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Review Article

Recent Advances in Deformity Correction-A Review Article

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Received: May 19, 2021; **Published:** June 29, 2021

Abstract

The field of deformity correction is advancing at a rapid pace and with the advent of newer techniques, the doctors are able to provide accurate correction with lesser and lesser time entailed in the process. It has become imperative that the surgeons can learn the latest techniques and instruments so that the patient can benefit from it. In this review article, we have tried to go through the latest in the field of deformity correction.

Keywords: *Hexapod; Ilizarov Fixator; Limb Deformity; Ortho Suv; Precice Nail*

Introduction

With the advent of new and improved techniques and software, all the fields of medicine have come a long way. These improvements in the techniques and the ability to plan the surgeries beforehand not only familiarises the surgeon regarding the steps of the surgery and the instruments and implants required for the surgery but also warns regarding the possible difficulties that can be encountered during the surgery.

In this article, we have highlighted the latest in deformity correction and the various planning modalities used.

Picture archiving and communicating systems (PACS)

This involves the use of computer software to visualize X-rays, CT scans, MRIs, Ultrasound images on the computer screen. This is now being preferred over printed films for the review of the same as the doctor can review the images which are warranted on a big screen along with the ability to magnify the area of concern so as to better study the same.

The software can also be used for the measurements of various angles and the drawing of the axes of the limbs. The measurements were previously done on X-rays directly or tracing on paper. The up gradation to the software makes these calculations fast and also easily accessible. PACS consists of software including HOROS, Micro DICOM, Free DICOM viewer, Synapse, and so on. PACS can also be used for planning purposes. For example, for the planning of the wedge for high tibial osteotomy, we can either use the Miniaci., *et al*. method or the Coventry method.

To get the correct assessment of the rotational deformity the rotational profile can be calculated in the axial section of the CT scans (Figure 1). This can be done easily in the PACS system on the computer. The CT scan can also be used to help in the 3D visualization of the deformity on the computer and hence, can look for any masked deformities or fractures which can be easily missed on X-rays.

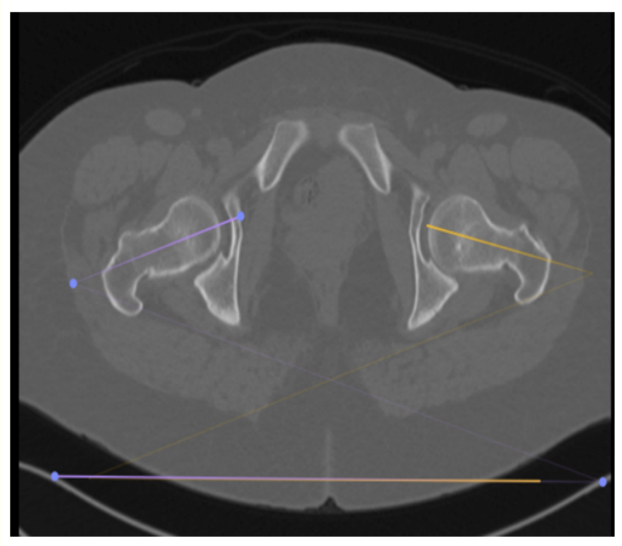

Figure 1: *Shows the calculation of the neck shaft angle on both sides. this gives an estimate regarding the possible retroversion of the hip.*

Deformity correction software

These software help in the calculation of the deformity present and the osteotomy required for the correction of the same. It helps the surgeon by simulating the correction of the deformity. The surgeon can plan and analyze the different osteotomies at different levels and then can choose the best technique for the patient.

The software includes Traumacad (Figure 2), Bone ninja app, Medicad and so on. The comparison of the commonly used software is given in the table below (Table 1) [1].

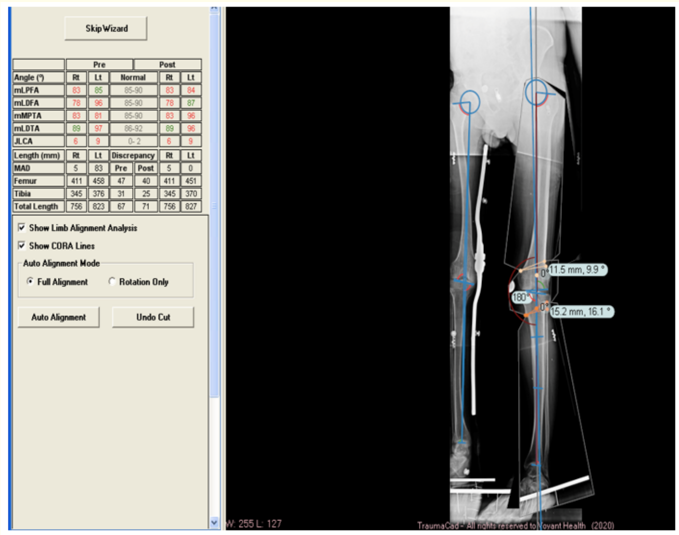

Figure 2: *Traumacad Software being used to assess the deformity and wedge calculation for the correction of the deformity.*

