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Review Article

Role of 3D printed customized implants in periarticular fractures: a narrative review

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ABSTRACT

“3D printing” is a common term used for a number of technologies which operate on the principle of converting a computer-generated 3D image into a physical model. Advantage of 3D printed parts is that they can assume complex shape, with solid and porous components that can be combined to provide the best combination of strength and performances and can help visualize the complex fractures which are difficult to apprehend with conventional imaging. Presently, the primary applications for 3D printing are the production of anatomical models for planning and surgery simulation, patient-specific instruments and custom-made prosthesis which have transformed how orthopedic problems are addressed now. This review aims to describe the utility and future directives into the application of this technology in orthopedics.

Keywords: 3D printing, Periarticular fracture, Complex fractures, Customized implants

INTRODUCTION

The advancement of technology in the medical field in the last 2 decades has had a great impact on the management of complex orthopaedic trauma surgeries.[1] Complex fractures, intra-articular fractures and pelvic fractures. With the help of computed tomography and magnetic resonance imaging, 3D reconstructed images can be created to obtain a better picture of fracture morphology.[2] It not only enhances the fracture pattern but It also aids trauma surgeons in planning, including determining the optimal surgical approach, implant placement, screw trajectory, and the need for specialized equipment. As now we have access to a wide variety of implants for a particular fracture, 3D printing could be applied to pick the best possible implant for the most favorable patient outcome.[3] It can be used post-surgery as well to look for correction obtained. The scope of 3D printing extends beyond just fractures, it could also be used to develop individual-specific prostheses.[1]

With this narrative review, we aim to provide the benefit of printing in the medical field along with the challenges faced.

3D TECHNOLOGY

The first phase of the printing process involves modelling. Typically, three-dimensional modelling of the component for manufacturing is carried out using computer-aided design (CAD) software. This software allows the creation of a prototype of the intended item on the computer. If the item to be produced already exists, it can be replicated by scanning it or downloading a pre-existing prototype onto the computer. Following the modelling phase, the part model is segmented into printable layers. Printing is the final action. A printed object is created by stacking more layers on top of the existing ones. As a result, production occurs in a layered structure.[1]

A concept or a requirement is first translated into a model in the printing process, and then into an actual product.

Because of this approach, manufacturing can be done quickly and easily. The bone model must be turned into an STL file in order to specify its surface and send it for printing on a 3D printer. The surfaces of 3D-designed models are subdivided into numerous triangles, and these triangles are then organized mathematically to generate the stereolithography file format, commonly referred to as "STL." In the STL format, surfaces are represented as a collection of triangles, with the surface being formed by simple triangles that interconnect like puzzle pieces. This sequential arrangement ensures that the printing process is executed in a step-by-step manner.[3]

3D printing methods can be categorized based on the physical state of the primary material, which can be solid, liquid, or powder. Various methods are employed for different material types, as indicated in Table 1.

3D printing technology is applicable to a range of materials, including metals, ceramics, composites, and polymers.[2] Among metal materials, commonly utilized ones include stainless steel titanium magnesium, aluminium and CreCo alloys.[4-11] Polymer, being the inaugural material group produced with this technology, still constitutes a substantial portion of the materials used today. Polymers find preference in various 3D printing technologies, such as the use of resin as the necessary supporting structure in the SLA method. Acrylonitrile butadiene styrene (ABS), polyamides, polylactic acid (PLA), polycarbonates (PC), and resins are among the most frequently employed polymer materials in this technology. Particularly in medical applications, the SLA method is favored for polymers like poly (ethylene glycol) diacrylate (PEGDA) and periodontal ligament (PDL), while material extrusion is chosen for ABS, polycaprolactone (PCL), polycarbonate (PC), polylactic acid (PLA), and poly (lactic acid). The SLS technique is preferred for acid-glycolic acid (PLGA), polyvinyl alcohol (PVA), polyetheretherketone (PEEK), and binder spraying methods are favored for polyvinyl and silica.

