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ORIGINAL ARTICLE

A retrospective study on the radiographic evaluation of the tibial component alignment in total knee arthroplasty and its postoperative significance

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Background

The goal of tibial component positioning in total knee arthroplasty is to achieve neutral tibial alignment. Malalignment of the tibial component alters the distribution of tibial loading, resulting in increased wear. The purpose of this study was to correlate two radiological parameters (mechanical and anatomical axis) of the tibial component in total knee arthroplasty with patient related outcome measures at 5 years.

Method

91 primary total knee arthroplasties were considered in this study. Tibial component alignment was assessed using post op radiographs. All x-rays were taken immediately post operatively. The Oxford Knee Score was used to quantify the patient's pain and function following the total knee arthroplasty. Patient follow up at Orthopaedic outpatients and date of discharge were also considered. The radiographic outcome was then correlated with the patient reported outcome over 5 years. Correlation was measured using either the parametric Pearson correlation coefficient (testing for a linear correlation) and its non-parametric counterpart; the Spearman's rank correlation coefficient.

Results

There is a very weak correlation between the Oxford Knee Score and the varus angle of deviation. The correlation is stronger in the valgus position, but still not statistically significant. There is also a weak negative correlation between the angle of deviation and the number of follow ups at Orthopaedic outpatients.

Conclusion

From our study, we can conclude that an angle of deviation of $\leq 6^{o}$ in both varus and valgus did not have a negative prognostic effect on patient outcome.

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Introduction

Total knee replacement is an increasingly common procedure; the number of procedures performed in the last two decades has increased by 162% in the US.[1] It is projected that the number of revisions will have increased by 600% from 2005 to 2030.[2]

Implant malalignment following primary Total Knee Replacement (TKR) has been reported to be the primary reason for revision in 7% of revised TKRs.[3] It has also been linked to a decrease both in implant survival[4] as well as inferior patient reported outcomes.[5]

The main objectives of knee arthroplasty surgery are attainment of anatomical knee alignment and soft tissue balancing. The analysis of the post-operative x-rays is a helpful adjunct to ascertain whether these objectives have been achieved and thereby improve future results.[6]

The anatomic axis of the tibia is created by a line drawn proximal to distal in the intramedullary canal. This bisects the tibia in half and determines the entry point for tibial medullary guide rod. The mechanical axis of the tibia on the other hand is a line from the centre of the proximal tibia to the centre of the talus. On anteroposterior evaluation, the mechanical and anatomic axis of the tibia commonly correspond exactly to one another.

Serial radiographs can indicate potential failures well before they manifest clinically. Therefore, radiography plays an important role in both the immediate postoperative period and during long term follow-up. The purpose of this study was to correlate two radiological parameters (mechanical and anatomic axes of the tibia) with patient related outcome measures at 5 years. Outcomes were quantified through the Oxford Knee Score (OKS),[7] a patient centered measurement tool that is widely regarded for its reliability, validity and high response rate when measuring patient outcome after TKR, and through number of patient follow-ups required in the 5 years after the TKR procedure.

Materials and Methods

A cohort of 92 primary TKRs carried out by an orthopaedic firm in 2015 was considered in this study. This consisted of all the primary TKRs carried out in that year excluding revision TKRs and any deceased patients. The list of patients was obtained from the inpatient records at Mater Dei Hospital (MDH). Seven different operators were involved in the TKRs carried out in this study. 51% of the procedures were carried out by a consultant orthopaedic surgeon while 49% were carried out by resident specialists in orthopaedics.

Tibial component alignment was assessed using post op radiographs on the MDH Universal Viewer (internal hospital software used to view and assess radiological imaging). Placement of the tibial component was measured using the angle between the line across the base of the tibial plate and the tibial shaft axis using the angle measurement function on the MDH Universal Viewer.

An angle of 90^0 corresponds to neutral placement; an angle $>90^0$ corresponds to valgus placement of the tibial component; an angle $<90^0$ corresponds to varus placement of the tibial component. All x-rays used in this study were taken immediately post operatively.

The OKS was used to quantify the patient's pain and function following the TKR. Patients were contacted and asked the 12 questions from the score between the months of March and April 2021. These were translated into the final score (from 0 to 48, where 0 indicates the worst possible symptoms and 48 indicates the least amount of symptoms). For 10 patients, the OKS score could not be established.