Traumacad	Medicad	Orthoview	Modi cas	Bone Ninja
TraumaCad provides digital tools to preoperatively plan procedures and simulate the expected surgical outcome, as well as quickly assess clinical measurements, prostheses size, and visualize osteotomies and fracture reductions. It saves time by automatically detecting the anatomical regions and calibration devices. With the latest updates the component sizes are also updated. With the Mobile App now this planning can also be done on the go. For the Joint replacement surgeries it automatically detects the sizes of the prosthesis and helps by decreasing the timing of the surgery. It is FDA approved software for the planning of software correction.	mediCAD is more advanced than TraumaCAD as it contains modules for the Patellofemoral measurements which help in dealing with the Patellofemoral arthritis as it takes into account the tracking of the surgery. It takes into consideration the rotation deformity of the tibia and femur along with the trochlear classification and the patellar height. In addition to coronal plane and saggital plane deformity planning the software can also plan for derotation osteotomy. Planning is done in 2D, 3D imaging, CT imaging, MRI and CT scan	Orthoview is a Web based deformity correction software. It can be integrated with PACS system and can be used for planning for joints, deformity correction along with fracture management. This software also includes digital templating for the prosthesis.	This is not only used for the orthopaedic planning and execution but is also used in various other surgeries. The Preoperative planning can also be used to manufacture patient specific 3D implant templates. It also lets the surgeon enter his preop planning in the navigation surgery or in robotic surgery. The robotic surgery is surgeon driven so if at any step there seems to be problem then we can control it. It can do the planning in 3D and is really efficient in executing the planning done preoperatively.	Bone ninja app deals with the planning of deformity correction. However, there are no predestined lines which can be used as a measure of the correction achieved. It can be used as a patient education tool.

Table 1: *Comparison of various deformity correction software.*

Navigation system for real time correction

Navigation system use has increased in recent times. The Navigation system uses markers which when placed on the bone can detect and show on the computer how the changes in alignment are happening. This helps in the real time visualization of the deformity correction on the operation table. This technique has been described while performing High tibial osteotomy and it has given good results [2]. The only drawback felt was the overcorrection of the deformity, as the correction dent take into account the dynamic component of the deformity which are visualized when weight bearing is done.

This technique is still new and has not been widely used. It requires a learning curve and the results are equivalent to HTOs done without navigation system. Also, the navigation system is expensive.

Six-axis devices

These devices are attached to the Ilizarov rings and help in the 3D correction of the deformity. This is done with the help of 6 moving struts which help in the correction. The movement of each strut can be calculated with the help of computer programs which make the trigonometric calculations easy. Currently the six axis devices in use are Taylor Spatial Frame (TSF) (United States) [3-5], Ortho SUV frame

(OSF) [5-7] (Figure 3), Russia, Ilizarov Hexapod Apparatus (IHA) (Germany) [3,5,8], Smart-correction device (Turkey-US) and TL-Hex (United States). A comparative table (Table 2) provides insights into the various six-axis devices being used nowadays. Research is underway to make these struts lighter which will help to make the frame also light and allow the patients to walk easily.

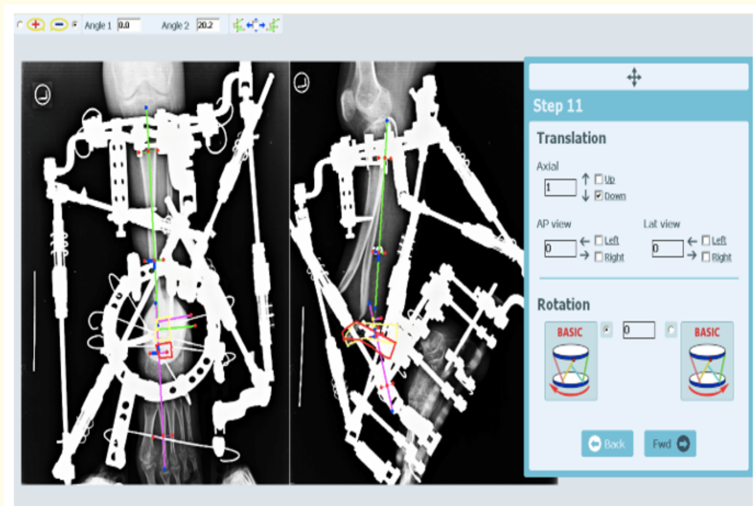

Figure 3: *Shows the software for the Ortho SUV frame. The bone ends also helps in the visualisation of the correction.*

