Computer Assisted Navigation (CAN)
In Total Hip Arthroplasty

Essay submitted for fulfillment

of the degree of M Sc Orthopedics

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LIST OF ABBREVIATIONS

- **ASIS** : Anterior superior iliac spine
- **CAS** : Computer assisted surgery.
- **CAOS** : Computer assisted orthopedic surgery.
- **CR** : Center of rotation.
- **CT** : Computer tomography.
- **DRB** : Dynamic reference base.
- **EM** : Electromagnetic.
- **GPS** : Global positioning satellite
- **HTO** : High tibial osteotomy.
- **LED** : Light emitting diodes.
- **MRI** : Magnetic resonance imaging.
- **MIS** : Minimal invasive surgery.
- **O.R** : Operating room.
- **ORIF** : Open reduction and internal fixation.
- **ROM :** Range of motion.
- **THA** : Total hip arthroplasty.
- **THR** : Total hip replacement.
- **TKA** : Total knee arthroplasty.
- **2-D** : Two dimensional.
- **3-D** : Three dimensional.

ABSTRACT

Computer assisted techniques have been successfully used in many surgical procedures. More recently, they have been used to improve accuracy and reproducibility of implant alignment in total hip arthroplasty procedures.

This study aims at evaluation of efficacy of at CT-navigation assistance on improvement of accuracy of placement of ace-tabular and femoral components compared with conventional methods and its efficacy on the Long term and short term results.

INTRODUCTION
THEORY OF DEVELOPMENT

The aim of any surgical intervention in orthopedics is the treatment of bone, joints or connective tissue such as ligaments or tendons. Those structures are usually located deep inside the human body often requiring extensive surgical exposure to gain access to the site of treatment. Modern surgical access represents a compromise. They are optimized to be as open as necessary but as minimally invasive as possible, this minimizes soft tissue trauma and consequently recovery time, but it bears a certain danger. [1]

Reduced intra-operative visibility can be seen as one reason for inaccurate performance of operations resulting in subobtimal or negative outcome.

Intraoperative visualization and orientation aids have been identified already long years ago as means to make surgical intervention safer, more reliable and ultimately more successful.

Throughout history, physicians have tried to improve visibility of the inside of the human body to understand complexity of normal and diseased body structures.

The milestone in improving visibility did not occur until 19th century, when Roentgen discovered the x-ray and introduced plain radiography. [2]

Surgeons in different specialties, especially orthopedics have succeeded in transferring the powerful images of radiography to the operating room via x-ray fluoroscopy.

The advent of the computer and subsequently computer tomography (CT) in late 20th century opened a new horizon of better accuracy and visibility.

Surgeons tried to transfer the operating room to the CT scan suite and vice versa to enable image guided surgery in real time, but their attempts were not successful.

The introduction of position tracking devices made the application of image guided surgery possible by linking the different steps of imaging, planning and surgical implantation even when performed at different times. [1]

Modern computer assisted technologies in the form of robotics and navigation started in 1980s with several neurosurgical applications. The technology was subsequently transferred from neurosurgery to orthopedics in the area of spine and then gradually to hip and knee surgery.

Practical application of computer assisted surgery (CAS) in hip arthroplasty started in early 1990s when robotic techniques were used for femoral canal preparation in total hip arthroplasty (THA).

The technical development gradually moved from active robotics toward passive navigation systems. [3]

PRINCIPLES OF COMPUTER ASSISSTED ORTHOPEDIC SURGERY

Definition of computer assisted surgery:

It is the application of computer-enabled technology at any stage (*preoperative*, *intra-operative*, and *postoperative*) in the surgical management of orthopedic conditions with the use of various systems *(active,semi-active, passive, or hybrid*) performed for several applications (*planning, simulation, guidance, robotic and/or training*).*[4]*

Classification and characteristics of computer-assisted orthopedic surgery (CAOS):

Picard, F., et al 2004 suggested a simple and clinically based classification system for CAOS. They classified CAOS into:

- Robotic systems (active and semi-active).
- Passive navigation systems (image free and image based). [5]

Robotics

Robot, taken from the Czech *robota*, meaning forced labor, has evolved in meaning from dumb machines that perform mechanical, repetitive tasks to the highly intelligent anthropomorphic robots. Although today's robots are still unintelligent machines, great strides have been made in expanding their utility.