Usefulness

Accuracy

This has been a major advantage of 3d printing. The generation of precise implants has greatly reduced intra-operative manipulation. It improved the positioning of the incision and screw trajectories.

Surgical time

With more practical pre-operative planning, the surgical time of the study has reduced drastically. There are less wound complications and infection rates.

Intra-operative

The blood loss and requirement of blood transfusion have decreased due to more precise surgery.

Demerits

Model inaccuracy

Some studies suggest that inadequate models may lead in inaccurate reduction. Artefacts might affect the acquisition of parameters and resolution of the image, leading to final errors in volume.

Time

The time required to build the model and plan surgery is cumbersome. It leads to unavoidable delays in surgery. The time required ranges from 10 hours up to 2 weeks based on several studies.

Cost

The cost of camera, printing machine, software is a barrier to this approach. The additional cost is weighed heavily on the patient increasing the economic burden.

Material

The material used in building these models could not be matched to the natural tissues. The rigidity and fragility is also undermined.

USES IN VARIOUS PERIARTICULAR FRACTURES

Upper limb fractures

Proximal humerus

You et al performed a RCT on 66 old patients (61-76-years age group) having complex proximal humeral fractures with 32 patients in the control and 34 patients in the test group. Using 3D printing in the test group, data was acquired from thin-slice CT scans and processed by Mimics software. Parameters like blood loss, surgery duration, need for fluoroscopy and time to the union were compared. Screw lengths measured pre-operatively were compared with intra-operative screws used. The 3D model offered more than just a 360-degree visual representation; it also provided a palpable understanding of the direction and severity of the fracture dislocation. This, in turn, assisted in preoperative diagnosis, surgical planning and design, implant measurement, pre-selection of the suitable anatomical locking plate, and simulation of surgical outcomes. In comparison to the control group, there were reduced surgical duration, decreased blood loss, and a lower number of fluoroscopy instances ($p<0.05$).[12]

Distal humerus

Kim et al conducted a randomized controlled trial (RCT) on the treatment of intercondylar humeral fractures using 3D-printed osteosynthesis plates. Thirteen patients were randomly assigned to undergo open reduction and internal fixation with either conventional plates (7 patients) or 3D-printed plates (6 patients) between March and October 2014. The comparison of operating time and elbow function took place during a follow-up of at least 6 months. All cases were monitored for an average duration of 10.6 months (range: 6-13 months). The 3D printing group exhibited a significantly shorter operating time (ranging from 70.6 to 112.1 minutes) compared to the conventional plating group (ranging from 92.3 to 117.4 minutes). Although there was no significant difference in elbow function between the groups, 3D-printing cases showed a slightly higher rate of favourable outcomes (83.1%) compared to conventional plating (71.4%).[13]

Table 1: Classification of 3D printing methods.

3D printing method	Material type	Material
Powder bed fusion		
SLS	Powder	Metal, ceramic, polymer, photopolymers
SLM	Powder	Metal, polymer
EBM	Powder	Metal, ceramic
VAT-polymerization		
SLA	Liquid	Ceramic, photopolymers
Directed energy deposition		
DED	Powder	Metal, photopolymers
Material jetting	Liquid	Photopolymers
Binder jetting	Liquid	Metal, ceramic, polymer

SLS: Selective laser sintering; SLM: selective laser melting; EBM: electron beam melting; SLA: stereolithography; DED: directed energy deposition

A research conducted by Zhang et al involved 18 cases with cubitus varus deformities, spanning from January 2006 to May 2008, with a male-to-female ratio of 12:6. The age range was 13 to 19 years. Utilizing rapid prototyping, templates were generated for these cases. MIMICS software was employed to create 3D models of cubitus deformities. Osteotomy templates, accurately tailored to the angle and range of osteotomy, were manufactured in a "reverse" manner based on the 3D model. These templates were then employed to guide the corrective surgery. At the 12-24 months follow-up, the average postoperative carrying angle for the 18 patients with cubitus varus deformity was 7.3 degrees, reflecting an average correction of 21.9 degrees.[14]

