

An Algorithm to Identify Knee Prostheses From Their Radiographic Appearances

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ABSTRACT: Modularity in total knee system design makes it important for the surgeon to know the model of prostheses being revised since components of different designs are not interchangeable. Preoperative information on the manufacturer and model of prostheses implanted may not always be available. This article describes an algorithm that allows surgeons to identify the prosthesis from standard radiographs. Ninety-nine percent of the knee prostheses implanted between 1985 and 1992 can be identified using this

algorithm. The algorithm uses the shape of the tibial keel, the type of baseplate, and the shape of the femoral component as branch points to identify the model and manufacturer of 15 primary total knee prostheses. In addition, certain models were found to have radiographic "fingerprints" such as the presence of a spiked tibial keel. This algorithm should be an aid to surgeons performing total knee revisions.

[*Am J Knee Surg.* 1999;12:7-13.]

INTRODUCTION

The number of total knee prostheses implanted in the United States has increased steadily over the past several years. A study on the frequency of total knee arthroplasty (TKA) in Olmsted County, Minnesota, reported a three-fold rise in the number of prostheses implanted between 1971-1974 and 1983-1986.¹⁰ An analysis of Medicare beneficiaries revealed that 68,491 TKAs were performed in 1988, and an estimated 129,000 TKAs are performed per year in both Medicare and privately insured patients.⁹ The number of total joint replacements performed worldwide is estimated to be 1 million per year.²

Survivorship analyses of total knee devices done at large centers demonstrate failure rates of 3% to 19% at 10 years.^{6-8,11-12,14} Lavernia et al⁴ have shown that 25% of primary TKAs are done by 20% of the practicing surgeons and that there is an inverse correlation between the number of arthroplasties performed by a surgeon and improved short-term outcome.

Along with the increasing number of primary TKAs being performed each year is an increasing number of revision TKAs being performed. A significant number of these surgeries will be performed by surgeons who did not perform the index procedure. This places the surgeon at a disadvantage if a single component is being revised or if an insert exchange is being performed. A method to identify the model and manufacturer of a knee prosthesis from preoperative anteroposterior and lateral radiographs would be of great benefit to the orthopedic surgeon involved in revision procedures. This article describes an algorithm to help the orthopedic surgeon planning a knee revision identify the type of prosthesis implanted during the original TKA.

MATERIALS AND METHODS

Several reports are available that identify market share for arthroplasty products. Using the *Frost and Sullivan Market Outlook Report*,³ we selected 10 companies that captured 98.2% of the total knee system market from 1988-1990. The product manager for each company was then contacted to determine the name and model of all knee prostheses marketed by each company since its inception. Revision stems, unicompartmental knees, and

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TABLE 1
TOTAL KNEE SYSTEMS INCLUDED IN THE STUDY

Manufacturer	Prosthesis
Zimmer	Miller Galante II Insall-Burstein II
Howmedica	PCA/Duracon Kinematic II/Kinemax I
J&J Orthopaedics	PFC
DePuy	Low Contact Stress (LCS) Anatomic Modular Knee (AMK)
Intermedics	Natural
Smith & Nephew Richards	Genesis
Dow Corning Wright	Ortholoc
Osteonics	Omnifit Series 7000
Biomet	AGC
Kirschner	Performance
Techmedica	Continuum Knee System (CKS)

hinged designs were excluded. A total of 15 knee prostheses were studied (Table 1). Radiographs of knees were then collected and examined.

Prosthesis Characteristics

Femoral Components. Radiographically, several characteristics of each component were identified. The femoral components could either have an anatomic (distinct left and right) or universal design. Femoral components also could be distinguished by the presence or absence of a central rod. In addition, most femoral components had two lateral pegs.

Tibial Components. The tibial components could be distinguished by the presence, absence, and shape of a central stem. If present, this stem could either be cylindrical, keel shaped, or spiked (Figure 1A). The cylindrical rods could have either a flat or a bullet end, or an extension rod in revision systems. The keel-shaped rods could have either a flanged or smooth-shaped keel. Keels could have a variable width relative to the tibial plate and variable lengths relative to the tibial rods. Flanged keels could have a variable number of flanges. A tibial component could have lateral pegs or screws, and the number of either could vary.

