CUSTOMIZED HIP IMPLANT PROSTHESIS- A LITERATURE REVIEW

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ABSTRACT - In total hip arthroplasty, the damaged bone and the cartilage is removed and replaced with the prosthesis implant. Though various innovations have come with implant sterilization, designing, fixation and robotic surgery, the long-term issue is to find an optimum patient specific hip implant which suits the patient's requirement. The aim and objective of the project is to design a highly accurate patient specific hip implant by standardizing the existing design and to prove that customized design is better than the conventional design. The geometric measurements of hip will be taken from the hip CT image using software MIMICS 21.0. The implant design would be carried out using CREO 5.0. The designed implant will be meshed and analyzed using FEA. By comparing the FEA results of conventional and customized implant, the proposed customized implant is best fit than conventional implant.

***Keywords**: Total Hip replacement, prosthetic implant, Customized implant, Finite Element Analysis.*

1. INTRODUCTION

A total hip replacement may be a operation within which each broken surfaces of the spheroid joint area unit replaced with prosthetic substitutes. it absolutely was initial performed within the 1960's and is claimed to be one among the foremost winning surgeries within the previous few decades. it absolutely was referred to as "The operation of the century". per the rule of thumb for hip replacements at a tertiary center in African nation, 90-95% of hip replacements can still be functioning well once 10-15 years. a complete hip replacement (THR) consists of exchange each the cotyloid cavity and therefore the leg bone heads whereas hemiarthroplasty typically solely replaces the leg bone head. Hip replacement is presently one among the foremost common medical science operations, tho' patient satisfaction short and semipermanent varies wide. just about fifty-eight of total hip replacements area unit calculable to last twenty-five years. the common value of a complete hip replacement in 2012 was $40,364 within the u. s., and regarding $7,700 to $12,000 in most European countries.

2. PATIENT-SPECIFIC HIP PROSTHESES DESIGN

The process starts with the Doctor (Dr.) mistreatment extremely machine-controlled and easy computer code. It allows surgeons to arrange and build 3D implant styles supported patient CT knowledge with few interaction steps and while not having any engineering or pc assisted style (CAD) knowhow. The computer code implements a style advancement that has been developed in shut collaboration with surgeons wherever users square measure guided step by step. The Dr. starts the advancement by commerce patient CT pictures from a USB-Stick or different knowledge media. Uni-lateral 3D slice pictures that contain the hip cup and stem space with most a pair of millimeters slice thickness and a frame angle of zero degrees square measure needed. After checking and complementing missing patient info, the Dr. marks anatomical properties like the patient's leg axis or the hip center within the patient pictures. This info is noninheritable on just about generated 2nd x-ray pictures or CT pictures that surgeons square measure already wont to operating with. 3D coordinates of the properties square measure gained by holding the Dr. work on 2 orthogonally orientated pictures.

Fig-1: User Interface for Defining Anatomical Properties

In the next steps, the Dr. defines size and position of the implant supported the noninheritable anatomical properties. The last designing step needs the Dr. to outline the realm of the hip stem which will have a patient specific form. For the ultimate check, the Dr. sees a 3D model of the patient specific implant, which might be inspected from all directions and well by rotating and zooming. The steps for rendering the 3D model can consists of the elements of the implant to be designed is explained within the following. The measurements for coming up with the three-D model were taken from the MIMICS computer code.

3. METHODS

The overall framework for the design optimization of the THR measurements includes parameter selection, modeling of the prosthesis with the bone, stress analysis, ROM calculation, and optimum design of the neck diameter. This framework is shown as a flow chart in Fig- 2.