The number of follow-ups in each case was not pre-determined by the firm. Prior to discharge, patients were advised to contact the firm for an outpatient's appointment only if they had any concerns. This policy applies to the firm under study.

Details regarding patient follow-up at Orthopaedic outpatients (OOP) and date of discharge were obtained from the Mater Dei electronic patient database.

The radiograph findings (alignment, angle, varus/valgus), OKS (0 to 48) and follow-up records were documented and tabulated. The radiographic outcome was then correlated with the patient reported outcome over 5 years.

Statistical analysis

Statistical analysis for any possible correlation between salient attributes (90° deviation of the tibial component, OKS and number of follow-ups (F/Us) was carried out). Correlation was measured using either the parametric Pearson correlation coefficient (testing for a linear correlation) or its non-parametric counterpart; the Spearman's rank correlation coefficient.[8] Correlation significance was confirmed using a two-tailed t-test with a significance level of 0.05.

The cohort sample size required to show a Pearson correlation coefficient of 0.32 with a statistical power of 80% and a significance level of 0.05 is 73 (as calculated in a similar study by Slevin et al[9] and confirmed in).[10] Thus, we are able to draw statistically significant conclusions on correlation within our cohort, both for F/Us (92 cases) and OKS score (82 cases).

Results

From a cohort of 92 patients, 60.9% had a varus placement of the tibial component (0.1° – 7° deviation) while 38.0% had a valgus placement (0.3° - 7.3° deviation). One of the patients had the tibial component in the neutral position (1.1%).

The average OKS for patients with the tibial component in varus was 41.06 while patients in valgus had an average OKS of 40.87. The patient with the tibial component in the neutral position had an OKS of 48.

The average number of F/Us for patients with the tibial component in varus was 4.20 while patients in valgus had an average of 3.97 F/Us (*Table 1*).

The F/Us and OKS scores for each patient against their corresponding tibial component deviation are plotted in Figure 1 for the entire dataset, in Figure 2 for varus datapoints and in Figure 3 for valgus datapoints. The dataset contains a number of outliers both for the OKS results (only two sub-20 OKS scores) and for the F/Us (only two patients requiring 20 or more F/Us). Thus, both the Pearson correlation coefficient and the Spearman's rank coefficient were calculated in order to measure the effect of the outliers on the correlation results. Correlation values and statistical analyses are provided in Tables 2-3 for the entire cohort, Tables 4-5 for patients with the tibial component in varus and Tables 6-7 for patients with the tibial component in valgus.

For all cases, no significant correlation was obtained between either F/Us or OKS and the angle of deviation (null hypothesis was not rejected in any case considered). Some minor discrepancies between the Pearson and Spearman coefficients were obtained, mostly caused by the presence of the afore mentioned outliers and the lack of a linear relationship between the variables considered. Additionally, the Pearson correlation between F/Us and angle of deviation was very close to being significant (Table 2) – it is possible that more data samples could continue to reinforce the weak negative correlation in the data.

Table 1: Key metrics computed from our patient cohort.[1]The OKS for 82 patients out of the total of 92 were available.

Patient Statistics				
	Varus	**Valgus**	**Neutral**	**Total**
Number of patients	56	35	1	92
Average Age	69.66	67.57	79.00	68.96
Percentage (%)	60.87	38.04	1.09	100
Average OKS[1]	41.06	40.87	48.00	41.07
Average number of F/Us	4.20	3.97	6.00	4.13

Figure 1: Scatter plot of OKS and F/Us against tibial component angle of deviation for all patients considered.