The tibial components also could be distinguished by the locking mechanism for polyethylene onto the tibial baseplate (Figure 1B). The metal baseplate could be flush or have an anterior lip. There could be metal grooves that serve as locking devices. Some components had a central metal stud that served as a locking mechanism for the polyethylene component.

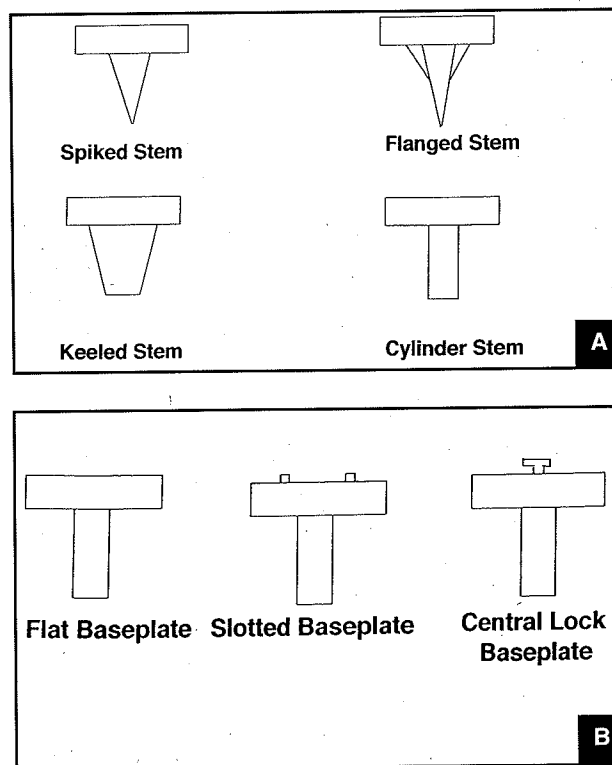


Figure 1. Diagrams showing the different configurations of central stems (A) and locking mechanisms (B) of tibial components.

Patellar Components. Patellar components could vary in the shape of their fixation peg (rod shaped, circular or cruciate), the number of pegs, and the presence or absence of metal backing.

RESULTS

During the study period, 15 primary knee prostheses were available to a surgeon performing primary TKA. The radiographic characteristics of each prosthesis were catalogued (Table 2). A stepwise algorithm was developed that allowed individual prostheses to be identified using three basic radiographic characteristics.

When viewed on the AP radiograph, the femur has either an anatomic (distinct left versus right component) or a universal (interchangeable left versus right component) morphology. Four prostheses had a universal femur: the Anatomic Modular Knee (AMK), the Kinematic II/Kinemax, the Continuum Knee System (CKS), and the Insall-Burstein II.

The tibial keels also could be used to distinguish the prostheses radiographically. Only one prosthesis had a spiked keel (Natural prosthesis), while five prostheses had smooth keels (Kinemax/Kinematic II, LCS, Series 7000, PCA, and Genesis prostheses).

TABLE 2
CHARACTERISTICS OF KNEE PROSTHESES

Company & Model	Femoral Shape/ Slope/Peg	Tibial Central Stem/No. Flanges/Lateral Pegs	Tibial PE Locking Mechanism/ Anterior Lip	Patella
Biomet AGC	Anatomic/moderate/ 2 lateral pegs	1 beam (all PE) or round tip cylinder/none/none	2 midline slots/2 slots	Not available
Depuy AMK	Universal/flat/central cylinder or 2 lateral pegs	Bullet tip or double-stacked cylinder or all PE I-beam/None/4 optional screws	Two midline slots/2 slots	Open circle
LCS	Anatomic/flat/round tip cylinder	Smooth keel/none/none	Rotating platform tibia/flat	Cross-shaped peg with anatomic- shaped patella
LCS Bicruciate Retaining	Anatomic/flat/round tip cylinder	Central "slot"/none/two	Rotating platform tibia/flat	Cross-shaped peg with anatomic- shaped patella
Howmedica Kinematic II/ Kinemax	Universal/flat/flat tip cylinder	Smooth keel or flat tip cylinder or slotted round tip cylinder/none/2 U- shaped or round cylinder pegs with flat-tipped cylinder central peg	Central knob/sloped midline single lip	
PCA/Duracon	Anatomic/sharp/ cylinder	None, smooth keel cylinder/none/no central peg, optional 2 lateral pegs or 2 lateral cups with 3 optional screws	Central knob/flat or single central rectangle	2 pegs
Intermedics Natural	Anatomic/flat/2 lateral pegs or screws with optional round tip cylinder	Spike/none/4 pegs with 2 optional screws	None/flat	3 pegs
Johnson & Johnson PFC	Anatomic/flat/2 lateral pegs or optional round tip cylinder	Flanged keel with optional PE cap/ 3/2 optional screws	None/flat	1 or 3 pegs
Kirschner Performance	Anatomic/moderate/ none	Flanged keel or round tipped slotted cylinder/4/4 optional screws	Central screw/flat	1 peg
Osteonics Omnifit	Anatomic/moderate/ 2 lateral pegs with optional curved cylinder central peg	Flanged keel (3/4 length)/3/2 optional lateral screws	None/flat	3 pegs
Series 7000	Anatomic/moderate/2 lateral pegs	Wide full width keel/none/none	None/flat	3 pegs
Smith & Nephew Richards Genesis	Anatomic/flat/2 lateral pegs with optional central cylinder	Flanged keel or double-stacked cylinder/2 or 3/2 optional screws	Anterior slots/2 midline anterior rectangles	1 or 3 pegs
Techmedica CKS	Universal/flat/round tipped cylinder	Flat tipped cylinder or flanged keel/3/none	Central knob/midline rectangle	3 pegs

