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Mobile Bearing Concept in Knee Arthroplasty

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1. Introduction

The rationale for mobile bearing design of knee replacement prosthesis is to increase its survival by reducing the rate of aseptic loosening and to improve the range of movement of the treated knee. The theoretical basis for the achievement of the first goal is the expected lower rates of the polyethylene insert wear in the mobile design in comparison to a fixed design, due to lower contact and constraint forces. A better range of movements following mobile bearing arthroplasty is expected as the result of additional moving surface between to fixed planes at the ends of the articulating bones, allowing mobility with congruency. These expected advantages of the mobile bearing design should be judged cautiously since the initial mobile bearing implants caused higher rates of breakage and disarrangement of the polyethylene inserts, when the implantation method wasn't strictly followed. In order to resolve these technical problems the rotating platform mobile prosthesis was developed.

Mobile bearing concept was implemented in a three compartment replacement prostheses and also in unicompartamental designs, especially for the medial compartment of the knee. Currently, following the more than two decades of the rising experience with implantation of a large number of mobile bearing prostheses, there is a significant amount of data for evaluation of the survival of these prosthetic designs. In order to declare on their higher expected efficiency these implants should show higher than 96-97% of ten year clinical survival, which should remain relatively stable up to 20 years of follow up, as reported in the several of fixed bearing designs. Unfortunately this data is not readily available, because only few well designed survivorship reports on mobile knee implants have been published yet. Furthermore the published data failed to provide a clear evidence of the superiority of mobile bearing design.

The endoprosthesis arthroplasty is the most popular surgical modality for treatment of advanced knee joint disease, either degenerative or inflammatory. The reason for this clinical trend is the ability to reduce pain and to restore the patient's ability to walk.

Although it has been shown that the improvement in ambulation, following knee arthroplasty, is mostly subjective, because other restrictions of a capacity to walk might be revealed following elimination of the pain in the knee (1), the reduction of the pain level while walking is considered by the patients as a significant improvement in the quality of life. For this reason a major effort is exerted by the clinicians and the industry to develop the most effective surgical techniques and prosthetic designs aiming to improve immediate postsurgical outcome of knee prosthetic arthroplasty and the longevity of the implanted prostheses. Several of the currently used prosthetic designs have already reached long term, above 10 years, survivorship of above 95%, therefore the “straggle” for the improvement in the prostheses longevity is aimed to the marginal 5% improvement of long term survivorship following the implantation by reducing the prostheses failure rate in long time scale. The success of this multidisciplinary effort of clinicians and engineers can't be overemphasized because the success will not only eliminate the need for revision surgery in patients, who are mostly in the age above sixty years, because of the expected prostheses' longevity consideration, but also will provide a prosthetic solutions for the younger patients with degenerative knees, who seek for a better treatment modality for their disability.

Therefore logically the widely used generic design of unconstrained knee prosthesis, with metal femoral component and polyethylene insert fixed on metal back-plate on tibia, with cemented or cementless fixation into articulating surfaces, should be improved in one or in several of its components in order to improve its long term clinical performance . Clearly these considerations do not related to the short term prosthetic failures, which are mostly attributed to a basically fault prosthetic design, as observed in the early constrained prostheses (2), to deficient surgical technique or to a complicated general medical condition of the patient that might lead to the prosthesis disarrangement, peri-prosthetic fracture or local infection.