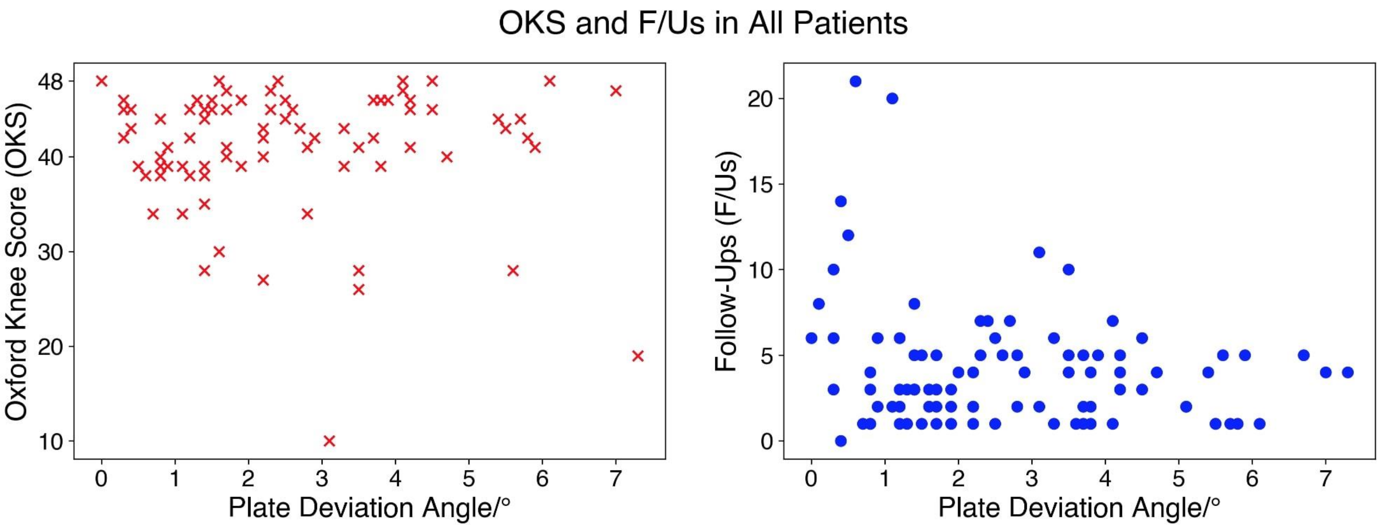

Figure 2: Scatter plot of OKS and F/Us against tibial component angle of deviation for varus patients.

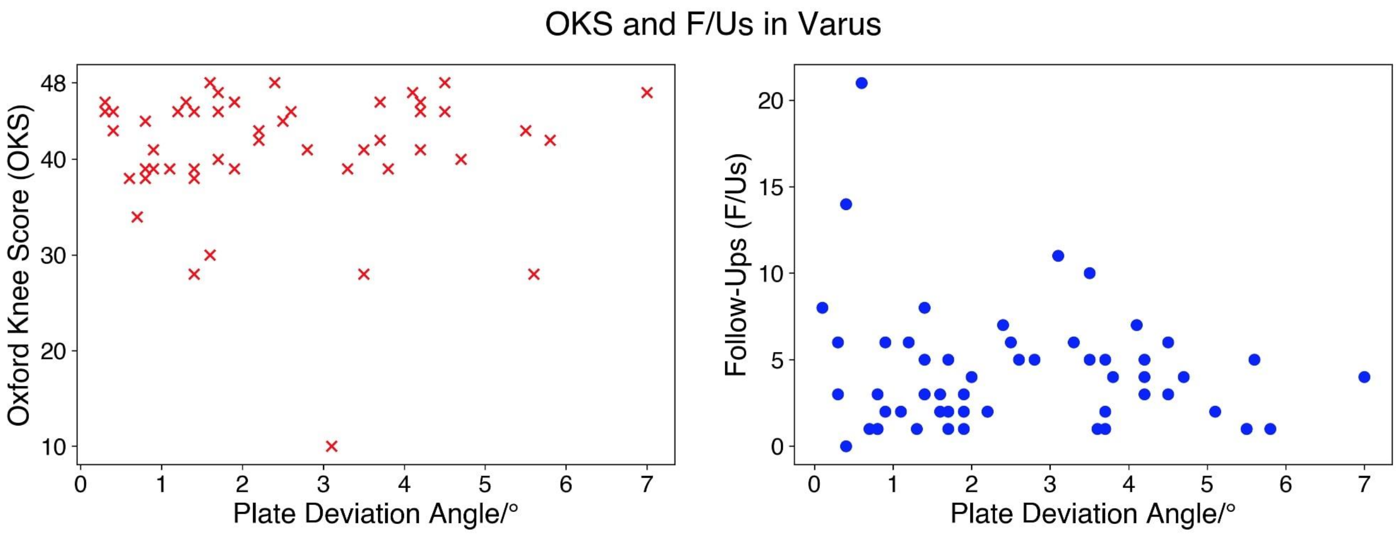

Figure 3: Scatter plot of OKS and F/Us against tibial component angle of deviation for valgus patients.