TABLE 2 (CONTINUED)
CHARACTERISTICS OF KNEE PROSTHESES

Company & Model	Femoral Shape/Slope/Peg	Tibial Central Stem/No. Flanges/Lateral Pegs	Tibial PE Locking Mechanism/Anterior Lip	Patella
Wright Medical (Dow Corning) Ortholoc	Anatomic/moderate/2 lateral pegs	Flanged keel or round tipped cylinder or no central keel/2 or 3/6 with or without central pegs, 4 optional screws	None/flat	1, 2, or 3 pegs
Zimmer Insall-Burstein II	Universal/flat/flat cylinder	Flat cylinder with grooved curve cylinder extension/none/none	Central knob PE goes down into plate/plate has 2 lateral slots	1 peg
Miller Galante II	Anatomic/sharp/4 lateral Cps or 2 posterior Cps with anterior cylinder 4 optional screws	No central peg or anterior flat cylinder optional with 2 posterior cups/screws/none/4 or 2 cup shaped pegs with optional screws	Central knob/flat	3 pegs

Abbreviations: PE=polyethylene.

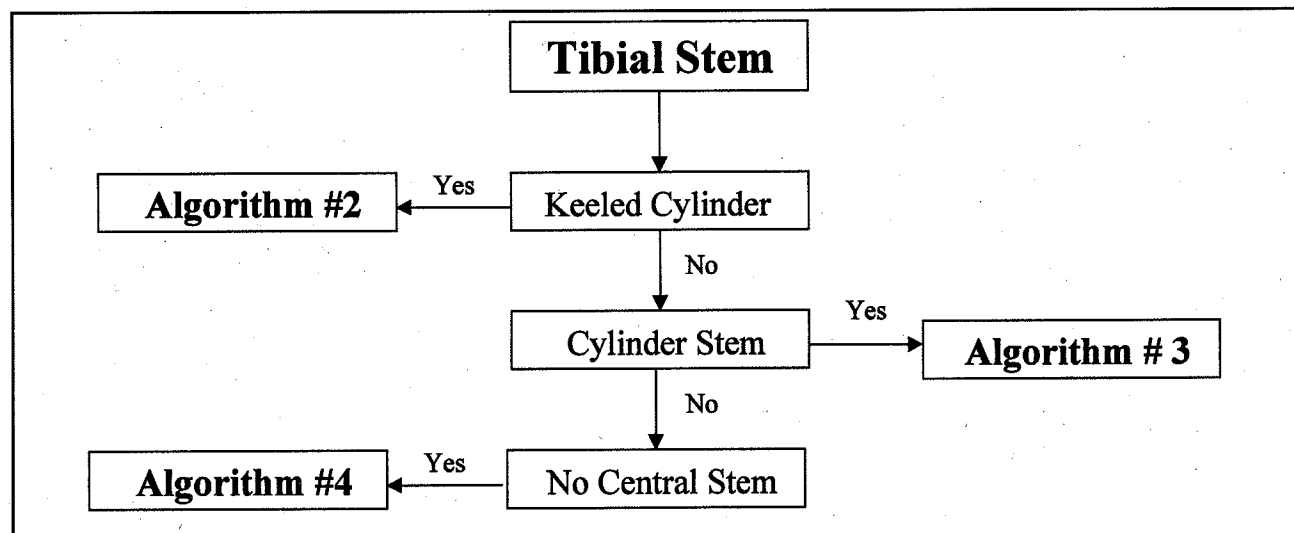


Figure 2. Algorithm 1 is used to identify a prosthesis by the type of tibial stem.

