

DEVICE AND METHOD FOR FITTING AN ARTIFICIAL KNEE JOINT USING UNIVERSAL ELECTRONIC TEMPLATES WHICH CAN BE ADAPTED TO ALL ARTIFICIAL JOINTS

Description

Technical Field:

Total knee arthroplasty (TKA) is the standard treatment for advanced knee osteoarthritis. The aim of a TKA surgery is to achieve long-term implant survival and successful functional outcome with cost effectiveness and minimal complications. The success of a TKA is dependent on surgical techniques that require a high degree of accuracy and reproducibility. Technical errors can have detrimental effects on function and survival. Component malpositioning may lead to wear and loosening, or patellar instability which results in early failure and revision surgery. Current surgical techniques rely on plain radiographs for preoperative planning and standardized conventional instrumentation for performing the procedure. Plain radiographs have limited accuracy. Conventional instrumentations have been reported to have limitations that affect the ultimate accuracy of surgery, especially bone cutting and implant alignment. Conventional instrumentations are complex tools with numerous jigs and fixtures. Their assembly is time consuming and may lead to errors. Their repeated use carries a theoretical risk of contamination. The use of alignment guides involves violating the IM canal. This can lead to a greater risk of bleeding, infection, fat embolism, and fractures. Each knee prosthesis has its own instrumentation. In the United Kingdom, there are more than 30 knee prostheses, and it is not unusual to have different prostheses used by different surgeons in the same department. This may overload hospital inventory, sterilization services, nurses' learning curves, and operating room time. Although conventional surgical instrumentations have been refined, additional technologic improvements have been limited. Computer-assisted navigation and robotic techniques have proved to be more accurate than conventional instrumentations. However, the broad application of such techniques is limited by cost, complexity, set-up time, and long learning curve. Recently, a new technique was introduced to overcome the listed drawbacks. This technique called "Patient Specific Instruments for knee arthroplasty", which is a new concept of utilizing computer-assisted preoperative planning to provide custom made surgical guides that can partly

or completely replace conventional instrumentation systems. This new technique of patient specific instruments (PSI) was first reported by Hafez et al¹⁻³

Background Art:

Patient Specific Instruments (PSI) for knee arthroplasty involves image-based preoperative planning, followed by the production of templates that match the surface geometry of the patient's bony structures. The templates are designed to transfer the preoperative planning to the intraoperative performance. The production machines range from computer numeric-controlled (CNC) to a more sophisticated technology of rapid prototyping (RP) which acts as a three-dimensional printer to produce physical objects from the three-dimensional computer-aided designs (virtual templates). A preoperative CT or MRI scan is imported to a special software system that has three-dimensional data of TKA implants to be used. Planning and virtual surgery is performed on the computer before it is done on real patients. This includes sizing, alignment, bone cutting and verification of optimal implantation and positioning. Two virtual templates are designed and transformed into surgical guides using rapid prototyping technology. Information built into these guides make them patient specific and can be used by surgeons as cutting guides or cutting blocks. Therefore, TKA can be done without using conventional intra or extramedullary guides. This revolutionary technique has potential advantages over conventional systems as it improves short term recovery, reduces operative time and the risk of bleeding and fat embolism as well as maintaining accuracy. It is particularly useful for cases of extra-articular deformities, especially in elderly patients. It is a midway between conventional techniques and other more complex computer assisted system such as navigation and robotics.

Problems with the current art:

The PSI technique is now produced by some implant companies manufacturing knee or other joint prostheses. The planning process and PSI for each company is based on the implant of that producing company; which implies that the PSI of one company cannot be used for the implant of another company⁴⁻⁶. Thus, these PSI's are company specific and they are very expensive, which is a significant disadvantage since this limits the wide spread application of current availability of PSI. Furthermore, there are manufactured implants used by many surgeons around the world that does not have PSI, which deprives patients of the privilege of PSI. In addition, a serious

limitation of current PSI technique is that the planning is done by technicians not by the surgeon, himself and the whole process is under the control of the implant company. Although the final planning may be made available for surgeons to review, surgeons are not in control of the planning. For this reason PSI technique is used for the straight forward knee replacement and not for complex cases of either intra-articular or extra-articular deformity.

References

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Disclosure of Invention:

The invention is a device and a method for preparing a knee joint for a prosthesis in a patient undergoing TKA surgery for any knee implant (prosthesis) in a universal and an open platform fashion. The universal device and an open platform and method are suitable to be used for any commercially and currently available knee implant. The device and the method are used for all on-shelf implants and all patient specific implants. The universal and an open platform device and method are suitable to be used for any on-shelf and any patient specific knee implants that could be produced in future.