Long standing clinical success of prosthetic knee replacement is dependent on the ability to provide stability with good range of movement, to resist the loosening processes and to provide material longevity of all prosthetic components. Near satisfactory range of movement and stability have been successfully achieved with widely used fixed bearing designs, however, component loosening remains their main long term problem (3,4). Although the early loosening processes, common in the original constrained designs, have been eliminated in the second generation unconstrained prostheses, late loosening, due to osteolysis caused by polyethylene wear of the fixed tibial bearings, remains unresolved (5). Therefore it is logical that the main target that should be addresses in order to reduce the late aseptic loosening of the knee prostheses would be the polyethylene insert and its susceptibility for wear following long standing and continuous exposure to compressing forces from the adjacent metal components. One of the steps for reducing the polyethylene wear was directed to improve the material characteristics of the polyethylene in order to avoid the free radicals release during the gamma sterilization by using a manufacturer process with high temperature towards the melting point with crosslinking induction and generation of ultrahigh molecular weight polyethylene that reduces the plastic insert susceptibility to mechanical wear (6). A high level of crosslinking had been used in several acetabular polyethylene designs in the last decade and showed less surface wear but, on the other hand, presented alteration in the

mechanical properties of the bearing insert. For this reason this method is of limited role in the knee prostheses.

Therefore other tribological factors should be addressed in order to reduce the cross shear and surface pressure of the polyethylene insert. High conformation between the femoral and tibial surfaces in the prosthesis can reduce the surface pressure and polyethylene wear. But in fixed bearing design the elevation of conformation causes restriction in the range of movement of the knee. Therefore in the fixed bearing prostheses some unconformity is deliberately allowed in order to provide a reasonable range of knee movement.

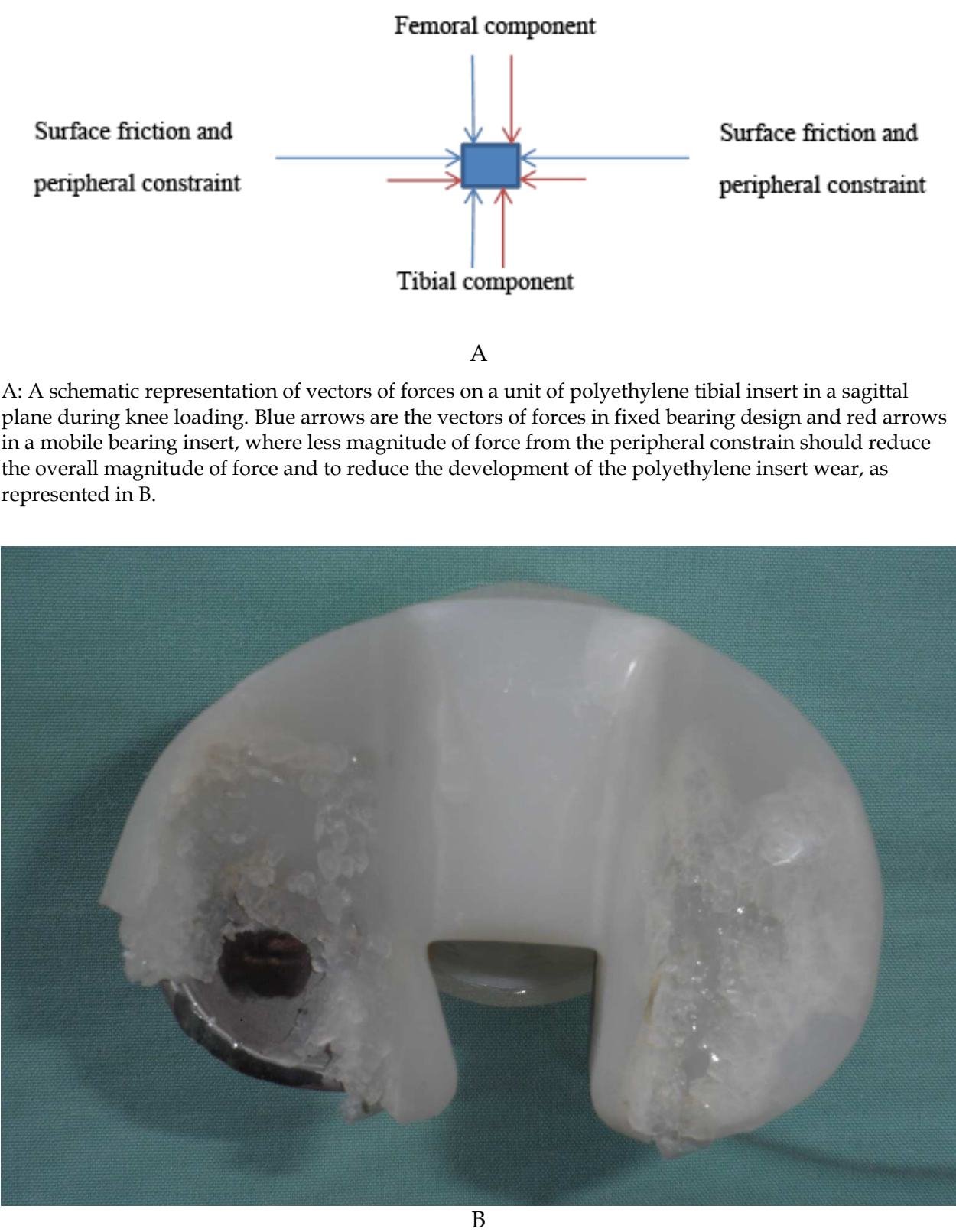
Another mechanical concept to reduce the bearing component wear, which is mainly induced by the high point and line contact forces between moving metal femoral component and static polyethylene tibial insert, has been developed. By this concept an "area" contact pattern has been introduced (7). The rationale of the "area" contact pattern is based on the assumption that the forces between the prostheses components may be distributed more efficiently by using a mobile bearing polyethylene insert (8). Subsequently the hypothetical advantage is in reduction of material wear and elimination of aseptic loosening (Figure 1).