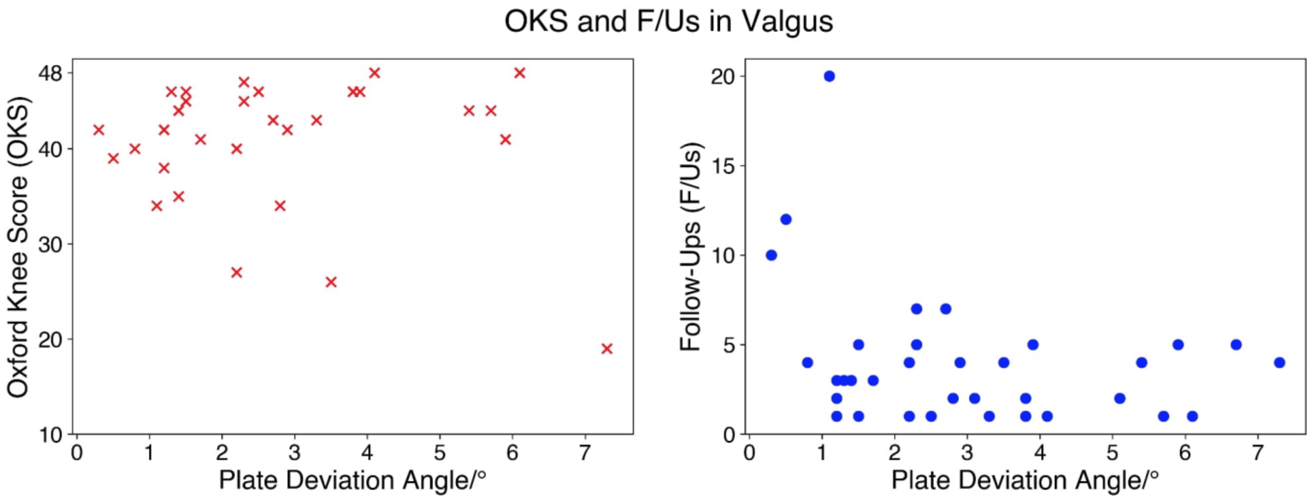

Table 2: Statistical analysis of follow-ups vs angle of deviation in all patients. In both cases, t-statistic is less than the critical value (0.05), which means we cannot reject the null hypothesis (i.e. the two quantities are uncorrelated).

Statistical Analysis of F/Us vs angle of deviation (all patients)		
	Pearson	**Spearman**
Correlation coefficient	-0.208	-0.101
Degrees of freedom (DF)	90	90
T-statistic	2.018	0.959
Critical value (0.05)	2.035	2.035

Table 3: Statistical analysis of OKS vs angle of deviation in all patients. In both cases, t-statistic is less than the critical value (0.05), which means we cannot reject the null hypothesis (i.e. the two quantities are uncorrelated)

Statistical Analysis of OKS vs angle of deviation (all patients)		
	Pearson	**Spearman**
Correlation coefficient	-0.058	0.124
Degrees of freedom (DF)	80	80
T-statistic	0.518	1.115
Critical value (0.05)	2.035	2.035

Table 4: Statistical analysis of follow-ups vs angle of deviation in patients with the tibial component in varus. In both cases, t-statistic is less than the critical value (0.05), which means we cannot reject the null hypothesis (i.e. the two quantities are uncorrelated).

Statistical Analysis of F/Us vs angle of deviation (Varus)		
	Pearson	**Spearman**
Correlation coefficient	-0.140	-0.021
Degrees of freedom (DF)	54	54
T-statistic	1.042	0.154
Critical value (0.05)	2.035	2.035

Table 5: Statistical analysis of OKS vs angle of deviation in patients with the tibial component in varus. In both cases, t-statistic is less than the critical value (0.05), which means we cannot reject the null hypothesis (i.e. the two quantities are uncorrelated)

Statistical Analysis of OKS vs angle of deviation (Varus)		
	Pearson	**Spearman**
Correlation coefficient	0.004	0.122
Degrees of freedom (DF)	48	48
T-statistic	0.026	0.853
Critical value (0.05)	2.035	2.035