Today robots are used to perform highly specific, highly precise, and dangerous tasks in industry and research previously not possible with a human work force. Robotics, however, has been slow to enter the field of medicine. The lack of crossover between industrial robotics and medicine, particularly surgery, is at an end. Surgical robots have entered the field in force. *[6]*

When discussing the use of robotic manipulators in computer assisted surgery, one must recognize that such devices are tools that are under the control of the surgeon. In much the same way that a ship captain is free to turn off an automatic pilot system based on an assessment of its performance, a surgeon may choose to disengage a robotic manipulator and continue a procedure using conventional methods. [7]

For certain surgical tasks, it may not be possible to achieve the goals of the preoperative plan accurately solely based on navigational guidance. For such tasks, it may be appropriate to incorporate a robotic manipulator to the computer assisted surgical system as an additional surgical tool. Benefits of robotic manipulators include high accuracy, insensitivity to radiation, ability to scale forces and motions to very large or very small magnitudes, ability to follow precisely complex three-dimensional trajectories, and lack of vibrations. *[8]*

Orthopedic surgery offers multiple uses for robot assistance, as a robot is more accurate in cutting and drilling bone than a surgeon is. Several applications of robot assisted intervention can be found, e.g., cementless hip replacement, total knee arthroplasty (TKA) and pedicle screw replacement.

Robotic systems are classified into active and semi active systems.

Active Systems :

Active robotic systems have the capability of performing a part or all of the bone preparation steps (drilling, cutting) autonomously, but under the surgeon's supervision and control.

A computer monitor displays in real time the three-dimensional (3-D) pictures of the surgical performance. These robotic systems typically require preoperative imaging (CT scans) and intra-operative registration to establish a relationship between the preoperative images and intra-operative anatomy. *[9]*

The first clinically used orthopedic robot was ROBODOC **(fig.1)**, which was initially used for total hip arthroplasty (THA) and then adapted for TKA. CASPAR, and ACROBOT are other orthopedic robotic systems that were initially used for TKA. There are new image-free robotic systems. *[10]*

Semi active Systems :

Semi-active robotic systems do not autonomously perform the surgical task. Control here is shared between the surgeon and the robot. Consequently, the actions are performed by surgeons and guided or restricted by the system.

A computer monitor displays in real time the (3-D) pictures of the surgical actions. Like active robotic systems, semi-active systems typically require imaging and intra-operative registration. *[5]*

