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# Preliminary report: rapid prototyping models for Dysplastic hip surgery

**Case Report**

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**Abstract:** Rapid prototyping (RP) is a technology used to produce physical models. The RP application is applied in the medical field to build anatomy models from high resolution multiplanar data such as Computed tomography (CT). CT of a female patient diagnosed with hip dysplasia was obtained prior to surgery. Specific software was used to prepare the physical model of the patient and was produced using fused deposition machine. Pre fused deposition models (FDM) were given to the orthopaedic surgeon to plan for the dysplastic hip dysplasia. The patient was scanned again using CT after surgery and a post model was produced. The outcome of the surgery was seen clearly by viewing the post model. Orthopaedic surgeon commented on his experience of using the models for the hip dysplasia surgery. These models were found to be very useful for pre surgery planning, determining procedure, implant sizes, positioning, bone grafting which also reduced surgery time by forty percent and increased surgeon confidence as rehearsal prior to actual surgery was made possible. This paper provides an understanding of the benefits of using RP models in hip dysplasia surgery as a good way to enhance both orthopaedic surgeon skill and knowledge.

**Keywords:** *Fused Deposition Models • Computed Tomography • Dysplastic Hip*



## 1. Introduction

Rapid Prototyping (RP) was mostly used in the automobile industry but is now applied in the medical field to build human anatomy models from high resolution multiplanar data such as Computed Tomography [CT] [1]. CT is an important tool in medical imaging as it provides detailed information on human anatomy and abnormalities which gives a good reason for being very useful for diagnostic purposes [2]. Geometry and physical properties of skeletal structures can also be viewed clearly [3,4]. RP and advanced medical imaging are having a great impact on the design of medical implants, preoperative planning and building of medical instruments. This is due to the fact that there is no such perception as a standard size when it involves humans [5]. RP is an invaluable tool to aid complex trauma and orthopaedic surgery. These models provide a better illustration of the human anatomy, enable viewing of internal structures, provide better understanding on related cases and can also help surgeons in making important decisions [6,7]. Besides this, RP models can be used for designing individual implants, prosthesis, and function as a teaching tool for surgeons and also as a communication tool between surgeons and patients [8,9].

Fused deposition modelling (FDM) is one of many RP technologies. FDM produces medical models with advantages. Materials used include: medical grade of acrylonitrile butadiene styrene (ABS), this can be sterilized with gamma radiation, tough, durable, can be cut and drilled with the operating theatre tools, is suitable for hospital environment, and resembles bone visually [10,11]. In this study, the use of FDM is concentrated in dysplastic hip (DH).

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DH is referred to as a range of development hip disorders. The hip can be mild or severely dysplastic [12]. The acetabular roof is not developed properly and can be seen as shallow while the femoral head is deformed but is retained within the acetabular socket with minimum coverage area [13-15]. This leads to smaller surface for weight-bearing that requires a larger force per unit area during daily activities [16,17].

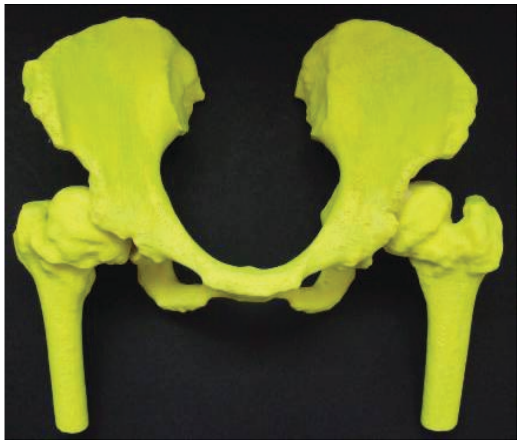
The most important morphological measurement for DH is centre-edge angle, acetabular angle, depth-to-width ratio and femoral head coverage by acetabular [18]. CT scan of patient's pre and post surgery can be used to determine these morphological measurements. The main problems faced by orthopaedic surgeons in DH surgeries include making decisions in reduction of the hip in acetabular reconstruction, accurate placement of bone grafting and femoral shortening to restore the contact between the femoral head and acetabular [19,20]. This is technically difficult and time consuming. In this study, FDM models were produced to assist the orthopaedic surgeon in DH surgery. CT scan was used to produce the FDM models for pre and post DH surgery. The outcome of the surgery was represented by the post FDM model. The main objective of this research was to show the benefits of FDM models in DH surgery.