Table 6: Statistical analysis of follow-ups vs angle of deviation in patients with the tibial component in valgus. In both cases, t-statistic is less than the critical value (0.05), which means we cannot reject the null hypothesis (i.e. the two quantities are uncorrelated)

Statistical Analysis of F/Us vs angle of deviation (Valgus)		
	Pearson	**Spearman**
Correlation coefficient	-0.285	-0.199
Degrees of freedom (DF)	33	33
T-statistic	1.705	1.167
Critical value (0.05)	2.035	2.035

Table 7: Statistical analysis of OKS vs angle of deviation in patients with the tibial component in valgus. In both cases, t-statistic is less than the critical value (0.05), which means we cannot reject the null hypothesis (i.e. the two quantities are uncorrelated)

Statistical Analysis of OKS vs angle of deviation (Valgus)		
	Pearson	**Spearman**
Correlation coefficient	-0.102	0.270
Degrees of freedom (DF)	29	29
T-statistic	0.552	1.513
Critical value (0.05)	2.035	2.035

Discussion

A successful TKR is the result of several factors. Patient related characteristics such as age, gender and body mass index play an important role in operative outcome.[11-13] Other factors relate to the surgical technique: restoration of limb alignment, correct component positioning as well as satisfactory ligament balance.[14-15] The cohort of patients we selected for this study included all the primary TKRs carried out in the same year by the same orthopaedic firm. This served to eliminate confounding factors such as changes in the prosthesis used and the surgeon's skill and experience.

The radiological definition of "normally" aligned TKA knees is debated,[16-17] but most papers on implant survival and radiological alignment have used some deviation of 3° from a neutral alignment as a threshold for what is acceptable for good long-term results.[18-20]

The goal of tibial component positioning is to maximize coverage to prevent settling,[21] and to achieve a neutral tibial alignment. The latter is achieved by a proximal tibial cut 90° to the mechanical axis.[22] Malalignment of the tibial component alters the distribution of tibial loading, which can lead to increased shear forces at the tibiofemoral interface, resulting in increased wear. Tibial malalignment of > 3° of varus has been reported to increase the risk of medial bone collapse.[20]

Such a 3° threshold has also been chosen in numerous other studies investigating results after TKA,[5,23] and an alignment within 3° of the mechanical axis has been considered to be the gold standard.[24]

The study by Kim et al. (2014)[25] showed an increased failure rate of 3.4% in TKAs with a tibial component alignment other than neutral, compared to 0% failure in neutrally aligned tibias. In our study, only 1 TKA had the tibial component in the neutral position (1.1%). One possible reason for this is that different patients may have different rotational axes and the aim of TKR is to replicate these axes and place the knee into the alignment it was in prior to the development of arthritis or deformity. The OKS of this patient was 48 (maximum score) implying the best outcome in terms of pain and function. However, the patient also required 6 F/Us which is higher than the average number of follow-ups in both varus (4.20) and valgus (3.97). In the rest of the cohort, no statistically significant correlation between the angle of deviation and our two patient outcome metrics was found.

Postoperative varus alignment has been associated with lower knee scores and increased failure rates [(26)]. From our study, there was no statistically significant difference in outcome between tibial components in varus, in neutral and in valgus.

One of the main limitations in this study was the sample size. A larger sample size with more examples of tibial component placement in the neutral position would have possibly provided more insight into whether there is a significant difference between the outcome of a netral placement *vs* varus/valgus placement. Additionally, 66% of cases had the tibial component with an angle of deviation $\leq 3^o$ from the neutral axis. A larger sample of cases with a higher angle of deviation would have also helped provide more representative results.