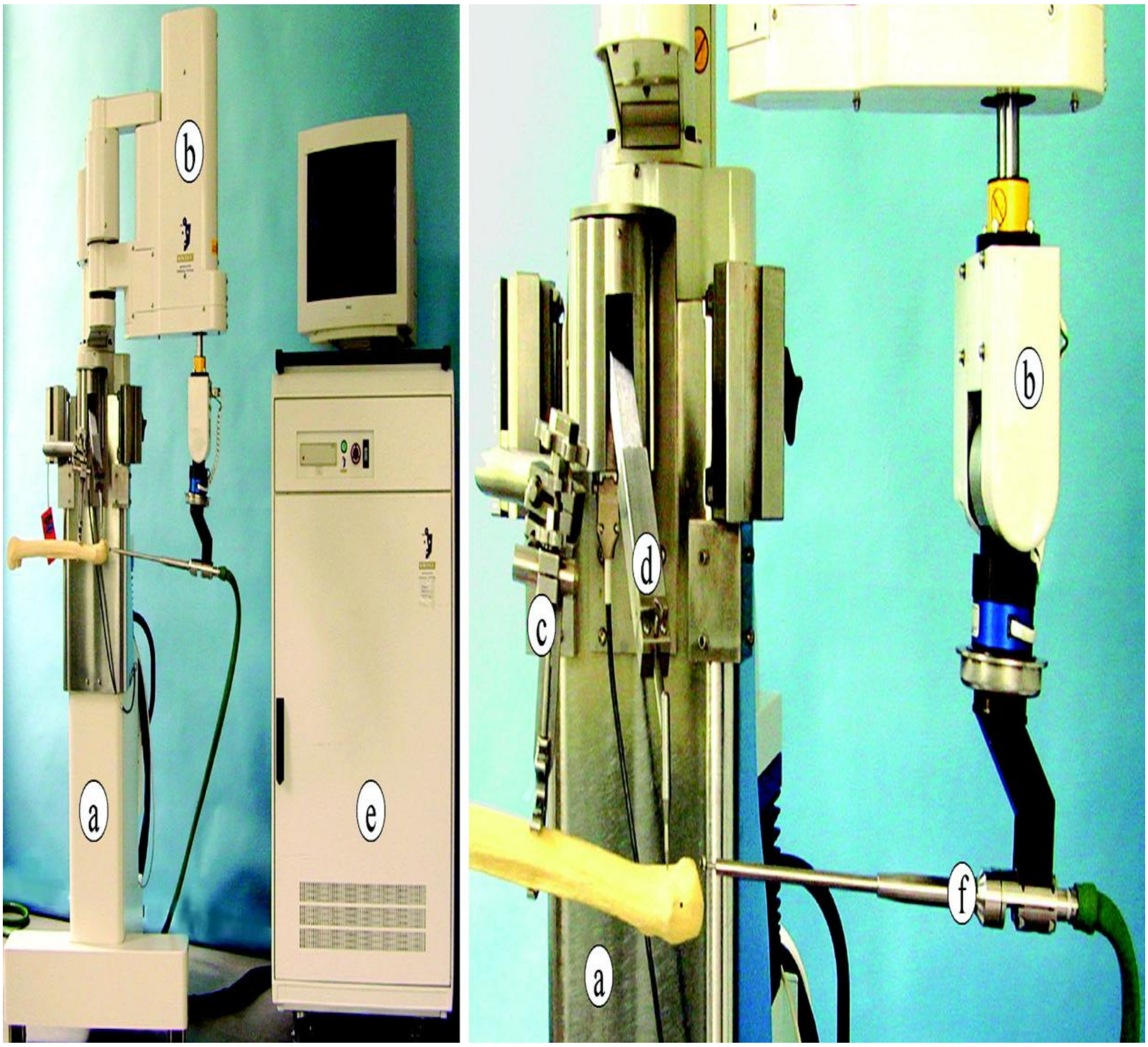

Fig. (1) The ROBODOC surgical robot. a = robot base, b = robot arm with 5° of freedom, c = the femoral fixator, d = the bone-motion detector, e = the control computer, and f = the pneumatic turbine with the reamer bearing sleeve. [5]

Passive Navigation Systems

The concept of surgical navigation system is similar to the real time global positioning satellite (GPS) vehicle tracking system in which the location and movement of the vehicle is constantly displayed on a map.

These systems do not perform the surgical action by themselves and allow surgeons to have full control. Their main role is to provide information and/ or guidance during the procedure. *[4]*

The navigation systems are further classified into **image based** with the use of preoperative CT or intra-operative fluoroscopy, or **image free** with reliance on intra-operative collection of data by the surgeon. CT- based navigation systems can provide full functionality, but they require preoperative CT scans. *[7]*

Fluoroscopic navigation systems are amenable to procedures that already use fluoroscopy, as in case of trauma surgery, but not for procedures in which fluoroscopy is not routinely required, such as TKA.

Image based navigation can allow some limited preoperative or intra-operative planning and surgical simulation.

Image-free navigation systems lack the 3-D patient specific anatomic data and relay on a generic model of bone that is represented by the key anatomic landmarks of average bone geometry. *[11]*

Navigation System (table 1)

Image-based

- CT-based system
- Fluoroscopic system

Image free

1. CT based navigation

The successful application of CT-based navigation technologies for spinal surgery soon let researchers and developers to apply this concept to other applications in orthopedic surgery.

Although CT-based navigation had opened a wide door for orthopedics by applying neurosurgery's stereotactic concepts to the skeletal apparatus, a considerable number of disadvantages became evident that could only partially be overruled by the excellent results, which were achieved with the new technology. Example of these drawbacks is that a CT scan had to be acquired preoperatively which is not required in all cases, for example, conventional THA does not require CT examination. Therefore, this radiation and cost-intensive procedure gained little acceptance if it had to be performed for navigation purposes only. *[10]*

Also the use of an intra-operative CT scanner usually requires considerable modifications to a clinics infrastructure with related investments.

Because of these drawbacks, CAOS failed to become state-of-the art in the general case. *[7]*

Navigation based on preoperative CT scan is preferred for spinal, pelvis and acetabular surgery and for joint replacement of severely