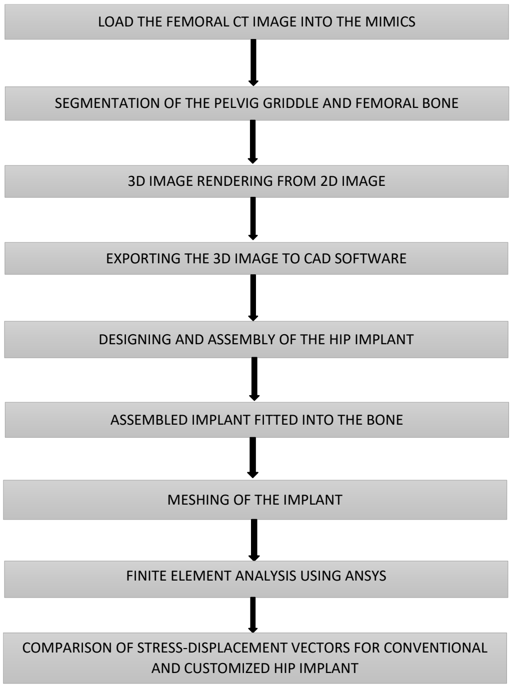

Fig-2: Flowchart illustrate of the proposed model

Model parameters considered in this study as well as ROM dependency related to these parameters are summarized in Table-1. Head-to-neck ratio, oscillation angle, neck-to shaft angle, cup anteversion, cup inclination, and stem antetorsion affect ROM in THR.5 These parameters were selected with consideration of ROM and maximum stress simultaneously generated at the prosthesis neck.

PARAMETERS		**ROM DEPENDENCY IN THIS STUDY**
Head to neck ratio	Head diameter	YES
	Neck diameter	YES
Neck to shaft Angle		YES
Theoretical femoral stem-offset		NO
Cup and stem Orientation	Cup anteversion	YES
	Cup inclination	YES
	Stem antetorsion	YES

Table-1: prosthetic implant parameter's and it's dependency towards ROM

3.1 DESIGN CONSIDERATIONS

3.1.1 ACETABULAR CONSIDERATIONS

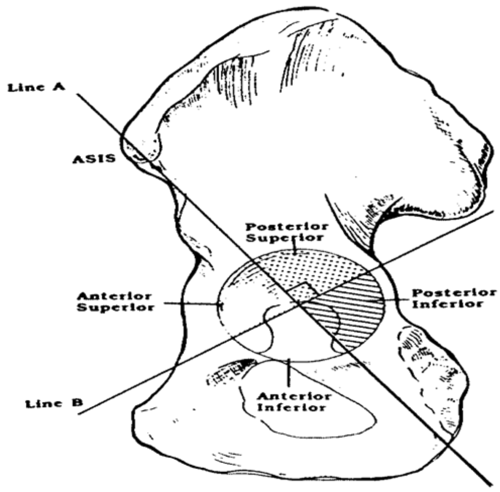

Fig-3: Acetabular Quadrants

Cementless cotyloidal parts ar gaining quality within the u. s. and within the remainder of the globe. These implants ar indicated for each primary and revision surgery. It seems the bony matrix of the cotyloid cavity is similar temperament for cementless fixation. Cementless fixation is best accomplished within the grammatical cotyloid cavity wherever the form is neural structure and also the implant will be placed in shut apposition with the fibrous tissue bone. rib cotyloidal parts, as compared to porous press-fit styles, have had the longer history of cementless application in total hip surgical procedure. The Europeans have pioneered and championed this idea in each primary and revision surgery. There ar four basic classifications of rib cup styles. it's crucial to know the variations in these styles and most of all to know the actual style chosen for implantation. an entire understanding of the planning can alter the doctor to maximize surgical techniques to attain an honest result.

Classification of rib Cups:

- Truncated cone
- Hemispherical ring
- Hemispherical shell with conelike threads
- Hemispherical shell with spherical threads

3.1.2 FEMORAL CONSIDERATIONS

The limb head is slightly larger than one 1/2 a sphere, and therefore the form is a lot of oval than spherical. The stresses on the limb head typically act on the anterior superior quadrant, and surface motion are often thought-about as slippery on the socket. 2 vital angles got to be considered: the neck shaft angle and therefore the angle of anteversion. additionally, to those 2 angles, the joint reaction force is full of limb head offset. Replacement of the traditional position of the limb head is important for correction of mechanical balance between abductor forces. unremarkably the leg bone is loaded from the skin cortex, and stresses square measure transferred internally. However, in an exceedingly stemmed reconstruction the biomechanical loading has been modified to an inside loading mechanism. Intramedullary stems place associate degree unnatural hoop stress on the bone. This hoop stress should be transferred into compressive hundreds to the proximal leg bone.

The target for cementless total hip stems of long-run painless stability relies on each primary and secondary fixation of the implant to the bone. a good cementless stem ought to resist subsidence, tilting and torsional forces. Primary mechanical stability is, therefore, a requirement for long-run success. Torsional fixation of the limb element is taken into account the foremost vital criteria for long-run success. it's solely logical that style options that improve fixation square measure doubtless to enhance clinical results. With cavitary and segmental bone injury it's troublesome to realize stability of the implant. during this state of affairs some authors have antecedently counseled distal fixation. it's our opinion that distal stability is preferred over distal fixation. this will be achieved by channel the distal finish of the stem.