Zheng et al conducted a comparable study involving 15 pediatric cases with cubitus varus deformities gathered between June 2015 and June 2016. An individualized osteotomy navigation template, matching the distal humerus, was 3D printed for each case. The osteotomy was then carried out using this template, followed by fixation with 2 Kirschner wires, and the elbow was immobilized in 20 degrees of flexion. Minimal complications were observed, and there was a zero revision surgery rate. The average union time was 6.7 weeks. According to Bellemore criteria, twelve patients achieved an excellent result, while two had a good result.[15]

Gemalmaz et al documented a case involving an 18-year-old individual who had undergone a previous operation and presented with a 40-degree cubitus varus deformity and a 20-degree flexion deformity resulting from a malunited supracondylar humerus fracture eight years prior. During the surgery, a custom 3D printed resection guide was employed. The surgical procedure enabled the attainment of a precise osteotomy, leading to accurate correction and a favorable functional outcome.[5]

Yang et al. conducted a randomized controlled trial (RCT) involving 40 cases of elbow fractures, with 20 cases in each group. Surgical duration, achieved anatomical reductions, blood loss, complication rates, and elbow function were assessed through unpaired t-tests to compare the two groups. The 3D printing group exhibited shorter surgical time, reduced blood loss, and higher scores in elbow function compared to the conventional group. Additionally, the patient satisfaction score was higher for the 3D model.[16]

Distal radius

Muinck et al conducted a systematic literature review on 3D-planned corrective osteotomies for distal radial malunion. Three-dimensional planning techniques were employed to address deformities that conventional planning techniques couldn't adequately handle. The analysis included 15 studies with 68 patients. Palmar tilt, radial inclination, and ulnar variance showed significant improvement, being restored to within 5 or 2 mm of their normal values in 96% of cases. There were also significant improvements in average grip strength, flexion-extension, and pro-supination. Complications were noted in 11 out of 68 cases (16%).[17]

Chen et al conducted a RCT in 2019 involving 48 patients with distal end radius fractures. The patients were randomly assigned to either the conventional group (25 patients) or the 3D model group (23 patients). In the first group, each distal radius fracture was digitally modelled in 3D, and the model was sent to a 3D printer to create a fully solid model. Key outcome measures for each surgery included the procedure length, blood loss volume, and intraoperative fluoroscopy frequency. Patient progress and surgical results were monitored using Gartland-Werley scores, radiographic evaluations, and wrist range of motion, classified as secondary outcome measures. Treatment of challenging fractures with 3D printing, when compared to standard care, resulted in decreased intraoperative fluoroscopy frequency, blood loss volume, and operating time. However, it did not show improvement in postoperative function. Patients found the 3D model helpful for understanding their condition and treatment plan, leading them to request explanations from the doctor using the model. While orthopedic surgeons considered the 3D model beneficial for patient communication, their satisfaction with its use for preoperative planning was notably lower.[18]

Hand

Zang et al planned thumb reconstructions with second-toe transfer using 3D printing. Five instances with grade 3 thumb abnormalities had their thumbs repaired between December 2013 and October 2015 using wrap-around flaps and second toe transfers that were designed using 3D printing technology. The surgical simulation software Boholo received input from CT images of the hands and feet. The healthy thumb was used to create the wounded thumb's mirror image. Models of the great toe and second toe were created in order to comprehend the donor site dimensions as well as to construct adequate iliac bone and superficial circumflex iliac artery flaps for the treatment of the donor site defect. The donor's toe and repaired thumb were 3D printed as polylactic acid models. Based on a 3D model of the donor location, a wrap-around flap of the first dorsal metatarsal artery and vein with the bone and joint of the second toe was created. By anastomosing the plantar digital nerve of the great toe and the dorsal nerve of the foot, the sensation was recovered. After two weeks, the exercises were begun. All of the repaired thumbs were still functional, but one patient developed partial flap necrosis that was treated with dressings. Recon-structured thumbs were aesthetically pleasing and functional overall.[19]

