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Long term results of a total knee prosthesis utilising an all polyethylene tibial component

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Abstract :

Introduction: The aim of this study was to assess the long term performance of a of a cemented total knee replacement utilising an All Polyethylene Tibial (APT) component and in addition to perform an engineering analysis of any failures to help refine surgical technique.

Materials & Methods: A total of 26 patients had a total knee replacement performed using a cemented cruciate retaining Depuy Press Fit Condylar (PFC) APT component and a cruciate retaining femoral component. At final review all patients were assessed using The Knee Society Score together with radiographs. An engineering analysis simulated loading conditions of the implants that failed and these were compared with the performance of a modular Metal Backed Tibial (MBT) component.

Results: A total of 20 patients were reviewed at mean time of 116 months following surgery. Knee Society Knee Scores and Function Scores in this cohort were 84/100 and 58/100 respectively. Two patients required revision for tibial component failure. Pre-operatively both had valgus deformities and in each case the tibial tray had been lateralised leaving a gap on the medial side where the APT component had no rigid support. The engineering analysis demonstrated that the volume of highly strained cancellous bone was greater in the APT design compared to the MBT design when a model with a 3mm medial gap was loaded. The stiffer MBT base plate acted more rigidly and shielded the stress applied to the proximal tibial cancellous bone.

Conclusion: The APT component demonstrated excellent clinical and radiographic performance at long term follow up. An engineering analysis of the failures in our case series suggests that careful placement of the implant on the prepared tibial surface with appropriate cortical support may be important in patients with poor bone quality and this has added to our understanding of the surgical technique required when using this implant.

Keywords : Total; knee; replacement; all; polyethylene; tibia

Introduction :

There has been recent renewed interest in knee replacements employing the use of an APT component. [1-5] The decreased cost of such implants over MBT modular components may help to reduce overall costs. [5,9,10] Modern tibial components employing such a design have been shown to have excellent clinical results and long term survivorship**.** [4,6,7,8] APT knee replacements avoid locking mechanism issues and backside wear associated with MBT components and the possible osteolysis that this may cause. [11,12] The APT component also allows increased polyethylene thickness with the same amount of bone resection as seen with a similar sized MBT component. Gioe & Maheshwari have summarised the advantages and disadvantages of APT and MBT components.[2] Our study reviews the approximate ten year results and overall survivorship of a knee replacement employing an APT component. An engineering analysis of the two failures within the cohort has increased our understanding of the surgical technique required for this implant and may aid in patient selection.

Material & Methods :

Local ethical committee and written informed consent was obtained from all patients. The indication for surgery was symptomatic osteoarthritis of the knee in all cases. All patients had their surgery performed as per the surgical technique for the implant. In all cases the tibial component implanted was a cemented PFC Sigma cruciate retaining APT component (Depuy, Johnson & Johnson, Leeds, UK) (Fig 1) and a cemented PFC Sigma cruciate retaining femoral component. The Knee Society Score [13] was used to assess all patients at the time of final follow up, pre-operative Knee Society Scores were not available. Antero-posterior and lateral radiographs were obtained at the time of final follow up and compared with previous radiographs for the presence and size of radiolucent lines at the bone-prosthesis interface of the tibial component using the Knee Society Total Knee Arthroplasty radiographic evaluation system. [14]

An engineering analysis using a three-dimensional finite element model of an idealised proximal tibia

with and without a metal backed tibial tray was generated using the Ansys ver. 6.0 modelling software (ANSYS Inc., PA, USA). The shape of the tibial tray was idealised to be an elliptical shape perfectly bonded to a 2mm Poly Methyl Meth Acrylate layer on the superior surface of the cancellous and cortical bone (1mm cortex). The effect of tibial tray coverage (lateralization of the tibial tray) was investigated by introducing a medial gap of 3mm on the superior cut surface of the tibia between the medial edge of the tibial tray and the cortical bone. An inferior load of 3200 N (4 x BW) was applied centrally to the superior surface of the medial tibial condyle simulating lateral lift-off during walking (Fig 2). The cancellous bone was modelled as an elastic/plastic material to allow collapse if the load exceeded the yield stress, while the remaining materials were modelled elastically. The mechanical properties of the cancellous bone were based on those of an 80 year old patient without disease (yield stress 4.5 MPa). [15]