	Taylor Spatial frame	**Ilizarov Hexapod Apparatus**	**Ortho SUV Frame**
Advantages	Comfortable for the patient Clickers present It can be used for fast correction of deformity or fracture reduction.	Struts are in construction instead of the cordon ball joints. Leads to less initial instability Changing the strut length easier than TSF Can be applied to any Ilizarov ring. Can be applied to any place in the ring.	External supports of any company and any shape or sizes can be used the rings can be applied at any angle to the bony axis. Bone can be centric or eccentric Strut attachment to the ring can be done directly or via 'Z' plate Struts can be fixed not only to the rings but can also be applied to the additional stabilizing supports It is advisable to make all the triangles equilateral however, it is not mandatory. The strut lengths depend on the length of the threaded rods used so to increase the length of the struts are re-equipped and don't need to be changed Correction of the bone contours can be visualized while seeing on the software. The change in the strut lengths can happen at the minimum rate of 0.25 mm at a time. Improves the quality of the regenerate No additional data is required to be entered in the program

Table 2: *Comparison of the various six axis devices.*

Octopods [9]

There is also the advent of an octagonal circular external fixator for the correction of the deformity. These are 3rd generation circular external fixation devices consisting of 4 main vertical struts between 2 rings and 4 diagonal assisting mobile struts. They are also known as octopods and can handle a wider range of deformity correction. They are superior to the hexapods (2nd generation external fixation devices) as they don't require changing of struts. The Adam frame external fixator is an example of the same. The X-rays are uploaded in the Jonah Bone Navigation software and the measurements are automatically taken by the software and the I-Tech Bone Correction software does the calculations for the bone correction. This helps in reducing measurement errors. These struts can also be used without the software.

Customized jigs for the deformity correction

With the help of 3D images, customized jigs can now be made for helping the correction of deformity. This can decrease the operating time and will give better results as the planning can be done prior to the surgery and all the different scenarios can be planned and the procedure can be performed uneventfully.

Various methods of limb lengthening

The Limb length discrepancies can be managed with the help of conventional lengthening by the Ilizarov technique or with intramedullary devices which can expand and hence, cause the lengthening process to occur. The following table (Table 3) analysis and lists out the advantages and disadvantages of all the modes of lengthening.

	Advantages	Disadvantages
Ilizarov Fixator [10]	Can manage gradual deformity correction along with the lengthening After the lengthening is over then no hardware is present in the bone Cheaper than the intramedullary devices	Cumbersome to the patient Fixator care has to be done till the bone consolidates High incidence of pin site infection Scars of the pin site may be of concern The muscle becomes transfixed by the wires and schanz screws leading to muscle contractures, joint stiffness and pain
Rail fixator	More convenient compared to Ilizarov especially in femur	Gradual deformity correction cannot be done While distracting there are chances of development of varus/valgus deformity as the surface which has the pins get more force as compared to the other surface (lateral surface of the femur causing slight valgus) Remaining disadvantages similar to Ilizarov procedure
Fitbone (Germany) [11-14]	Electronic motorised lengthening activated by an external transmitter which doesnot warrant rotation movement to lengthen the scars are lesser than the External fixator It is very convenient to use Since the muscles are not transfixed with the wires and screws the pain happening during the distraction is less.	3-17% of device related re-operation rate has been seen 25% of patient are unable to reach the entire length of planned lengthening After these studies the implant has been upgraded No deformity correction possible More expensive than the fixators
Albizzia (France) [11-14]	Fully implantable nail and the distraction is achieved by 20º torsion along the horizontal axis of the bone. Rest advantages same as Fitbone	Large amount of pain associated with large degree of torsion required for the lengthening This led to failed lengthening or return to the OT for closed manipulation of the lower limb These implants have also been upgraded after these issues No deformity correction possible More expensive than the fixators
Phenix nail (France) [11-14]	Activated by a large handheld magnet. By rotating the magnet around the leg, the nail rotated with the help of an internal crankshaft mechanism leading to distraction Rotating the magnet in one direction leads to the lengthening and in the other direction leads to shortening	Only a small number of cases have been done and it awaits FDA approval.