According to this concept Pappas MJ and Buechel FF developed a total knee prosthesis with mobile bearing (7), and Goodfellow JW and O'Connor J developed the unicompartamental mobile bearing "Oxford Knee" design (9).

The expectation from the later unicompartamental design was to develop a prosthetic method that will replace the technically demanding osteotomies in younger patients with unicompartamental degenerative disease. This goal was achieved only partially, since the unicompartamental design could be successful only in patients who answer to the very strict clinical and radiographic criteria.

The former, LCS® mobile meniscal bearing total knee replacement system, has been designed to lower contact stress with preservation of the crucial low constraint properties. Initially after the introduction of this system for the widespread clinical use in 1977-80 one large multicenter (10) and three independent (11,12,13) middle term follow up studies have been published showing favorable subjective outcome results in 90-97.5% of patients with 94.6 – 95.3% of six to eight years survivorship of cementless LCS® mobile bearing posterior cruciate retaining prostheses. These outcome results are close to the survivorship data reported by the system designers, that showed 97.9% and 95.1% of five and twelve years survivorship rates respectively (14).

Conversely there have been a number of reports of high rate mechanical failures of the LCS® system (8,15). These short term follow up studies showed a tendency for mobile bearing dislocation and breakage. These findings can also be supported by cadaveric biomechanical testing (16). Thus the potential susceptibility of LCS® posterior cruciate retaining design for early mechanical failure may overcome the benefits of long term low loosening rates. In an additional later report on a medium term experience with 35 cementless LCS® mobile meniscal bearing total knee replacements in patients with osteoarthritis there was an evidence of 97.1% five year survivorship (17). This high survival rate, with a satisfactory functional outcome, at middle term follow up, has been achieved by following an optimal technique of implantation, according to the designers recommendations, i.e. the tibial component should be situated perpendicularly to



A: A schematic representation of vectors of forces on a unit of polyethylene tibial insert in a sagittal plane during knee loading. Blue arrows are the vectors of forces in fixed bearing design and red arrows in a mobile bearing insert, where less magnitude of force from the peripheral constrain should reduce the overall magnitude of force and to reduce the development of the polyethylene insert wear, as represented in B.

B: Reprehensive example of an advanced wear of a polyethylene insert of a fixed bearing design.