3.1.3 HEAD SIZE AND RANGE OF MOTION

Range of hip movement when THA is decided by patient specific, surgical and prosthesis-specific factors. Head size is barely one in every of the implant characteristics touching vary of movement. it's been incontestable in finite part analysis and in vitro that increasing head size given a relentless neck thickness, i.e., increasing the head-neck quantitative relation, ends up in a wider impingement-free vary of movement. This result reaches its limits at head sizes of thirty-eight metric linear unit, wherever vary of movement is not any longer restricted by implant-to-implant however rather by bone to soft tissue/bone impingement, that has been confirmed within the following in vivo studies.

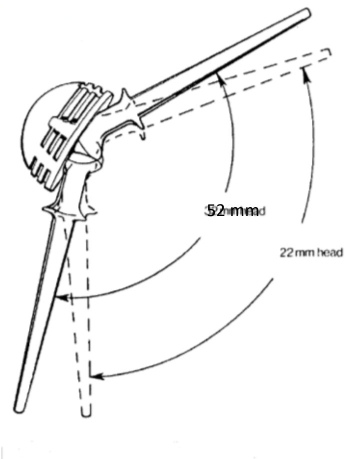

Fig-4: Range of Motion

Intraoperative measurements victimization CT-based navigation has incontestable larger vary of movement in THA with a fifty-two metric linear unit head compared with a forty metric linear unit head. Neck diameter plays a very important role in THR restorative style as a result of it affects each computer memory and mechanical fracture susceptibleness. THR restorative style variables, like neck-to-shaft angle, head-to neck quantitative relation, and cup-stem orientations, ar proverbial parameters that influence computer memory. Head-to-neck quantitative relation could be a significantly vital parameter for mechanical safety and impingement free computer memory. Modifying the scale of the pinnacle and neck impacts not solely the mechanical stress at the restorative neck, however additionally theoretical computer memory. during a study by Matsushita et al, surgical measurements incontestable a larger vary of hip movement in THA with thirty-two metric linear unit compared with twenty-six metric linear unit heads increase in vary of movement was addicted to leg bone offset instead of ever-changing from twenty-six metric linear unit to thirty-two metric linear unit head. during a more modern study, there was no distinction in either vary of movement or patient-reported outcomes between patients operated on with a thirty-six metric linear unit head and people with head sizes > thirty-six metric linear unit. this is often in accordance with a previous in vitro study that incontestable lack of further advantages to vary of movement once increasing leg bone head size > thirty-eight metric linear unit.14 victimization leg bone heads > thirty-six metric linear unit so as to boost vary of hip movement is thus questionable.

3.1.4 STEM CONSIDERATIONS

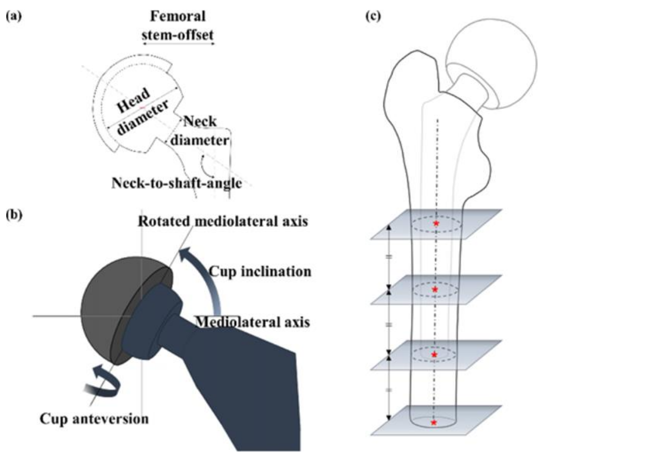

Fig-5: (a) Definition of head diameter, neck diameter, theoretical femoral stem-offset, and neck-to-shaft angle, **(b)** Cup inclination angle and anterior cup open angle (cup anteversion). Axis to define cup inclination is mediolateral axis and the rotated mediolateral axis defines cup anteversion, **(c)** Determination of femoral longitudinal axis

The stem is a geometric design that features a proximal anterior flare that works in tandem with a 30° proximal conical flare collar. These two specific features aid in axial and torsional stability while providing increased surface geometry, resulting in increased compressive stress to the proximal femur. The neck shaft angle is 135° with 10° of anteversion. Lateral displacement of the femoral head is 40 mm. The proximal conical collar allows for settling of the implant resulting in increased surface contact throughout the entire proximal stem geometry. In addition, the conical shape acts as a step in transferring hoop stress into compressive loads. While providing improved fit and fill, the proximal conical shape provides a seal occluding wear debris from entering the femoral canal.