In our study, we did not consider any possible preoperative varus or valgus knee deformities which could also have influenced the final outcome. Obtaining neutral alignment can be challenging in patients with substantial preoperative deformity [(26)]. Knees with substantial preoperative varus alignment are more likely to have postoperative varus alignment.[27-28]

When compared to other scores, the OKS is easier to use and has a higher response rate. However, it does not take into consideration the patient's comorbidities. Patients undergoing total knee replacement are generally elderly and it is rare to find patients without either comorbid medical conditions or arthritis affecting other joints.[29]

Other scores which could have been used in the study and which are commonly found in the literature include the Hospital for Special Surgery Knee Score (HSS Knee Score) and the Knee Society Score (KSS). These scores include pain and function but also consider other parameters like range of motion, muscle strength, flexion deformity, instability, and subtractions.[30]

Only AP views of the knee joint were considered in this study and the tibial shaft length was not uniform in the post op radiographs. Radiographs of the whole tibia or the use of CT scanograms could have given more reliable results.[31]

Most studies carried out considered both the femoral and tibial components of the knee joint. The femoral component was not considered in our study. This could have influenced the final results.

Gromov et al. (2014)[17] state that tibial components should be placed in neutral alignment (90^o). Most studies show that a deviation of 3^o from the neutral alignment is acceptable for good long-term results. From our study, we can conclude that the angle of deviation does not seem to have any negative correlation with patient outcome, both for varus and valgus TKRs.

SUMMARY

- The goal of tibial component positioning in total knee arthroplasty is to achieve neutral tibial alignment.
- Malalignment of the tibial component alters the distribution of tibial loading, resulting in increased wear.
- Most studies show that a deviation of 3^o from the neutral alignment is acceptable for good long-term results.
- This study correlated two radiological parameters (mechanical and anatomical axis) of the tibial component in total knee arthroplasty with patient related outcome measures.

- From our results there was no statistically significant difference in outcome between tibial components in varus, in neutral and in valgus.
- In our study, the angle of deviation in both varus and valgus does not correlate with patient outcome following TKR, as measured by OKS and number of F/Us.

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References

1. Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total knee arthroplasty volume, utilization, and outcomes among Medicarebeneficiaries, 1991-2010. *JAMA* 2012;**12**:1227-1236.
2. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007;**4**:780-785.
3. Schroer W C, Berend K R, Lombardi A V, Barnes C L, Bolognesi M P, Berend M E, et al. Why are total knees failing today? Etiology of total knee revision in 2010 and 2011. *J Arthroplasty* 2013; 28 (8): 116–9.
4. Ritter M A, Davis K E, Meding J B, Pierson J L, Berend M E, Malinzak R A. The effect of alignment and BMI on failure of total knee replacement. *J Bone Joint Surg* (Am) 2011; 93 (17): 1588–96.
5. Choong PF ,Dowsey M M, Stoney J D. Does accurate anatomical alignment result in better function and quality of life? Comparing conventional and computer-assisted total knee arthroplasty. *J Arthroplasty* 2009; 24 (4): 560–9.
6. Dragosloveanu S, Cretu B, Cristea S, Stoica C, Dragosloveanu C. Radiographic Evaluation of Alignment Following TKA, a Systematic Review. *Maedica (Bucur)*. 2017;12(3):214-218.
7. Dawson, J.; Fitzpatrick, R.; Murray, D.; Carr, A. Questionnaire on the Perceptions of Patients about Total Knee Replacement. *The Journal of Bone and Joint Surgery*. *British volume* 1998; 80-B (1): 63–69.
8. Mukaka, M. M. A Guide to Appropriate Use of Correlation Coefficient in Medical Research. *Malawi Med J* 2012; 24 (3): 69–71.
9. Slevin O, Amsler F, Hirschmann MT. No correlation between coronal alignment of total knee arthroplasty and clinical outcomes: a prospective clinical study using 3D-CT. Knee Surg Sports Traumatol Arthrosc. 2017
10. Hulley, S. B.; Cummings, S. R.; Browner, W. S.; Grady, D. G.; Newman, T. B. *Designing Clinical Research: An Epidemiologic Approach*, 4th ed.; Lippincott Williams & Wilkins, 2013.
11. Mason JB, Fehring TK, Estok R, Banel D, Fahrbach K. Meta-analysis of alignment outcomes in computer-assisted total knee arthroplasty surgery. *J Arthroplasty*. 2007 Dec;22(8):1097-106.
12. Windsor RE, Scuderi GR, Moran MC, Insall JN. Mechanisms of failure of the femoral and tibial components in total knee arthroplasty. *Clin Orthop Relat Res*. 1989 Nov;(248):15-9; discussion 19-20.
13. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS. Factors affecting the durability of primary total knee prostheses. *J Bone Joint Surg Am*. 2003 Feb;85(2):259-65.
14. Maestro A, Harwin SF, Sandoval MG, Vaquero DH, Murcia A. Influence of intramedullary versus extramedullary alignment guides on final total knee arthroplasty component position: a radiographic analysis. *J Arthroplasty*. 1998 Aug;13(5):552-8.
15. Dennis DA, Channer M, Susman MH, Stringer EA. Intramedullary versus extramedullary tibial alignment systems in total knee arthroplasty. *J Arthroplasty*. 1993 Feb;8(1):43-7.
16. Abdel M P, Oussedik S, Parratte S, Lustig S, Haddad F S. Coronal alignment in total knee replacement: historical review, contemporary analysis, and future direction. *Bone Joint J* 2014; 96-B 7): 857-62.

