.31±3.43)分,VAS疼痛评分中二部分骨折患者为(1.53±0.81)分,三部分骨折患者为(2.12±0.63)分,四部分骨折患者为(3.14±1.22)分,详见表3。

表3 33例患者术后1年患侧Constant—Murley 肩关节功能评分与VAS评分( $\bar{x} \pm s$ )

Neer分型	Constant—Murley 肩关节功能评分	VAS评分
Ⅱ部分	78.42±4.31	1.53±0.81
Ⅲ部分	74.34±3.82	2.12±0.63
Ⅳ部分	69.31±3.43	3.14±1.22

## 五、并发症及转归

术后1年发生肩关节僵硬患者6例(18%),加强肩关节康复治疗有所缓解;肩关节撞击4例(12%),给予内固定物取出后缓解;肱骨头坏死2例(6%),未出现明显临床症状;螺钉部分穿出1例(3%),给予内固定物取出后症状消失。典型病例见图19~44。

## 讨 论

### 一、老年肱骨近端骨折治疗进展

肱骨近端骨折约占全身骨折的6%。是除桡骨远端和椎骨的第三常见的骨质疏松性骨折<sup>[2]</sup>。对于骨质疏松性骨折,主要以粉碎性骨折为主,往往伴有骨缺损并严重破坏了肱骨头血运,若治疗方式不当

极易导致严重并发症,故大部分老年骨质疏松性肱骨近端骨折需采取手术治疗<sup>[3, 11-12]</sup>,此类骨折复位具有挑战性,固定失败时有发生。多年来,临床上已经发展了几种手术治疗方法,包括各样式的钢板,髓内钉,以及经皮固定技术等<sup>[13-14]</sup>。为治疗老年骨质疏松性肱骨近端骨折,相关学者研制了锁定钢板系统<sup>[15]</sup>。

二、锁定钢板系统治疗肱骨近端粉碎性骨折优缺点

锁定钢板系统在肱骨近端粉碎性骨折的治疗中具有许多优点,生物力学研究表明,在抗旋转及稳定性上锁定钢板较非锁定钢板更加优秀<sup>[16]</sup>,锁定钢板上肱骨距螺钉可提供内侧支撑,减少术后内翻畸形的发生率<sup>[17]</sup>。虽然锁定钢板较传统钢板治疗肱骨近端骨折具有较大优势,但锁定钢板治疗老年肱骨近端骨折中有较多研究指出其相关并发症的发生率较高,如螺钉切出、内翻畸形及肩峰撞击等<sup>[18]</sup>,而有学者指出发生以上情况的因素往往与高龄患者骨骼质量差,骨折复位难度大有密切关系<sup>[19]</sup>。我们在治疗中发现仅仅依靠锁定钢板治疗骨质疏松性肱骨近端骨折无法较好的进行内侧支撑,需要辅助髓内支撑增强锁定钢板稳定性。

### 三、增加锁定钢板稳定性的措施

目前临床上较为常用提供有效内侧支撑的手段主要为骨移植和骨水泥填充。骨移植方面,自体骨移植一直是植骨的第一选择,但由于自体骨数量有限,增加手术创伤,延长手术时间,增加患者痛苦,另外,自体骨质量无法得到保障,甚至出现并发症。正是这些缺陷使自体骨移植在临床应用受到一定的限制。同种异体骨来源广泛,数量充足,质量有所保障,其生物相容性好,可降解,解决了自体骨来源限制,同种异体腓骨在术中透视可显影便于术中操作。因此临床上主要选择同种异体腓骨来进行髓内支撑,Kim等<sup>[20]</sup>将164名Neer分型Ⅲ、Ⅳ型肱骨近端骨折患者分别单纯钢板组与异体腓骨组,结果为同种异体腓骨移植联合锁定钢板组优异,其颈干角差

异小于单纯钢板组,差异具有统计学意义。但同种异体骨价格昂贵,且可能发生排斥反应和疾病传播。

骨水泥填充最早应用于临床是治疗疼痛性椎体内血管瘤<sup>[21-22]</sup>。骨水泥种类繁多,主要包括羟基磷灰石、聚甲基丙烯酸甲酯、硫酸钙骨水泥、磷酸钙骨水泥等,已广泛应用于其他部位的骨质疏松性骨折(如老年髌部骨折、胫骨平台骨折、椎体压缩骨折、脊柱结核及病理性骨折),并得到了良好的疗效。由于应用部位及用途的差异,骨水泥成分也有所变化<sup>[23]</sup>。Katthagen等<sup>[24]</sup>报道提出使用PMMA及磷酸钙(calcium phosphate cement, CPCs)骨水泥辅助锁定钢板,是增强肱骨头内固定的一种有效方法。多项生物力学实验表明<sup>[25-27, 29-30]</sup>,骨水泥不仅增加了骨折端及锁定钢板的稳定性及负载能力,还增加了内固定-骨结构的刚度及扭转失效负荷,降低了骨折块的移位及退钉的发生率<sup>[27]</sup>。Rödere等<sup>[28]</sup>提出局部填充的骨水泥加强了螺钉在肱骨头中的稳定性,具有更高的抗拔出强度。然而,注入PMMA加强螺钉的注入时机难以把握,且无法提供有效髓内支撑、具有放热聚合以及骨水泥渗漏等缺点<sup>[31]</sup>。

#### 四、3D打印技术辅助治疗进展

3D打印技术使二维图像转变为三维立体形态成为可能,使手术医师有机会直观模拟骨折复位情况,并对内固定物进行预先塑型及对放置位置进行调整,为患者制定个体化手术方案。近年来3D打印技术其在医学领域的应用逐渐成熟,为肱骨近端骨折的治疗提供了新的思路<sup>[32-34]</sup>。Howard及彭飞等学者应用3D打印技术打印1:1骨折模型,术前模拟骨折复位固定情况,选择最合适的内固定钢板及确定放置钢板位置,术后获得满意<sup>[35-36]</sup>。

#### 五、研究进展及局限性

我们在临床治疗中发现目前国内使用的肱骨近端内侧支撑重建技术如自体或同种异体腓骨髓内支撑、注入式骨水泥加强螺钉技术等都存在其自身相对的缺点。本研究目的是为改进PMMA加强螺钉无法提供有效髓内支撑,具有放热聚合以及骨水泥渗漏等缺点,并进一步加强骨水泥支撑强度提出3D打印技术结合PMMA(聚甲基丙烯酸甲酯)髓内支撑技术。研究中我们使PMMA骨水泥在体外进行凝聚成型后置入骨折断端,不仅防止体内放热、渗漏,而且PMMA骨水泥凝聚成型后强度足以承受支撑肱骨近端内侧。在本次研究结果中可见改良的3D打印技术结合聚甲基丙烯酸甲酯髓内支撑辅助

philos锁钢板治疗粉碎性骨质疏松性肱骨近端骨折技术可获得满意治疗效果,值得临床上推广。

研究不足之处在于:病例样本量不足,术后随访时间尚且不够,相关测量数据存在误差,研究没有解决PMMA非生物相容性和非生物降解性等缺点。因此我们在今后的研究中将完善可降解类骨水泥的实验,进一步提高3D打印技术结合骨水泥髓内支撑技术的治疗效果。

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