Results :

Between May 2000 and October 2002, 26 patients, 18 females and 8 males, had total knee replacements performed with APT components. The mean age of patients was 69.7 years at the time of surgery (range 58 - 81). One patient had died at the time of latest follow up, 3 patients declined follow up but were having no problems with their knees and two were revised leaving a total of 20 patients available for long term review (77 % of the original cohort). Mean duration of follow up was 116 months (sd 7.95). At follow up, patients' mean Knee Society Knee Score and Function scores were 84 (sd 7) and 58 (sd 17.8). No radiolucencies were identified at the bone-prosthesis interface (of either the tibial and femoral components) of the 20 remaining patients who had not required revision surgery at 10 year follow up. One patient sustained a late periprosthetic femoral fracture following a fall 55 months after their index procedure which successfully united following plate fixation. Survivorship of the implants in this study available for long term follow up was 91 % (20/22). Pre-operatively the two patients requiring revision had a valgus deformity (Fig 3a) and in both the tibial tray was lateralised (Fig 3b), leaving a gap on the medial side of the APT component which had no cortical support. Both patients suffered from medial collapse with subsidence of the tibial tray within 2 years of their surgery (Fig 3c).

The engineering theoretical analysis demonstrated that the volume of highly strained cancellous bone, shown by the size of the coloured area in Figures 4a & 4b, was greater in the APT design (Fig 4a) (75% load transfer) compared to the MBT design (48%) (Fig 4b) when a 3mm medial gap was present. The stiffer metal backed tibial base plate acted more rigidly and shielded the stress applied to the proximal tibial cancellous bone compared to the all polyethylene tibial component. The engineering explanation of the failures explained the macroscopic observations that the two failed APT implants were bent in the centre with the medial side sloping inferiorly.

Discussion :

Previous studies of early APT components showed high failure rates with aseptic loosening that was attributed to poor surgical technique or errors in design. [16,17] Design features of significance included polethylene type and implant conformity which may be a particularly important factor in the design of APT components [18] . Farris & Ritter [18] compared the performance of a compression moulded APT component with a minimum thickness of 10mm, with that of the AGC MBT (Biomet, Warsaw, Indianna, USA) total knee replacement. The AGC knee was designed with the same geometry (flat on flat in the coronal plane) as the APT and had a 15 year survivorship of 98.86 %. [19] Farris & Ritter [18] found that the APT had a disappointing 68.11% 10 year survival. They postulated that this was due to low conformity of the implant which led to peripheral edge loading on the upper tibial surface which was not seen with the MBT. Our engineering analysis demonstrated that the load transfer within the cancellous bone of the proximal tibia was greater in the APT design compared to the MBT design. This is purely related to the stiffness of the metal backed tray and not to the specific manufacturers' design as design details were not modelled in our study.

Tibial coverage is challenging in knees as the posterior medial tibial bone is not generally well covered due to the anatomical shape of the proximal tibia. [20] When a medial 3mm gap was present with poor cortical support, the APT component transferred a greater load to the underlying tibial bone than the metal backed design. We have demonstrated that when using APT designs in patients with poor bone quality cortical support may be important.

It was these older poor results with the APT that promoted the uptake of modular metal backed tibial components. [2] Many of the suggested benefits of MBT components [2] however have only been been

observed in vitro.

Recent systematic reviews and meta-analysis however support APT in total knee replacement. [22,23] There is also an argument to use APT components in total knee arthroplasty as a cost reducing measure. Muller & Deehan [5] analysed data from the National Joint Registry of England and Wales (NJR) in 2004 and reported that MBT components were on average £598 more expensive than APT prostheses. They reported that of the 42,791 total knee replacements performed that year only 0.006 % of cases were performed using an APT implant. They extrapolated that if 35,000 of those total knee replacements had been performed using an APT component (over an MBT) then the cost savings would amount to £21 million. The most recent report from the NJR reveals only a modest increase in the use of such components to 0.59% of all total knee procedures.[24]

Of the studies in the literature which have specifically addressed the performance of the Depuy PFC APT component [4,5,9,25], none has demonstrated superiority of the MBT over the APT component. Some authors have urged surgeons to exercise caution in using the APT in certain patient groups [26-28] – including those with marked pre-operative deformity / bone defects and in younger patients. Bettinson & Pinder [3] in a recent RCT with a minimum of ten year follow up comparing APT and MBT components found the overall revision rate for the APT in younger patients was extremely low, suggesting that these implants even have a role to play in knee arthroplasty in the younger more active age group.