The device is a patient specific instrument, which is based on a method comprising of image based (CT, MRI or computed X-ray) 3-D preoperative planning to design the virtual templates, which are then converted to physical templates using computer aided manufacturing such as computer numerical control (CNC) or additive manufacturing such as rapid prototyping technologies. A method of planning and complete virtual surgery of TKA, which includes several steps; 3-D reconstruction

and segmentation of computed tomography (CT) or MRI scan data. The preoperative planning that is comprised of 3-D evaluation of the anatomy and pathology of the knee joint and identification of landmarks and axes followed by complete planning including sizing alignment, bone cutting and positioning of implants (prosthetic components) followed by simulation of surgery and template designing. That method lead to the production of the templates (instruments). One femoral and one tibial template were designed in the form of cutting blocks to allow bone preparation based on preoperative planning. This was achieved by creating slits in the templates to allow bone cuts in the distal femur and the proximal tibia. The template was designed to have five cylindrical locators for the femur and four for the tibia. These locators were created in the internal surfaces of the templates, matching the surface shape of the distal femur and proximal tibia. Because these locators were patient-specific, they could only allow the templates to be placed in a unique and secure position. The locators were cannulated to allow passage of the fixation pins that provided additional stability to the templates over the bone. The femoral template is meant to allow the surgeon to perform the distal cut through the specified slit and also guide the surgeon to mark the distal femur for the position of and direction of anterior cut and rotation. Then a conventional cutting guide is used to make the remaining 3 cuts of the femur (posterior, anterior chamfer and posterior chamfer cuts). There is a slit in the upper part of tibial template to indicate the direction of tibial rotation and guide the position of the stem and keel if needed. There is a projection in the front of the lower part of tibial template to allow the attachment of a rod that goes down to the ankle as a double check for tibial rotation. Surgical simulation of bone cutting and implant positioning were performed using virtual templates. The final design of the custom templates (patient-specific instruments) was transferred electronically to a rapid prototyping machine. Patient-specific instruments then were produced from a material that is biocompatible and durable. Once manufactured, the templates were sterilized and used by the surgeon to perform TKA.

The device is specifically designed for TKA and the planning is based on a universal TKA prosthesis. The device has 2 parts; a femoral part and a tibial part both of them are independent of any commercially available knee implants and can work universally with all currently available implants or any implants introduced in future. The device has locating probes that are cannulated and have optional metallic sleeves

to allow fixation pins to pass through and securely fix the instrument to the bone. The method involves planning for the whole TKA surgery including sizing, alignment and rotation with simulation of the virtual surgical result. No need for preoperative coupling with other surgical instruments such as drills or sleeves that are related to a particular company. The preoperative plan is transferred to a two piece instrument that can replace the conventional instrumentation for TKA such as intramedullary, extra-medullary guides, sizing, rotation guides for both tibial and femur. The instrument is designed in the form of a cutting block, through which most of bone machining steps are carried out. The paths for the bone machining steps mentioned in claim 10 such as saw and drills in addition to the path for fixation pins are multidirectional but they are accurately positioned to prevent any intersection. Surface matching of the templates relies on protruding locating probes that match bony surfaces away from the cartilage i.e. positioned on a “cartilage free area”. There is also one protruding removable probe for the femur that is positioned on a cartilage free area. The device is an instrument (tool) not just a template. The instrument is positioned directly to the bone with no other interfaces (guides, sleeves or cutting blocks).

The same technique can be applied for other knee procedures such as unicompartmental, bicondylar and patellofemoral arthroplasty.

Description of Drawings:

Figure 1: Femoral template

All views (1-A, 1-B, 1-C, 1-D, 1-E, 1-F, 1-G, 1-H)

The figure has several views of the femoral template from (1-A to 1-H).

The template was designed to have five cylindrical locators for the femur (labels 6 and 10 in figures 1-A, 1-D and 1-E). These locators were created in the internal surfaces of the templates, matching the surface shape of the distal femur. Because these locators were patient-specific, they could only allow the templates to be placed in a unique and secure position (figure 1-F and 1-G). The locators were cannulated to allow passage of the fixation pins that provided additional stability to the templates over the bone (label 7 in figures 1- F and 1-G). The femoral template is meant to allow the surgeon to perform the distal cut through the specified slit (label 4 in figure 1-B). The template also guides the surgeon to mark the distal femur for the position of and direction of anterior cut and rotation at the margin (free end) of the template (figure 1-C and 1-D).

Figure 2: Tibial template

All views (2-A, 2-B, 2-C, 2-D, 2-E, 2-F, 2-G, 2-H, 2-I)

The figure has several views of the tibial template from 2-A to 2-I.