Lower limb

Acetabulum

A review of 13 research using 3D printing to treat acetabular fractures was published in 2021 by Cao et al. The patients ranged in age from 32.1 (SD 14.6) to 51.9 (SD 18.9). Overall, 3D printing assisted surgery decreased the length of the procedure by 38.8 minutes (95% CI: -54.9, -22.8), the amount of blood lost during the procedure by 259.7 ml (95% CI: -394.6, -124.9), and the amount of time needed for instrumentation. Traditional surgery was less likely than 3D printing-assisted surgery to result in good or excellent hip function (RR, 0.53; 95% CI: 0.34, 0.82) and was also more likely to result in complications (RR, 1.19; 95% CI: 1.07, 1.33).

As a result, 3D printing improved the effectiveness of treatment for acetabular fractures. It might enhance surgical and clinical results.[20]

In a retrospective review of 52 bi-columnar acetabular fractures, 52 patients were separated into groups A and B based on their desire to use 3D printing services. This analysis was done by Chen et al in 2019. The use of 3D printed patient-specific pre-contoured plates and computer-assisted virtual surgical procedures was implemented in group A (28 patients). Group B (24 patients) used the traditional approach. Hip function, fracture type, surgical time, blood loss during surgery, complications, and radiographic quality of the reduction were all compared between the groups. All patients were treated by the same surgeon. All of the patients in group A underwent actual surgery that was nearly identical to the preoperative simulated operation. Surgery time and blood loss were significantly reduced in group A compared to group B (p=0.05), but satisfaction with the quality of the postoperative fracture reduction and hip function was marginally higher in the 3D printing group.[21]

A case series of 12 acetabular fractures was described by Hurson et al. They were categorised and planned utilising 3D printing prior to surgery, and it was demonstrated that these models helped surgeons, particularly freshly trained surgeons, better comprehend the unique fracture anatomy. In a case-control research by Maini et al, 10 cases in which pre-contoured plates were manufactured using 3D printing technology were compared to 11 controls in which conventional planning and surgery were performed. They discovered that intra-operatively contoured plates for acetabular fractures were succeeded by patient-specific pre-contoured plates created using a 3D model. Real-time 3D pelvic modelling was also discovered to be a reliable method for pre-operative planning in acetabular fractures. Additionally, Bagaria et al came to the conclusion that 3D printing could aid surgeons in comprehending complicated fractures and achieving near anatomical reduction.[22]

Downey et al conducted a prospective observational study in 2019 involving 20 patients with acute displaced pelvi-acetabular fractures, comparing ten cases with 3D-printed models to ten non-printed cases. The comparison cohorts were matched for fracture classification, sex, and age. Parameters considered included classification assistance, intra-operative time, estimated blood loss, screening amount, post-operative reduction and infection, EQ-5D-5L, teaching/educational assistance, and pre-operative counselling. Notably, while the 3D-printed models provided more information on fracture patterns, they did not result in changes to the CT-planned approach, procedure, or patient outcomes. However, the models received high scores on the surgeon's questionnaire. They proved beneficial for trainee education and patient consenting and counselling. Nevertheless, there were no significant improvements in time-to-surgery, surgical time, estimated blood loss, screening amount, fracture reduction, or infection rate. The quality of life questionnaire indicated no significant difference at approximately 12 months post-surgery, with statistical tests including Cohen’s effect size and Fisher’s exact test.[23]