The authors of this study acknowledge that it has several limitations. We agree that limited conclusions can be drawn from such a small case series and that many larger studies alluded to elsewhere in this article have already attested to the efficacy and long term success of the APT component. Furthermore the absence of pre-operative Knee Society Scores did not allow readers to gauge the magnitude of improvement following surgical treatment. Our intention was to summarise our experience with this implant over the long term, summarise the literature regarding it and to continue to raise awareness of its use. The strength and novel aspect of our article however lay in the engineering analysis of our failures which alerts potential users of this implant to its potential pitfalls and to exercise caution and attention to detail when using it.

Conclusion :

The APT component demonstrated excellent clinical and radiographic performance at long term follow up in our study. Furthermore, an engineering analysis of the failures in our case series suggest that careful placement of the implant on the prepared tibial surface may be of greater potential importance than wear debris in determining long term survivorship and has added to our understanding of the surgical technique required when using this implant.

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Figure Legends

Fig 1 The Depuy cruciate retaining APT component

Fig 2 Cross section of finite element model with idealised eliptical geometry

Fig 3a Pre-operative antero-posterior radiograph with valgus deformity

Fig 3b Immediate post operative radiograph of same patient with APT component in situ

Fig 3c 17 months post-operative antero-posterior radiograph with medial collapse subsidence and physical deformation of the tibial implant

Fig 4a Strain distribution in the proximal tibia for the APT design with a 3mm medial gap

Fig 4b Strain distribution in the proximal tibia for the MBT design with a 3mm medial gap

Fig 1

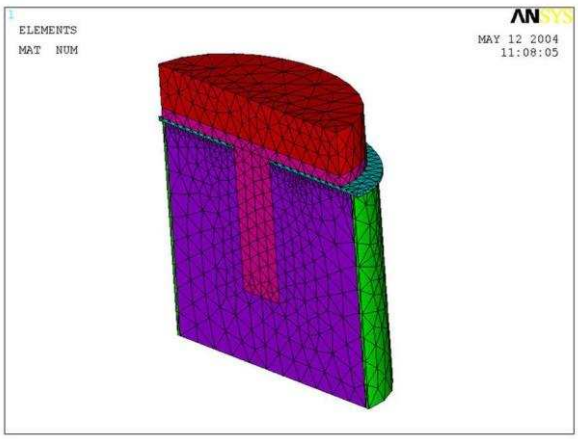

Fig 2

Fig 3a

Fig 3b

Fig 3c

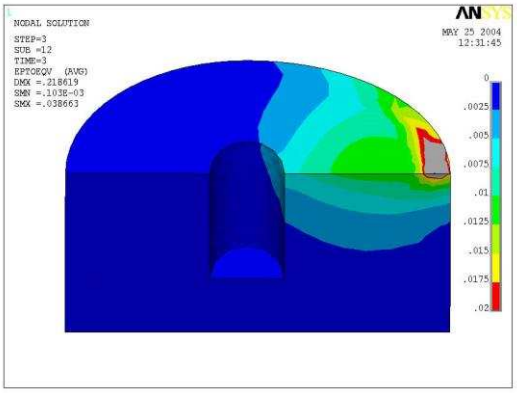
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Fig 4a

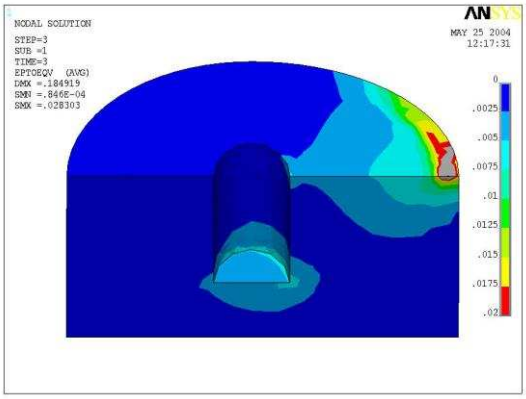
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Fig 4b