Five prostheses had flanged keels: PFC, Omnifit, Performance, Ortholoc, and CKS. Ten devices offered cylinder shaped stems: Performance, Ortholoc, Genesis, the AMK, AGC, CKS, Insall-Burstein II, Miller Galante II, Kinemax, and PCA. Three prostheses had no central tibial stems: Miller Galante II, the PCA, and the LCS (bicruciate retaining). A keeled cylinder defines a cylindrical stem with a keel emanating from each side of the cylinder.

The devices could be identified further by the type of locking mechanism present to lock the polyethylene tibial component onto the tibial baseplate. Six components had a central metal knob or screw to secure the polyethylene tray: Kinematic II/Kinematic, PCA/Duracon, Performance, CKS, Insall-Burstein II, and Miller

Gallante II. Some components relied on the use of slots either in the polyethylene or the tibial baseplate to secure fixation. These "slotted" components were found on the following prostheses: AGC, AMK, Genesis, CKS, and Insall-Burstein II. Asymmetric tabs on the lateral view involve metal prominences that are present on the anterior and posterior surfaces of the tibial tray. These prominences serve to capture the polyethylene insert. Tibial lips are small metal prominences on the tibial tray that are curved on the most superior edge. They also serve as a mechanism to capture the polyethylene insert.

Using these characteristics, a series of algorithms was developed to radiographically distinguish each of the 15 prostheses (Figures 2-5).