The proximal half of the femur was removed. Femoral head and implant insertion sites were also removed in the model. The cutting plane for removal of femoral head consisted of two planes. The first plane was aligned with the sagittal plane to cut vertically and another plane was orthogonal to the prosthetic neck axis which was defined by the neck-to-shaft angle.

4. FINITE ELEMENT ANALYSIS

FEA is a computational technique that is used to solve real world problems. Using FEA, it is possible to analyses and assess certain physical properties of objects. ANSYS software is used to perform analysis. It is flexible, innovative, reliable, user friendly and compatible on complex structures like human bone joints. To calculate the principal stress at the prosthesis neck, FE analysis was performed using commercial software ANSYS. The distal end of the femur was fully restricted in each of the three directions.

An external remote force vector was applied to the face of the acetabular cup. The femoral neck region was investigated as the main area to evaluate the risk of fracture. The loading condition consisted of an in vivo force generated at the femoral head and was adapted from an open database source, Orthoload. Orthoload provides joint implant forces and moments which were directly measured using sensors in instrumented implants in patients.

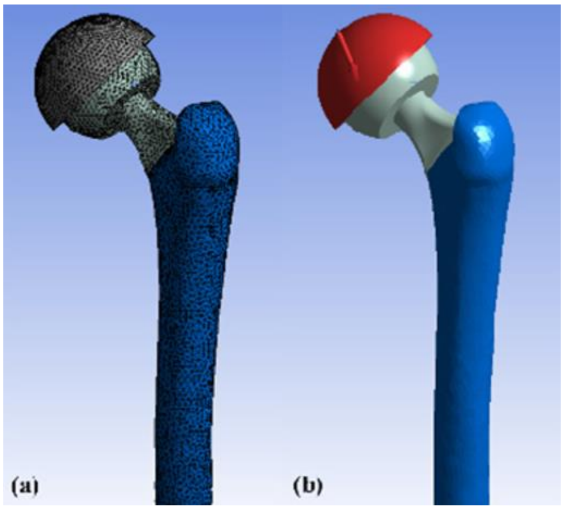

Fig-6: (a) Mesh model of femur and total hip prosthesis. **(b)** Force applied at acetabular cup component model in time frame of maximum force vector applied (red arrow)

5. ASSIGNING MATERIAL PROPERTIES

The bone is a composite material made up trabecular and cortical bone. The primary tissue of bone is made up of osseous tissue, is a relatively hard and lightweight composite material, formed mostly of calcium phosphate also called as calcium hydroxyl apatite which gives strength and rigidity to the bone. It has relatively high compressive strength, of about 170 MPa but poor tensile strength of 104–121 MPa and very low shear stress strength (51.6 MPa), meaning it resists pushing forces well, but not pulling or torsional forces. For the surface of the bone with cortical structure, the appropriate properties are added and for the region with trabecular bone together with the properties of calcium content. In the case of implants, four types of biomaterials are taken into consideration, depending upon their role as hip implants, such as Stainless steel 316L and UHMWPE, Tantalum, Ni-Ti alloy and Co-Cr alloy.

7. CONCLUSION

The hip implant was enhanced by introducing the patient-specific hip implant. The patient-specific hip implant will give better result than the ordinary hip implant. Since the geometric measurements obtained for patient-specific hip implant and for the conventional hip implant shows the mismatch. so, it is important to perform the total hip replacement surgery with the customized hip implant. Such a personalized design can eliminate a high percentage of postoperative complications that result particularly from choosing a standard hip stem that does not match with patient anatomy, thus reducing the number of revisions and implant mechanical wear. This study proposed a quantitative methodology to optimize the neck diameter of the THR prosthesis using FE analysis and multi-objective optimization, which considered both mechanical stress at the prosthesis neck and five physiologic hip ROMs.

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