Fig. 1. Rationale for mobile bearing concept in knee arthroplasty prosthesis:

longitudinal axis of tibial metaphysis with 5° - 10° of posterior inclination relatively to the anatomical axis of tibia in the sagittal plane, the sagittal flexion angle of the femoral component should be close to 5° relatively to the anatomical axis of femur and overall coronal alignment of the components should be around 5° of valgus (18). The average three dimensional component alignment in this study group has not deviated more than 3° from the recommended by the designers' optimal orientation. Therefore it might be suggested that the high survival rates of the prosthesis and good functional outcome in the majority of evaluated patients in this study should be attributed to the effective surgical technique. This was reflected by the satisfactory functional knee scores in 77% and complete pain elimination in 89% of the evaluated knees. Therefore there is evidence that in the middle term the mobile bearing design of total knee replacement can be as effective as the conventional fixed bearing designs. Additional reports on short and middle term outcome of knee replacement with LCS® mobile meniscal bearing cementless design revealed rates of aseptic loosening in the range of 0.4 - 1.8% (8,14), which are compatible with most of the effective fixed bearing designs (19). However, the real advantage of mobile bearing system in reducing the rate of osteolysis should be established in the long term survivorship studies.

The emerged susceptibility of mobile bearing meniscal surfaces to early failure due to dislocation or breakage (8) may provoke a reasonable hesitation to its widespread use. Although the designers of the LCS® mobile meniscal bearing prosthesis claimed that strict operative technique and precise prosthetic placement should avoid its mechanical failure (18), there are only few independent studies that support this claim by showing 0.6% rate of meniscal bearing failure in 2 - 10 years of follow up (13, 17). And on the other hand there is some evidence that greater deviation from the desired three dimensional placement of the mobile bearing prosthesis does not significantly reduce its 10 years survivorship and preferable functional outcome (20). Therefore there is no clear evidence of the precise factors contributing to the mobile inserts disarrangement.

In order to reduce the revealed possibility of mechanical failure of meniscal type mobile bearings, a more stable "rotating platform" mobile polyethylene bearing was designed. In this design a single polyethylene insert, without rotational constraint, was used. The rotating platform knee is assumed to follow the normal femoral rotation upon the tibial axis during knee flexion, which is normally between 16° - 23° degrees (21). But it was found that the measured rotation of the bearing surface in the implanted prostheses is significantly less than expected, e.g. only in 12% of the knees there was more than 10 degrees of rotation.

Additional theoretical advantage of a mobile bearing prosthesis is the expected better patellar tracking due to the self-alignment of the mobile bearing. But this assumption has not been proven in patients, because there was no clinical evidence of a diminished post-operative anterior knee pain even in the first year after surgery (22).

The cautious approach for the efficiency of mobile bearing prostheses is even supported by the results of their biomechanical testing. It has been shown by a simulator based experiment, utilizing six million cycles of repetitive testing of prosthesis movement of mobile bearing designs with rotating platform and one fixed bearing implant, that there was no difference in the amount of in vitro wear (23).

Therefore, according to the published data it is still unclear if the theoretical advantage of the mobile bearing design is reflected in the improved clinical outcome (24,25).

Furthermore a meta-analysis of 33 studies assessing 3532 operated knees failed to present an evidence of a better clinical outcome, including the complication rate, functional and radiological results, of the mobile bearing design for knee arthroplasty in a comparison to standard fixed bearing devices (26).

This disappointing fact is probably related to the original intention to improve the current fixed bearing design survival at its marginal failure occurrence part by addressing mostly the mechanics of the polyethylene bearing insert. It seems that the differences in the bearings' fixation shouldn't be addressed for this purpose, in spite of the theoretical mechanical advantage of the mobile bearing. This suggests that different innovative methods for improvement of the prosthetic longevity should be investigated. These methods will probably be related to the other mechanical or material components of the knee prosthesis design. On this stage there is no clear evidence that the mobile bearing concept of knee prosthesis has justified the advantageous theoretical expectation for its superiority over the fixed bearing implants.