## 2. Material and Methods

A female patient age 78 years old was diagnosed with DH having classified as Crowe II. After obtaining the medical ethics approval (No. 690.7) and also the patient's consent to participate in this study, the patient was sent to the radiographer for CT scan. CT scan was performed at 0° gantry tilt acquired using SOMATOM Sensation 16 (Siemens, Germany). Scanning was done at 78 mAs and 140 kV with 0.75 mm in-plane resolution. 3D data set acquired produced 344 axial slices with a slice thickness of 1 mm. The data was saved in the digital imaging and communication in medicine (DICOM) format.

Data processing step is an important step as it determines the quality of the FDM model produced. Mimics software version 13.0 (Materialise NV, Leuven, Belgium) was used to convert the CT scan image data. CT images were imported into Mimics software. Threshold was performed to create the first step of the segmentation mask at a lower value of 226 and an upper value of 3071 Hounsfield units. Threshold process was done to differentiate the bone from the surrounding tissue. Region growing was performed to split the segmentation object into separate masks. Manual segmentation was also done due to the inconsistent density of the patient's hard tissue. Selection of the high quality parameter for 3D digital model was calculated and generated. 3D digital model was remeshed to reduce the triangles and smooth the model before converting to the Standard Triangulation Language (STL) format.

**Figure 1.** Pre FDM Dysplastic Hip Model.



Important morphological measurements for hip dysplasia (DH) which were centre-edge angle, acetabular angle, depth-to-width ratio and femoral head coverage by acetabular were measured using the Mimics Software. A fused deposition machine type Dimension SST1200es manufactured by Stratasys of Eden Prairie, USA was used to produce the FDM model. STL file was processed using CatalystEx software version 4.0.1 (Stratasys of Eden Prairie, USA). Fused deposition machine produced the models from acrylonitrile butadiene styrene (ABS) thermoplastic. The pre FDM model was given to the surgeon for planning of DH surgery. The anterior approach was used. Cobalt chromium and Ultra High Molecular Weight Polyethylene cup Exeter implants from Stryker was used for the surgery. Metal on polymer was used to restore the hip stability. The patient was sent for CT scan again after surgery. The above method was repeated to obtain the DH morphological measurements after surgery and to produce the post FDM model.

## 3. Results

The pre FDM model produced for the surgery is shown in Figure 1. Preoperative planning on the FDM model was done on both the acetabulum and the femur. Using the FDM model, optimal position and size of the components was determined using templates. The femoral template size that fit the proximal femur and equalized leg lengths was selected. The femoral template was placed in line with the long axis of the femur and the neck resection