In 2019, Hsu et al published a retrospective analysis that comprised 29 patients who had acetabular fractures fixed with locking plates. The Letournel-Judet classification was used to categorise different forms of fractures. The two surgical groups were compared regarding operation time, instrumentation time, blood loss, post-operative fracture reduction quality, and complication rates. In contrast to the control group, the 3D-printing group demonstrated significantly shorter instrumentation time and total surgical time for fractures involving the posterior wall or posterior column (222.75±48.12 and 35.75±9.21 minutes, respectively; p<0.05). Additionally, there was significantly less blood loss in the 3D-printing group for fractures involving the anterior column (43.40±10.92 minutes and 433.33±317.28 ml, respectively p<0.05). Consensus-determined post-operative radiological outcomes for both groups were similar (good/fair: 14/3 versus 11/1; p=0.622). The 3D printing group experienced fewer complications (16.67 versus 29.41%) than the conventional group.[24]

In a retrospective study conducted in 2020 by Ansari et al, acetabular fractures were included and categorized into two groups (conventional and 3D printing) over the course of a year. The study assessed operative time (from skin incision to suture), intraoperative blood loss (recorded from anaesthetist notes), intraoperative fluoroscopy times, postoperative complications, fracture reduction quality (classified as good if <2 mm displacement, fair if >2 mm displacement), and Harris hip score at the final follow-up as comparison indices for the two groups. Significant variations were observed in operative time, intraoperative blood loss, and the number of intraoperative fluoroscopy pictures. The average operation time was 62 minutes less in the 3D printing group. There was no difference in the degree of reduction in either of the groups (p>0.05).[25]

Pelvis

In a study conducted by Cai et al between 2014 and 2016, 137 cases underwent minimally invasive cannulated screw repair for unstable pelvic fractures using 3D printing technology. A retrospective evaluation of postoperative reduction, intraoperative fluoroscopy requirements, fracture healing time, and function was performed for both the 3D printing group (n=65) and the control group (n=72). No noticeable differences were observed between the two groups concerning age, gender, fracture type, duration from injury to operation, injury etiology, and combined injury. The control group exhibited significantly longer recovery times and a higher average number of fluoroscopies. In the 3D printing group, 21 out of 65 patients (32.3%) had an excellent reduction, and 30 out of 65 patients (46.2%) had a good reduction, while in the control group, 22 out of 72 patients (30.6%) had an excellent reduction, and 36 out of 72 patients (50%) had a good reduction based on the Matta radiological rating system. According to the Majeed functional rating standards, the 3D printing group had 27 out of 65 patients (41.5%) rated as excellent and 26 out of 65 patients (40%) as good, compared to 30 out of 72 patients (41.7%) rated as excellent and 28 out of 72 patients (38.9%) as good in the control group. Overall, there was no noticeable difference in functional results between the two groups.[26]

Wu et al assessed the application of 3D printing technology in surgically repairing ancient pelvic fractures. Initially, 16 dried cadaveric human pelvic bones were used to validate the anatomical precision of 3D models generated from radiography data. Subsequently, the surgical procedure was assessed using 3D printed models in nine patients treated between January 2009 and April 2013. For type C pelvic injuries, the average time from injury to reconstruction was 11 weeks (range: 8-17 weeks). Creating a model from CT DICOM data took approximately 7 hours (range: 6-9 h). In all nine patients, a strong correlation was observed between preoperative planning and postoperative follow-up radiographs. There were no reported wound issues or non-unions. According to the Majeed score, the outcome was excellent in two cases, good in five, and poor in two patients.[27]

In 38 patients between August 2012 and February 2014, Zeng et al examined the effectiveness of 3D printing-assisted internal fixation for unstable pelvic fracture utilising a minimally invasive para-rectus technique. On a 3D printed pelvic model, the ideal entrance locations, plate alignment, and screw trajectories were practised during a simulated operation. The precise implant location was confirmed by radiographs. The results were 94.4% excellent and good on Majeed's assessment and 97.37% excellent and good on Matta's score. The average surgical time was 110 minutes, with a 320 ml intraoperative blood loss, and a 6.5 cm incision. The method was therefore practical, safe, and efficient with the benefits of low trauma, a little bleeding, quick healing, and precise reduction. 35 Interestingly, curved peri-acetabular osteotomies have also been performed during pelvic and hip surgeries using 3D-printed intraoperative guides.[28]