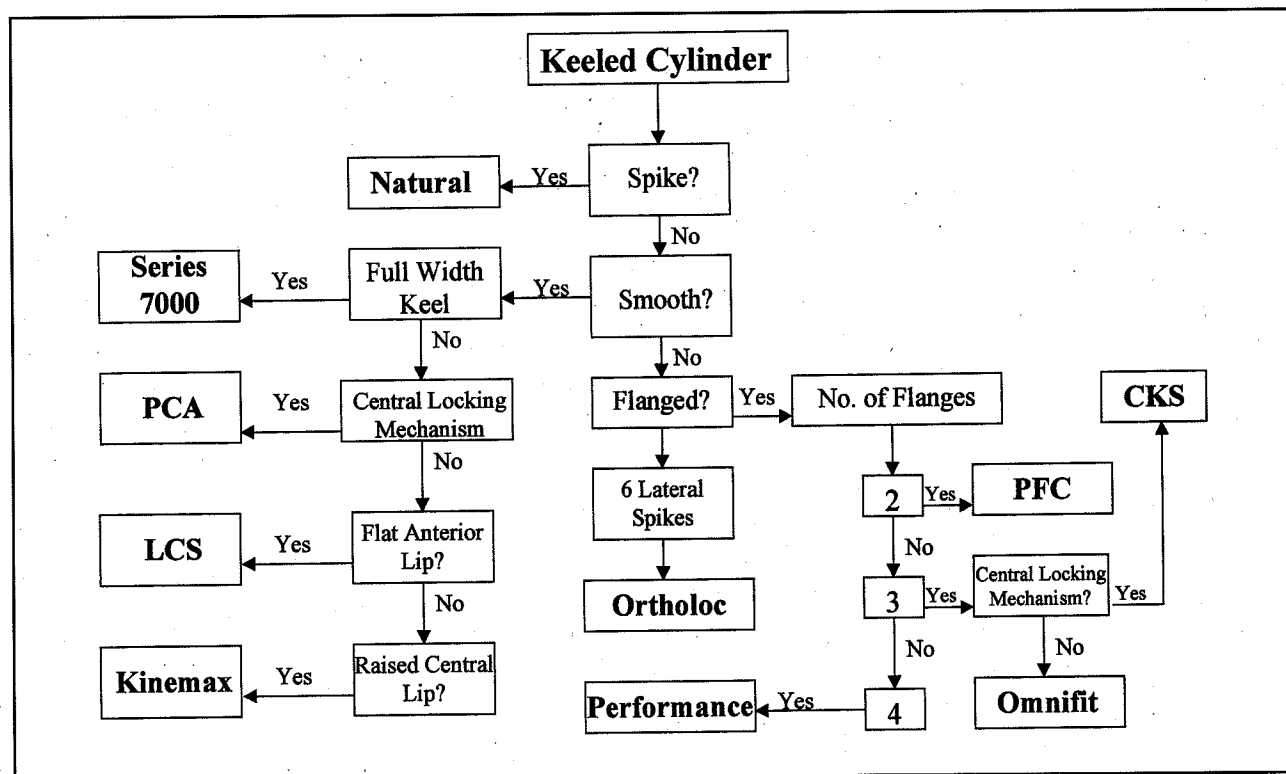


Figure 3. Algorithm 2 is used to identify a prosthesis by the type of cylinder.

DISCUSSION

A literature review revealed no studies that classified the different models and manufacturers of total knee prostheses that have been marketed or are currently available in the United States. The Food and Drug Administration requires a premarket notification (510[k]) or a premarket application for any implantable medical device, including total knee prostheses.⁵

A listing of the number of devices sold under the various codes for TKA by manufacturer is available. However, there are 12 separate code numbers for total knee prostheses, and when contacted, the FDA was unable to provide a list of currently available knee prostheses. There is no list of the type, models, and indications for the different knee prostheses available on the market today.

Examining the unique characteristics of knee prostheses provided us with a sequential set of steps that allowed us to separately identify each prosthesis. All of the features of the tibial and femoral components can be identified on AP and lateral radiographs of good quality.

As an illustrative example, the algorithm could be used to identify the two prostheses in Figures 6 and 7. The Natural device (Figure 6) can be identified by its keeled stem, which is spike shaped (Figure 3); this prosthesis has the unique radiographic fingerprint of being the only pros-

thesis with a spiked keel. The PCA prosthesis (Figure 7) can be identified using the algorithm for devices; this prosthesis has no central stem and two lateral bullet-shaped pegs.

There has been no previous report in the literature that describes a method to identify specific knee prostheses based on their radiographic characteristics. The closest available publication is a chapter in the *Imaging Atlas of Orthopaedic Appliances and Prostheses*,¹ which radiographically depicts certain knee devices, but does not include a means of differentiating one device from another.

The algorithm presented here demonstrates that it is possible to identify a total knee device from its radiographic appearance. This should benefit surgeons who perform knee arthroplasty revision by decreasing intraoperative time by ensuring that the proper revision components are available. This issue also becomes increasingly important in the current climate of cost containment.

CONCLUSION

This article presents a series of algorithms that allows the surgeon to identify total knee prostheses prior to revision knee arthroplasty. The algorithms outline a sequential set of steps that can be used to pinpoint the model and manufacturer of an unidentified total knee