2. References

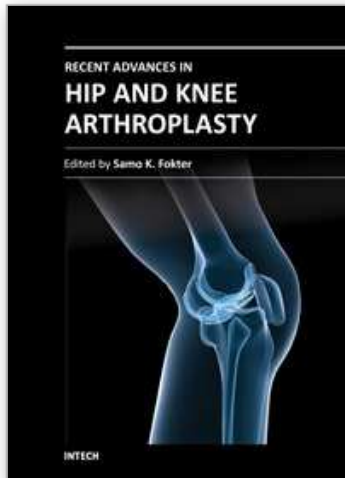
- [1] Rosenberg N, Nierenberg G, Lenger R, Soudry M. Walking ability following knee arthroplasty. A prospective pilot study of factors affecting the maximal walking distance in 18 patients before and six months after total knee arthroplasty. *Knee*, 2007; 14(6):489-92.
- [2] Riley D, Woodyard JE. Long-term results of Geomedic total knee replacement. *J Bone Joint Surg*, 1985; 67B: 548-50.
- [3] Wright TM, Bartel DL. The problem of surface damage in polyethylene total knee components. *Clin Orthop*, 1986;205: 67-74.
- [4] Peters PC, Engh GA, Dwyer KA, Vinh TN. Osteolysis after total knee arthroplasty without cement. *J Bone Joint Surg*, 1992; 74A: 864-876.
- [5] Ayers DC. Polyethylene wear and osteolysis following total knee replacement. *Instr Course Lect* 1997;46: 205-213
- [6] Fisher JD, Jennings LM, Galvin AL, Jin ZM, Stone MH, Ingham E . 2009 Knee Society Presidential Guest Lecture: Polyethylene wear in total knees. *Clin Orthop Relat Res*, 2010; 468:12-18.
- [7] Buechel FF, Pappas MJ. New Jersey low contact stress knee replacement system. Ten year evaluation of meniscal bearings. *Orth Clin N Am*, 1989;20(2): 147-177.
- [8] Weaver JK, Derkash RS, Greenwald AS. Difficulties with bearing dislocation and breakage using a movable bearing total knee replacement system. *Clin Orthop Relat Res* , 1993; 290: 244-252.
- [9] Goodfellow JW, O'Connor J. The mechanics of the knee and prosthesis design. *J Bone Joint Surg*, 1978; 60B: 864-876.
- [10] Sorrells RB, Fenning JB, Davenport JM. Comparison of the clinical results and survivorship of noncemented cruciate sacrificing versus cruciate sparing total knee

