3D printing in designing of anatomical posterior column plate

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ABSTRACT

Background: Acetabulum has a complex anatomy due to which anatomical acetabular plates are still under developmental phase. Although intra-operative contouring of reconstruction plate is done as a standard practice, it is associated with increased operative time and morbidity of patient. We have designed an acetabular plate for posterior fixation from experience of previous studies performed in our institute on acetabular fracture fixation which should be appropriate for most of the patient of Indian origin. Apart from avoiding intra-operative contouring of acetabular plates it also helps in preventing intra articular screw penetration.

Methods: We selected five consecutive patients with acetabular fracture needed to be operated from posterior approach and designed patient specific plate template from virtual surgical planning and 3D printing. These plate templates were then matched with our acetabular plate design and were used intra-operatively. Many parameters were assessed to evaluate accuracy of our plate design in those five patients.

Result: All the plate templates appear to match our designed plate and no intra-operative contouring was required with our plate design.

Conclusion: This was a pilot study and we need a large sample size to study accuracy of our acetabular plate design which might avoid intra-operative contouring, decreasing morbidity of patient and prevent wastage of resources in pre-operative planning and computer designing.

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1. Introduction

Anatomical peri-articular plates are now standard of care in most of the articular fractures. Anatomical plates for acetabular fractures are still under developmental phase. Intra-operative contouring of reconstruction plate is the standard practice.¹ Fixation of posterior column of acetabulum normally has two possibilities: Either a single or two plates. The positions of two plates are also constant; the anterior plate being adjacent to acetabular rim making a beginning from ischial tuberosity following the curve of acetabulum and ending in the supra-acetabular area. The standard fixation is by 2 screws each in

the ischial tuberosity and supra-acetabular area. The second plate runs adjacent to the greater sciatic notch and Sacro-iliac joint superiorly.

Only few studies have been done for development of posterior plate design for fixation of acetabular fractures.^{2–4} However, none of the studies came out with any conclusive plate design or any further direction on design development of acetabular plates for posterior fixation.

Over eight years of our published experience on acetabular fracture fixation has brought out few facts which have been the basis of the posterior anatomical plate design.^{5–8} We intend to share our initial experience with a new design of posterior column plate for acetabular fractures. The philosophy of this new design is an outcome of printing 3D templates of posterior fixation plates and evaluating these prototypes.

2. Methodology

It was an observational study which included consecutive five patients who came to our institute from January to March 2018 with acetabular fracture and required posterior fixation. Kocher-

Abbreviation: NCCT, Non-Contrast Computed Tomography; 3D, 3 Dimensional; DICOM, Digital Imaging and Communication in Medicine.

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langenbeck approach was used for posterior fixation. Written informed consent for the operative procedure and associated risks were taken from all the patients.

2.1. Concept development of plate design

Over last eight years, 180 cases of posterior fixation of acetabular fracture were done. All the patients were part of the ongoing research on acetabular fractures in the department.^{5–8} These patients were virtually planned and desired plate templates were 3D printed. Over the period of time it was observed that the plates had some constant features.

We observed that posterior column is invariably fixed with one 8–9 holed and one 7–8 holed 3.5 mm reconstruction plate. Also, posterior column plate has three curves in coronal and sagittal plane each. We have named them as ischial, acetabular and iliac curves (Fig. 1 a & b). Another important point is that usually the difference in the curve of plate for fixation in two different individuals will come in acetabular portion only. This difference in our experience has also been very insignificant since most of our patients were male patients of height 5 feet 5 inches to 5 feet 7 inches. This would correspond to an acetabular cup size of 50–54 mm diameter.

These 3D printed plate templates which were collected over the time period of eight years were manually evaluated by three independent observers (Figs. 2 and 3). All three observers came out

with the result that there is a fixed contour of a posterior column plates. Final design was generated from a plate template of one patient and five plates (3 for right and 2 for left side) were manufactured using the design.

These plates carried the same plate specifications of 3.5 mm reconstruction plates, so no in-vitro testing was done. An additional feature added was that there were no screw holes in the unsafe zone of the posterior column to avoid joint penetration.

Evaluation of the following parameters was done:-

- a) Pre-operative:- Matching of patient-specific plate template with our design.
- b) Intra-operative:-
 - I. Whether exposure to apply the plate was to be changed or standard one was used.
 - II. Whether the plate was positioned in anatomical area or needed to be deviated.
 - III. Requirement of intra-operative re-contouring.
- c) Post-operative:- Post operative reduction of fragments in CT scan according to MATTA and MERITT criteria.⁹

3. Observation and results

From January to march 2018 five consecutive patients with fracture acetabulum fixed with posterior approach were assessed and following data were recorded:-

- a) Pre-operative:- The contour of all the five patient specific templates matched our design.
- b) Intra-operative:-
 - I. Standard exposure was sufficient for application of our designed plate.
 - II. No deviation from anatomical area was required for positioning of our plate design.
 - III. No recontouring of our designed plate was required intra-operatively.
- c) Post-operative:- In all the patients, reduction assessed according to MATTA and MERITT criteria⁹ came out to be anatomical (Fig. 4 and Table 1).