17. Gromov K, Korchi M, Thomsen M G, Husted H, Troelsen A. What is the optimal alignment of the tibial and femoral components in knee arthroplasty? *Acta Orthop* 2014; 85(5): 480-7.
18. Jeffery R S, Morris R W, Denham R A. Coronal alignment after total knee replacement. *J Bone Joint Surg (Br)* 1991; 73(5): 709-14.
19. Ritter M A, Davis K E, Meding J B, Pierson J L, Berend M E, Malinzak R A. The effect of alignment and BMI on failure of total knee replacement. *J Bone Joint Surg (Am)* 2011; 93(17): 1588-96.
20. Berend M E, Ritter M A, Meding J B, Faris P M, Keating E M, Redelman R, Faris G W, Davis K E. Tibial component failure mechanisms in total knee arthroplasty. *Clin Orthop* 2004; (428): 26-34.
21. Lemaire P, Pioletti D P, Meyer F M, Meuli R, Dörfl J, Leyvraz P F. Tibial component positioning in total knee arthroplasty: bone coverage and extensor apparatus alignment. *Knee Surg Sports TraumatolArthrosc* 1997; 5 (4): 251–7.
22. Ritter M A, Herbst S A, Keating E M, Faris P M, Meding J B. Patellofemoral complications following total knee arthroplasty. Effect of a lateral release and sacrifice of the superior lateral geniculate artery. *J Arthroplasty* 1996; 11 (4): 368–72.
23. Huang, Nathaniel &Dowsey, Michelle &Ee, Eric & Stoney, James &Babazadeh, Sina& Choong, Peter. (2012). Coronal Alignment Correlates With Outcome After Total Knee Arthroplasty Five-Year Follow-Up of a Randomized Controlled Trial. The Journal of arthroplasty. **27**. 1737-41.
24. Lombardi A V, Berend K R, Ng V Y. Neutral mechanical alignment: a requirement for successful TKA: affirms. Orthopedics 2011; 34 (9): e504–6.
25. Kim YH, Park JW, Kim JS, Park SD. The relationship between the survival of total knee arthroplasty and postoperative coronal, sagittal and rotational alignment of knee prosthesis. *Int Orthop.* 2014 Feb;38(2):379-85.
26. Magnussen, Robert & Weppe, Florent & Demey, Guillaume & Servien, Elvire & Lustig, Sébastien. (2011). Residual Varus Alignment does not Compromise Results of TKAs in Patients with Preoperative Varus. Clinical orthopaedics and related research. 469. 3443-50. 10.1007/s11999-011-1988-6.
27. Heyse TJ, Decking R, Davis J, Boettner F, Laskin RS. Varus gonarthrosis predisposes to varus malalignment in TKA. *HSS J*.2009;**5**:143–148.
28. Lewallen DG, Bryan RS, Peterson LF. Polycentric total knee arthroplasty: a ten-year follow-up study. *J Bone Joint Surg Am.* 1984;**66**:1211–1218.
29. Whitehouse, S. L., Blom, A. W., Taylor, A. H., Pattison, G. T. R., & Bannister, G. C. (2005). The Oxford Knee Score; problems and pitfalls. The Knee, 12(4), 287–291.
30. Alicea, J. (n.d.). Knee Scores in Total Knee Arthroplasty. Surgical Techniques in Total Knee Arthroplasty, 31–38.
31. Jeffcote B, Shakespeare D. Varus/valgus alignment of the tibial component in total knee arthroplasty. Knee. 2003 Sep;10(3):243-7.