- replacements. Presented at The American Academy of Orthopaedic Surgeons, San Francisco, California, February 1993.
- [11] Huang CH, Lee YM, Su RY, Lai JH. Clinical results of the New Jersey low contact stress knee arthroplasty with two to five years follow-up. *J Orth Surg ROC*, 1991;8: 295-299.
- [12] Jordan LR, Olivo JL, Voorhorst PE. Survivorship analysis of cementless meniscal bearing total knee arthroplasty. *Clin Orthop Relat Res*, 1997; 338: 119-123.
- [13] Keblish PA, Schrei C, Ward M. Evaluation of 275 low contact stress (LCS) total knee replacements with 2- to 8- year follow up. *Orthopaedics*, 1993;1(2): 168- 173.
- [14] Buechel FF, Pappas MJ: Long-term survivorship analysis of cruciate-sparing versus cruciate sacrificing knee prostheses using meniscal bearings. *Clin Orthop Relat Res*, 1990; 260: 162-169.
- [15] Bert JM. Dislocation/subluxation of meniscal bearing elements after New Jersey low-contact stress total knee arthroplasty. *Clin Orthop Relat Res* ,1990;254: 211-215.
- [16] Matsuda S, Whiteside LA, White SE, McCarthy DS: Knee stability in meniscal bearing total knee arthroplasty. *J Arthroplasty* 1999;14: 82-90.
- [17] Rosenberg N, Henderson I. Medium term outcome of the LCS cementless posterior cruciate retaining total knee replacements. Follow up and survivorship study of 35 operated knees. *The Knee*, 2001; 8(2): 123-128.
- [18] Buechel FF. Letters to the editor. *Clin Orthop Relat Res* ,1991; 264: 309-311.
- [19] Lemaire R. Will bearing mobility result in a decreased incidence of TKR loosening? *J Bone Joint Surg* , 1999; 81B(suppl 2): 127.
- [20] Vogt JC, Saabach C. LCS mobile-bearing total knee replacement. A 10-year's follow-up study. *Orthop Traum: Surg Res*, 2009;95:177-82.
- [21] Wasielewski RC, Komistek RD, Zingde SM, Sheridan KC, Mahfouz MR. Lack of axial rotation in mobile-bearing knee designs. *Clin Orthop Relat Res*, 2008; 466:2662-8.
- [22] Breugem SJM, Sierevelt IN, Schafroth MU, Blankevoort L, Schaap GR, van Dijk CN. Less anterior knee pain with a mobile-bearing prosthesis compared with a fixed-bearing prosthesis. *Clin Orthop Relat Res* ,2008; 466:1959-65.
- [23] Haider H, Garvin K. Rotating Platform versus Fixed-bearing Total Knees. An In Vitro Study of Wear. *Clin Orthop Relat Res*. 2008; 466:2677-85.
- [24] Smith H, Jan M, Mahomed NN, Davey JR, Gandhi R. Meta-analysis and systematic review of clinical outcomes comparing mobile bearing and fixed bearing total knee arthroplasty. *J Arthroplasty*, 2011 - *in press*
- [25] Jacobs W, Anderson PG, van Limbeek J, Wymega AAB. Mobile bearing vs fixed bearing prostheses for total knee arthroplasty for post- operative functional status in patients with osteoarthritis and rheumatoid arthritis (Review). *The Cochrane collaboration*, 2008;(3):1-15.

- [26] Smith TO, Ejtehadi F, Nichols R, Davies L, Donell ST, Hing CB. Clinical and radiological outcomes of fixed- versus mobile-bearing total knee replacement: a meta-analysis. *Knee Surg Sports Traumatol Arthrosc*, 2010;18(3):325-40.

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Recent Advances in Hip and Knee Arthroplasty

Edited by Dr. Samo Fokter

ISBN 978-953-307-841-0

Hard cover, 452 pages

Publisher InTech

Published online 27, January, 2012

Published in print edition January, 2012

The purpose of this book is to offer an exhaustive overview of the recent insights into the state-of-the-art in most performed arthroplasties of large joints of lower extremities. The treatment options in degenerative joint disease have evolved very quickly. Many surgical procedures are quite different today than they were only five years ago. In an effort to be comprehensive, this book addresses hip arthroplasty with special emphasis on evolving minimally invasive surgical techniques. Some challenging topics in hip arthroplasty are covered in an additional section. Particular attention is given to different designs of knee endoprostheses and soft tissue balance. Special situations in knee arthroplasty are covered in a special section. Recent advances in computer technology created the possibility for the routine use of navigation in knee arthroplasty and this remarkable success is covered in depth as well. Each chapter includes current philosophies, techniques, and an extensive review of the literature.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Nahum Rosenberg, Arnan Greental and Michael Soudry (2012). Mobile Bearing Concept in Knee Arthroplasty, Recent Advances in Hip and Knee Arthroplasty, Dr. Samo Fokter (Ed.), ISBN: 978-953-307-841-0, InTech, Available from: <http://www.intechopen.com/books/recent-advances-in-hip-and-knee-arthroplasty/mobile-bearing-concept-in-knee-arthroplasty>

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