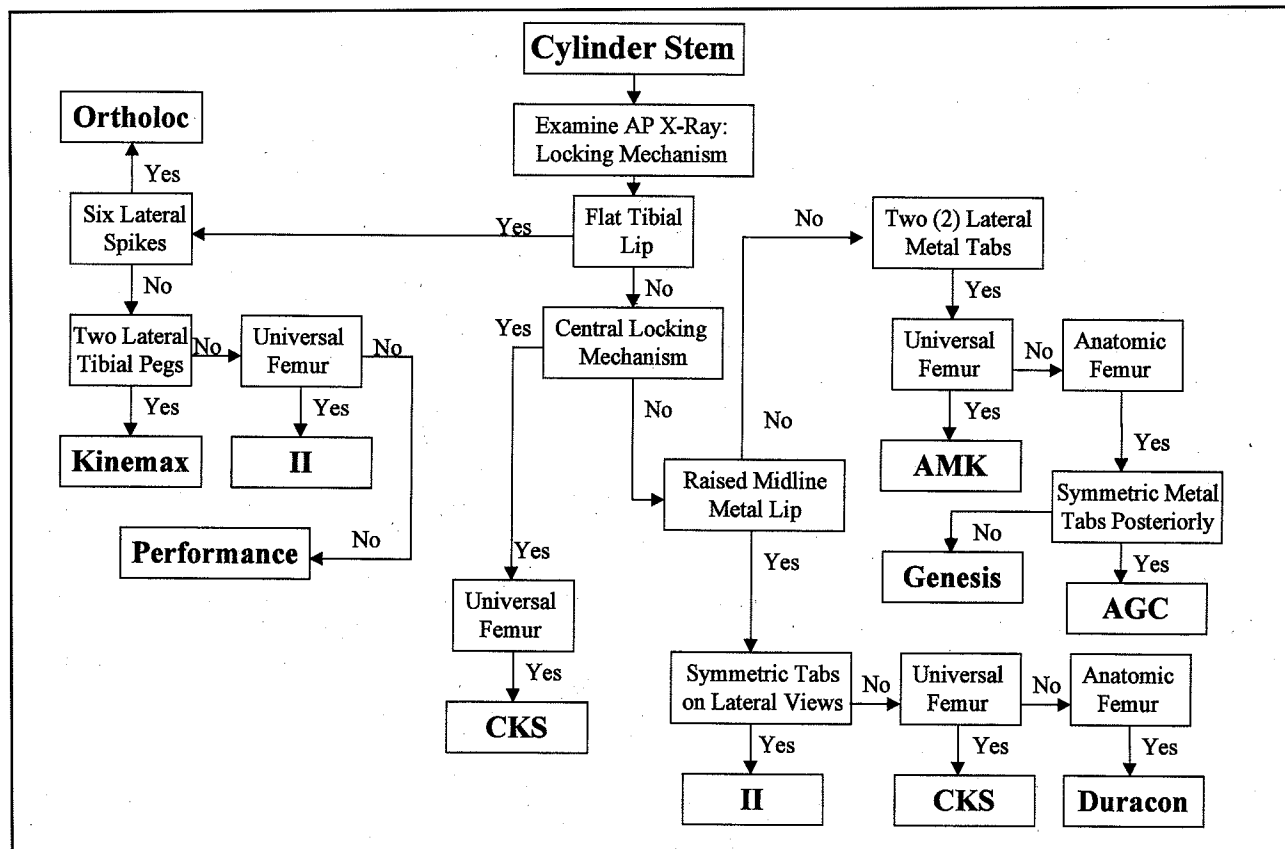


Figure 4. Algorithm 3 is used to identify a prosthesis by the type of cylinder stem.

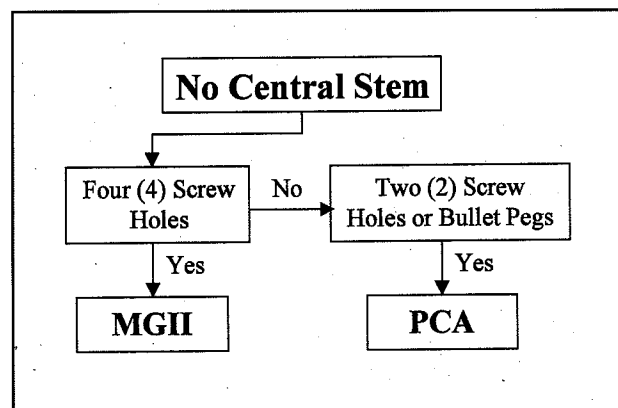


Figure 5. Algorithm 4 is used to identify a prosthesis with no central stem.

prosthesis using data readily available to the orthopedic surgeon: good-quality AP and lateral radiographs of the knee.

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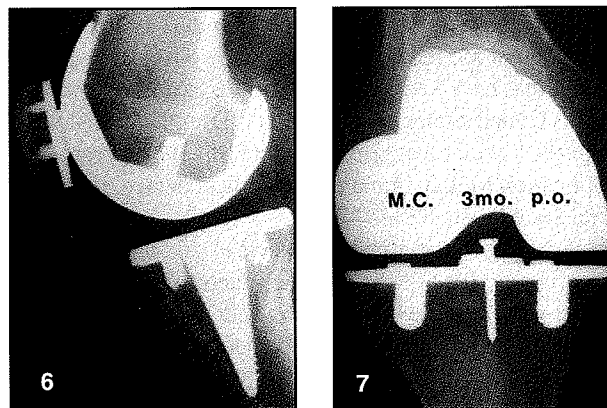


Figure 6. The Natural prosthesis can be identified using algorithm 2. Its keeled stem is spike shaped, and this prosthesis is the only prosthesis with a spiked keel. Figure 7. The PCA prosthesis can be identified using algorithm 4; this prosthesis has no central stem and two lateral bullet-shaped pegs.

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