Distal femur

21 examples of distal femoral fractures that were treated with 3D printing and the Mimics programme were examined by Lin et al. The navigation module practised placing the plates and screws. The screw entrance points' 3D coordinate values were discovered. With the aid of the navigation module, 21 plates and 180 screws were installed. In 21 cases, CT with 3D reconstruction was done after surgery. With no appreciable variations in the geographic location of screw entry sites, plate position was compatible with the prediction made by Mimics software.

Arnal-Burron et al employed 3D-printed cutting guides for opening-wedge distal femoral osteotomies in 12 consecutive cases, comparing them to 20 controls who underwent standard surgery. The group utilizing 3D guides exhibited superior accuracy in axial correction, surgical time, fluoroscopic time, and financial outcomes.[29]

Similarly, Shi et al addressed valgus knee malalignment along with lateral compartment disease through medial closing-wedge distal femoral osteotomy (MCWDFO), utilizing 3D-printed cutting guides and locking guides in 12 cases, as opposed to a traditional approach in 21 cases. For patients presenting with lateral compartment disease and valgus deformity, the use of 3D-printed cutting and locking guides demonstrated enhanced precision in

MCWDFO, resulting in faster surgery and reduced fluoroscopy time. Interestingly, Chen et al also reached the conclusion that the accuracy of distal femoral osteotomy for treating valgus knees with osteoarthritis could be significantly enhanced by employing 3D-printed cutting blocks.[30]

Proximal tibia

When dealing with tibial plateau fractures and employing 3D printing, Huang et al investigated and contrasted the discrepancies in screw placement between preoperative and postoperative screw trajectories. They considered screw lengths, entry point locations, and screw directions to achieve optimal fixation results. Notably, there was no observable difference between the ideal and actual screw trajectories in terms of screw length, entry point, or projection angle aberrations.

In addressing displaced tibial plateau fractures, Giannetti et al conducted a comparative analysis of the outcomes of minimally invasive reduction and internal fixation with and without the utilization of 3D printing in 40 consecutive adult cases. Among these cases, 16 had preoperative and intraoperative 3D models, while 24 cases relied solely on CT images. The use of 3D printing resulted in a significant reduction in surgery time, blood loss, and radiation exposure. No complications were reported, and the functional outcomes were identical.[31]

In order to treat a 36-year-old man who had suffered a Schatzker type 2 right proximal tibial fracture as a result of a car accident, Vaishya et al. used a 3D-printed model to outline the patterns of the fractures and to determine the precise location of the plate and the screw trajectories. The fracture needed an additional screw from above the proximal end of the plate to fix the pieces adequately, according to a 3D-printed model. To achieve anatomic reduction with the least amount of blood loss and soft-tissue dissection, the LISS system was employed in conjunction with an additional 7 mm cancellous screw proximally. The plan could be explained to the patient prior to surgery, and there was little additional expense. As a result, this technology has a lot of potential in the Indian context.[32]

In a study conducted by Yang et al between September 2012 and September 2014, 7 patients underwent 3D printing-assisted osteotomy for the treatment of malunited lateral plateau fractures. Data from CT images were used for 3D reconstruction. According to Schatzker classification, the first fracture types were 3 kinds I, 1 type II, and 3 types III. 9.4 mm was the average lateral tibial plateau collapse (range from 4 mm to 12 mm). The osteotomy was precisely planned and carried out thanks to 3D printing technology, which also helped to speed up surgery and cut down on blood loss and postoperative deformity.[33]