Table 3: *Comparison of various mechanism of limb lengthening.*

Holography projections in orthopedics [15]

Holography is a non-contact 3D projection of any part of the human body or any of the internal organs. This can be used in the planning of complex surgeries of deformity correction. It can be used to study the frame design and the strain present on pins and rods. It can help in planning as the muscles, blood vessels, and nerves are visualized in 3D and with this, the surgeon can plan the plane of dissection and the correct placement of pins and screws. This technology also provides information regarding the osteochondral defects, cost-effectiveness of the surgery, surgical training, and eventually improves patient care. Current limitations to this technology include the complicated method to load the data for the projection. Also, the holography method does not produce complex structures.

Further research is going on in this technology and soon doctors will be able to take measurements of the deformities and improvement in the planning aspect with the availability of producing complex holographic images. With the advancements in the technique, the surgeons will be able to perform surgery on the hologram and will be able to practice surgical steps and anticipate if any change of steps is required or the complications which can happen during the surgery.

Use of 3D printing [16,17]

3D printers are becoming more and more common with the indications expanding in the medical field. The DICOM images of the CT and MRI are processed in a 3D model which can then be manipulated or used as a template on which virtual planning can be done. With the help of 3D printing, the model can be made and various plans can be executed to see the best outcome. 3D printing can also be used for making specialized Jigs which can help in the accurate correction of the deformity by osteotomy along with the markers in the jigs which can be followed by internal fixation. Metal 3D printing can be used to make specialized implants or specific instrumentations which can be beneficial for the surgeon. The specialized implants can be made as per the requirement as generated by the preoperative planning on a 3D model on the computer.

The 3D printing works with a concept of additive manufacturing which means that the raw materials are added as per the program instead of the other manufacturing processes in which the material is shaved off as per the plan. With the 3D printer, it is easy to use stronger materials like titanium.

It can also be used for teaching purposes where various bone models can be created for teaching purposes. Also, it can help in the surgeon visualizing the deformity and planning for the same by printing of the bone model and planning the surgery on it.

Further research is underway in which 3D printing of the biocomposite structures are being looked into to allow implantation instead of a bone.

Use of 4-D printing [18]

4D printing is the use of smart materials with existing 3D printing machines. The smart materials can change shape with time and other parameters like humidity/pressure/temperature, etc. 3D printing produces a static output which does not change with time as it uses various materials like metals, powders, thermoplastic polymers, UV curable resins, etc. 4D can be used to produce materials like bones of the wrist and ankle, organs like skin, liver, kidney, and tissues in which the mechanical properties change with the activity of the patient like muscles, cardiovascular tissues.

Use of 5-D printing [19]

It is a new technology which is one up on 3D printing. 5D printing produces curved surfaces instead of straight surfaces. The main difference is its use of 5 axis printing. The printing bed can move in 2 more axes apart from the X, Y and Z-axis. This produces stronger materials as compared to the 3D printer. It is better in printing strong bone implants and also artificial bones. It has 2 advantages - it can print curved surfaces and the output is 4 times stronger than the 3D printed output. It also uses less material. The planning and the data input is the same as in 3D printing.

The orthoplastic approach [20]

It is the partnership between Orthopaedic and Plastic surgeon which has become the need of the hour. The salvage of complex trauma with comminuted fractures and soft tissue damage depends on the successful stabilization by the orthopedic surgeon and soft tissue coverage by the plastic surgeon. With the help of microsurgery, the orthoplastic limb surgery is slowly gaining momentum. The benefits of orthoplastic surgery are quicker bone union, more durable soft tissue coverage, lower chances of revision surgery, less pain, better function, fewer complications, shorter hospital stay, and higher patient satisfaction. With the better salvage of complicated trauma with this orthoplastic surgery, the rate of amputations has reduced, and the long-term results have improved.

Apart from orthoplastic surgery, other evolving branches are allotransplantation, regenerative surgery, robotic surgery, vascular repair, nerve injury, and brachial plexus injury. Not only surgery the orthoplastic approach can also be used for tumour excision, exposed/ infected prosthesis, osteomyelitis, and avascular necrosis.

Conclusion

With the advent of newer techniques and gadgets the time and the accuracy of deformity correction has improved and it is bound to improve even further as technology advances.

Funding Support

No funding taken.

Conflicts of Interest/Competing Interests

The authors did not have any conflict of interest or competing interests.

Ethics Approval

Not applicable.

Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Availability of Data and Material

Referencing done according to the data taken.

Code Availability (Software Application or Custom Code)

Not applicable.

Authors' Contributions

All the work was done by the single author.

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Volume 12 Issue 7 July 2021