The template was designed to have four locators for the tibia as indicated by label 6 in figure 2. These locators were created in the internal surfaces of the templates (figures 2-A, 2-D and 2-E), matching the surface shape of the proximal tibia (Figures 2-F, 2-G and 2-H). Because these locators were patient-specific, they could only allow the templates to be placed in a unique and secure position (Figures 2-F, 2-G and 2-H). The locators were cannulated to allow passage of the fixation pins which provided additional stability to the templates over the bone (Figure 2-I). A slit in the upper part of tibial template indicates the direction of tibial rotation and guides the position of the stem (label 3, Figure 2-B) and keel (label 2, Figure 2-B) if needed. Another slit in the front of the tibial template allows the attachment of a rod that goes down to the ankle as a double check for tibial rotation (label 5 in Figure 2-B).

Claims

1. A device for preparing a knee joint for a prosthesis in a patient undergoing total knee arthroplasty (TKA) surgery for any knee implant (prosthesis) in a universal and open platform fashion, this device consists of two parts: a femoral part and a tibial both are designed in the form of cutting blocks that have locating probes, slits and a surface for bone cutting, guide for adjusting rotation and holes for pin fixation. The tibial part has a hole for the creation of the stem and a slit for the creation of the keel.
2. A method of planning and complete virtual surgery of TKR in a universal and an open platform technique leading to the production of the device mentioned in claim 1, this method comprises of several steps including: sizing of implants, alignment, bone cutting and positioning of implants (prosthetic components) as well as virtual surgery.
3. The universal and an open platform device in claim 1 that is suitable to be used for any currently available knee implants (all on-shelf implants) regardless of different shapes and configurations of these implants
4. The device in claim 1 used for all patient specific implants.
5. The device in claim 1 consists of two parts: a femoral part and a tibial part. Both of these parts are independent of the design of knee implants and can work universally with all different designs of implants.
6. The device in claim 1 contains locating probes that are cannulated and have optional metallic sleeves to allow fixation pins to pass through and securely fix the instrument to the bone.
7. The device in claim 1 is designed in the form of a cutting block, through which most of the bone machining steps are carried out.

8. The trajectories for the bone machining steps mentioned in claim 1 such as saw and drills in addition to the path for fixation pins are multidirectional but they are mathematically positioned to prevent any intersection
9. Surface matching of the device in claim 1 relies on protruding locating probes that match bony surfaces away from the cartilage i.e. positioned on a “cartilage free area”
10. The device in claim 1 has one protruding removable probe for the femur that is positioned on a cartilage free area
11. The device in claim 1 is positioned directly to the bone with no other interfaces (guides, sleeves or cutting blocks)
12. The universal and open platform device is suitable for any knee implants that could be produced in the future regardless of the design or the shape of knee implants.
13. The universal and open platform method in claim 2 is suitable to be used for any commercially and currently available knee implant (on-shelf implants).
14. The universal and open platform method in claim 2 is suitable to be used for any patient specific knee implants.
15. The universal and open platform method is suitable to be used for any knee implants that could be produced in future regardless of the design or shape of knee implants
16. The method in claim 2 includes 3-D evaluation of the anatomy and pathology of the knee joint and identification of landmarks and axis followed by complete planning, including sizing of implants, alignment, bone cutting and positioning of the implants (prosthetic components) in a universal and an open platform technique.
17. The method in claim 2 includes simulation of surgery and template designing in a universal and an open platform technique.

18. The method in claim 2 leads to the production of the device in claim 1 (instruments) that guide the bone cuts or guide the accurate positioning of the conventional cutting jigs to be used for all implants in an open platform technique (universal)

19. The method of claim 2, comprising image-based 3-D preoperative planning to design the virtual templates which are then converted to physical templates using additive manufacturing such as rapid prototyping techniques

20. The method in claim 2 involves planning for the whole TKA surgery including sizing, alignment and rotation with simulation of the virtual surgical result

21. The method in claim 2 does not need for preoperative coupling with other surgical instruments such as drills or sleeves that are related to a particular company

22. The preoperative plan used in claim 19 is transferred to a two piece instrument that can replace the conventional instrumentation for TKA such as intramedullary, extra-medullary guides, sizing, rotation guides

23. The method in claim 2 is independent of the design of knee implants and can work universally with all different designs of implants

Labeling data :

- 1) Body of template – cutting block (Femoral or Tibial)
- 2) Slit for marking rotation & passage of Keel
- 3) Hole for making passage of Stem
- 4) Slit for distal femur cut
- 5) Slit for marking rotation
- 6) Locating probes (proximal end)
- 7) Hole for pin fixation (distal end)
- 8) Void area (permissive hole – space) for positioning of tibial tibial tuberosity
- 9) Flat cutting surface for anterior cut & rotation
- 10) Removable locating probe
- 11) Slit for proximal tibia cut
- 12) Cartilage free bone area
- 13) Projection in the front of the lower part of tibial template
- 14) Fixation pins
- 15) Saw Blade
- 16) Powered saw