Tibial pilon and malleolar fractures

Chung et al effectively managed challenging distal tibial fractures by employing 3D printing technology. This allowed for a comprehensive understanding of intricate fracture patterns, preoperative templating, selection of anatomical plates, and planning of screw trajectories.[34]

Talus

Utilizing CT scans of 15 normal feet, Wu et al investigated the utilization of 3D printing for optimizing posterior screw placement and determining safe zone geometry for the fixation of the talar neck. The 3D reconstruction was accomplished using Mimics software, and 4 mm screws were simulated from the lateral tubercle of the posterior process to the talar head. Evaluation was conducted at nine areas where the screws did not breach the cortex, assessing screw trajectories and lengths. Measurements were taken for the furthest and closest locations to the subtalar joint within the safe zone, as well as the horizontal angle perpendicular to the sagittal plane and the anteversion angle parallel to it.

The identified safe zone spanned from the 30% location to the 60% location, exhibiting a width of 13.6±1.4 degrees and a maximum height of 7.8±1.2 degrees for each safe zone. The establishment of a safe zone for posterior screw fixation, with fewer fractures, offers potential benefits such as enhanced stability, accelerated procedures, and reduced complications.[35]

Calcaneum

By mirror imaging from the opposing side, Chung et al employed 3D printing to produce models of intact ipsilateral calcaneum and calcaneal fractures. For the percutaneous fixation of calcaneal fractures, they also produced preshaped calcaneal plates.

Wu et al assessed the efficacy of intraarticular calcaneal fractures treated from March 2015 to May 2016 using cannulated screw fixation and percutaneous minimally invasive reduction assisted by 3D printing. Saunders classified 12 instances as type II and 7 cases as type III, but Essex-Lopresti classified 13 cases as tongue type and 6 cases as joint-depression type. To accomplish pre-fracture anatomy, a thin slice CT scan of both calcanei was acquired, and mirror images of the contralateral side and the fractured side of the calcanei were printed.

On X-ray films, Bohler and Gissane angles showed a significant improvement right after surgery and did not alter considerably at the most recent follow-up. The outcomes were exceptional in 10 feet, good in 7, and fair in 2, according to the AOFAS score of 76e100 (mean 88.2).[36]

Atypical femoral fracture: bowed femur

To explore the technical complexities associated with the use of commercially available intramedullary nailing devices for treating atypical femoral fractures with significant bending, Park et al employed preoperative templating and 3D printed models. The 3D printing generated an average anterior bow radius of curvature and lateral bowing angle of the femur, measuring 772 mm and 15.48, respectively. Various aspects, including the nail's location within the medullary canal, distal tip penetration of the femoral cortex, and perforation near the knee joint, were examined. Unreamed femoral nails, cannulated femoral nails, Sirus nails, the "opposite side" expert Asian femoral nail, and Zimmer Natural Nails were all adequately contained in the medullary canal in the sagittal plane. In the coronal plane, only Sirus' nail fit appropriately. However, the distal tips of all other nails, positioned between 2.8 and 11.7 cm above the distal femoral condylar end, penetrated the anterior cortex. Notably, none of the nails, including the proximal femoral nail, achieved satisfactory fracture reduction during simulation. Utilizing a nailing system with a short radius of curvature and adopting patient-specific approaches could enhance the fit of these nails.[37]

CONCLUSION

The collaboration of engineering in medical field has greatly improved the outcomes. With the help of 3D printing models, patients can have better surgical outcomes compared to conventional methods. The use of 3D printing in trauma and limb reconstruction has improved the accuracy of surgeon, reducing the intraoperative time, but at the same time increasing the pre-operative planning time and decision making. Overall the complication rates have reduced with better functionality results.

However, the availability of 3D printing is a major limitation as it is not easily accessible to all. The developing countries cannot outweigh the economic burden it costs. With the ever emerging science, the cheaper and more reliable models can greatly overcome these demerits of printing.

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