**Figure 2.** Dysplastic hip surgery.

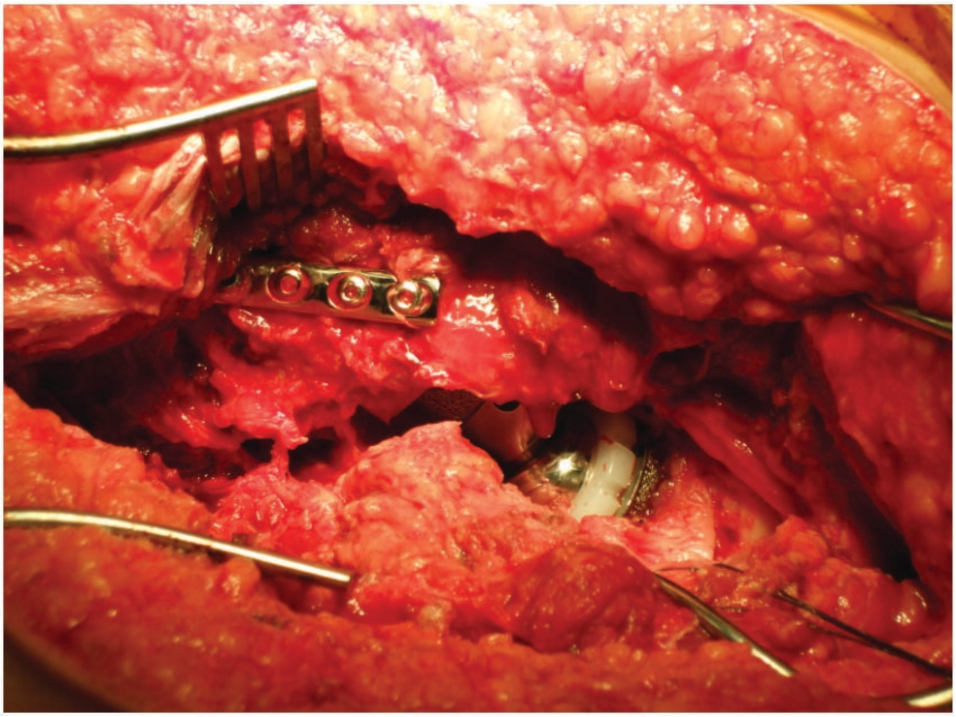


**Figure 3.** Post FDM Dysplastic Hip Model.

line was drawn at the point where the selected stem provided the desired amount of leg length. The distance between the planned center of rotation of the acetabular component and the planned center of the femoral head constituted the adjusted leg length. Neck osteotomy was determined by the stem size and desired leg length. Also with the FDM model, acetabulum was reamed progressively until a hemispherical dome was achieved. A trial cup sizer was placed into the reamed acetabulum using the cup impactor. After removing the cup impactor from the trial shell, the desired liner trial was placed into the cup trial. Hole was initiated for the femoral preparation which was advanced until sufficient. Reaming was done. Proper alignment of the reamer was important to ensure correct component positioning. Template size for implant was determined. Through templating and trailing, offset was restored by matching the cup's center of rotation with the desired head center of rotation. Trial reduction was done using the trial acetabular liner, trial femoral head, optimal liner and modular head for implant stability.

The orthopaedic surgeon (David, Personal Communication, 2009) found the model very useful towards planning of DH surgery. The size of the femur stem and acetabular cup was determined by means of the pre FDM model. Sizes of the implants were decided before surgery compared to the conventional method of determining the sizes of implants during surgery. A size 33.0 mm femoral head offset cobalt chromium stem implant and 22.0 mm diameter acetabular cup made of Ultra High Molecular Weight Polyethylene was used to restore the hip stability. Bone grafting was done. Surgery time was reduced by forth percent. Figure 2 shows the position of implants during surgery. He found the differences minimal which was about +/- 0.2 mm. The post FDM model shown in Figure 3 helped the surgeon to view the outcome of the surgery and to compare with the pre model.

The DH morphological measurements obtained during pre and post surgery which was based on CT

**Table 1.** Dysplastic Hip Morphological Measurements based on patient's CT scan data.

| Dysplastic Hip parameters | Pre Surgery | Post Surgery | Reference |
|---|---|---|---|
| Centre-edge angle (CE) | 19.53° | 36.05° | > 25 o is normal [17] |
| Acetabular angle (Sharp's) | 32.38° | 8.01° | > 10 o is abnormal [21] |
| Coverage of femoral head by acetabular | 44.10% | 77.80% | <75% is pathologic [18] |
| Depth to width ratio | 69.0% | 61.00% | ~ 60% is normal [18] |

scan data is shown in Table 1. After surgery the results showed that the centre-edge angle obtained was more than 25°, acetabular angle was less than 10°, coverage of femoral head by acetabular was more than 75% and depth to width ratio was more than 60% based on the reference indicated by other studies [17,18,21]. The DH surgery was successful.

## 4. Discussion

The surgeon was satisfied with the pre and post FDM models. He mentioned that these models provided better visualization of the diagnosed region. The model was also useful for pre surgery planning, determining surgery procedure, implant sizes, positioning and bone grafting. He also commented that it was a good opportunity to rehearse prior to surgery as it helped to reduce surgery time. The post FDM model gave him the opportunity to view the outcome of surgery physically. He also used the pre and post FDM models to discuss this case with his fellow colleagues and students. The patient did not complain of having any pains or discomfort and was discharged after three days of surgery with a fast route to recovery.

FDM model is an important tool to aid orthopaedic surgery as preoperative surgical planning is an important step. FDM models allow rapid manufacture of accurate three dimensional models of DH based on the patient CT scan data. CT scan data provided the quantification of preoperative appearance and postoperative improvement [22,23]. This model can be cut and drilled with the operating theatre tools making it easier for the surgeons to rehearse. The use of this model improves quality of the preoperative planning, increases surgeons confidence, reduces complexity of the surgery, reduces surgery time, ensures successful surgery outcome and faster patient recovery can be expected. This paper provides an understanding on the benefits of using FDM models in DH surgery which also helped to enhance the orthopaedic surgeon's skill and knowledge.

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