4. Discussion

Intra-operative contouring of reconstruction plate is the standard method to match the plate contour to reduced acetabular fracture surface. However, this method has many drawbacks. Matching the contour of the reconstruction plates to the pelvis for acetabular fracture fixation is a challenging task due to the complex anatomy. It becomes even more difficult for young surgeons with limited experience of acetabular surgeries. It increases surgical duration and invasiveness.¹ Further, multiple bending attempts on the straight plate reduce the strength of the implant. Inaccurate contouring can also lead to malreduction while tightening the screws.⁴ All these reasons can lead to less favorable immediate outcome as well as long term function. One of the solutions to the above mentioned issues is pre-contoured plate. Many researchers have used diverse techniques to overcome the drawbacks of intra-operative contouring. Computer based virtual planning and rapid prototyping technology has been utilized in various ways to obtain pre-contoured plates for acetabular surgeries and yielded favorable outcomes.^{1,4,5,9–16} Kesu et al. developed a W-shaped angular plate for posterior column acetabular fracture fixation in cadavers but its efficacy in living human acetabular bone is yet to be established.² Meng xu et al. developed a custom made locking plate for acetabular fracture

Fig. 1. A & b: Our designed plate from front and side along with plate template.

Fig. 2. Creation of virtual model of pelvis from CT scan.

Fig. 3. Patient specific plate template created on virtual model of pelvis.

fixation in 49 patients. Although results were appreciable there was too much interdependence of various specialties with high technical demand.⁴

The custom made locking plates matched the surface, reduced surgical duration, avoided joint penetration and provided secure fixation. However, the manufacturing process for the plate

Fig. 4. Pre-operative and post-operative images of a patient.

Table 1

Details of all patients assessed in our study.

Serial number	Sex	Age in years	Mode of injury	Type of fracture	Associated injuries	Time taken to get operated after injury
1	Male	55	Fall from bike	Transverse	Fracture both bone leg with fracture 1st and 2nd metatarsal of ipsilateral limb	8 days
2	Male	20	Road traffic accident	Posterior column	Fracture shaft of femur with sciatic nerve injury	1 day
3	Male	20	Road traffic accident	Posterior wall	None	1 day
4	Male	20	Road traffic accident	Transverse	None	4 days
5	Male	34	Dashboard injury	Posterior column	Sciatic nerve injury	1 day

averaged 6.9±2 days and processing the plates delayed the surgery by 2.6±1.3 days in one third of the patients.⁴ Other authors who used rapid prototyping and computer based planning for each patient separately, also reported regarding the extra time which was required for workup before surgery could be done. Wu et al. reported that they took nearly 7 h (range 6–9 h) for each patient specific planning to produce 3D virtual model from the DICOM data.¹⁵ The median time taken by Fornaro et al. was 130 min (range 83–221 min).¹³ Maini et al. reported that an average of 4.3 h was spent for each case to acquire patient specific pre-contoured plate.⁵

Moving from time consuming patient specific solutions to anatomical acetabular plate which can be used in all the patients of a particular population can be helpful in saving time and prevent delay in surgeries. It can also simplify the process. Our anatomical posterior column plate design is based on our years of observations while we used virtual planning and 3D printing techniques for pre-contoured plates. The plate was designed on Indian pelvis and then mirrored to obtain anatomical plate for contra-lateral side. Our experience with this design in all the five pilot study cases has been favorable with the plates matching the surface of reduced fracture without any need for any further intra-operative contouring. So, this posterior anatomical plate

design does not only save intra-operative time, but also avoids spending considerable time in patient specific workups. Since the manufactured plates were directly used without any further bending, their strength could be preserved. Absence of holes over the acetabular area helped in avoiding putting screw near the unsafe zone and further added to the strength of the implant. Using these anatomical plates also avoids patient specific designing, 3D printing implants etc thereby not increasing any cost for the management. Cost for 3D printing of these plate templates is 50–60 INR. Cost of manufacturing our designed plates were around 5000–7000 INR which is comparable with 3.5 mm Recon plates available in market hence, no extra burden is put on patient for application of our designed plate.

We have observed that the curve of the plate for the acetabular portion is the one, which may vary as per the patient's acetabular size. A positive correlation between individual's height and acetabular size has been reported in literature.¹⁷ All five patients in this pilot studies were male patients with height range from 5 feet 5 inches to 5 feet 7 inches. We believe that one would need only few sets of such anatomical posterior column plates for a range of acetabular sizes.

Overall, this anatomical posterior column plate seems to be a cost effective and accurate design, which provides the benefits

equivalent to patient specific pre-contoured plates while avoiding extra efforts and time on patient specific planning. However, this is the first Indian design of posterior column anatomical plate ever reported based on CT scan of Indian pelvis. A larger sample size study comparing this design with the standard intra-operative contouring as well as pre-contoured plates obtained by various other techniques including virtual planning and 3D printing is required to establish sound evidences and facts.

5. Conclusion

This was a pilot study in which we want to share our initial experience about a specific design of posterior acetabular plate with defined curves which prevents recontouring of acetabular plate intra-operatively which ultimately decreases intra-operative time and complications. Also this design prevents joint penetration while fracture fixation. This specific design also prevents too much resource wastage in pre-operative planning and 3D printing which is beneficial for both patient and doctor. Although results were very motivating, we need a large sample size of Indian population to see any variation in these study results.

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Conflicts of interest

The authors have no conflict of interest.

Consent

Informed consent was obtained from every individual participants included in the study.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jcot.2018.07.009>.

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