Posterior Bearing Overhang Following Medial and Lateral Mobile Bearing Unicompartmental Knee Replacements. A Prospective Cohort Study. Level 2 evidence.

B. R. Martin [1*], E. C. Pegg [2], B. van Duren [3], H. R. Mohammad [1], H. G. Pandit [3], S. J. Mellon [1], D. W. Murray [1].

[1] Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, UK
[2] Department of Mechanical Engineering, Centre for Orthopaedic Biomechanics, University of Bath, UK
[3] Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds, UK

* Correspondence: Dr B. R. Martin
benjamin.martin@ndorms.ox.ac.uk
Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences,
University of Oxford, UK

Abstract
This study explores the extent of bearing overhang following mobile bearing Oxford unicompartmental knee replacement. The Oxford components are designed to be fully congruent, however knee movements involve femoral rollback, which may result in bearing overhang at the posterior margin of the tibial implant, with potential implications for; pain, wear, and dislocation.

Movement is known to be greater, and therefore posterior overhang more likely to occur, with; lateral compared to medial implants, anterior cruciate ligament deficiency, and at extremes of movement.

32 knees with medial, and 20 with domed lateral, unicompartmental knee implants (Oxford Phase III, Zimmer Biomet) had sagittal plane knee fluoroscopy during step-up and forward lunge exercises. Within the 32 medial implants, 16 were ACL deficient, and 16 ACL intact. The bearing position was inferred from the relative position of the femoral and tibial components. Based on the individual component sizes and geometry the extent the posterior part of the bearing which overhung the posterior part of the tibial component was calculated.

There was no significant posterior overhang in knees with medial implants. Knees with lateral domed implants exhibited overhang at flexion angles beyond 60°, the magnitude of which increased with increasing flexion angle, reaching a maximum of 50% of the bearing length at 140° (range 0-140°). This demonstrates a clear difference between the kinematics, and prevalence and extent of posterior bearing overhang between medial and lateral OUKRs.

Keywords: Unicompartmental Knee Replacement Mobile Bearing.

Introduction

The occurrence and magnitude of posterior bearing overhang is of interest as it may be a factor contributing to pain due to soft tissue irritation, affecting the risk of bearing dislocation, or influencing wear and bearing failure.

Medial and lateral OUKRs incorporate fully congruent ultra-high-molecular-weight polyethylene mobile bearings. The preservation of the cruciate ligaments plus the ability of the bearing to follow the path of the femoral component whilst sliding relative to the tibial component means the kinematics of knees with OUKR more closely resemble normal compared to knees with total knee replacement (TKR) [1]. In addition to improved function [2-5], patients can expect faster recovery [6-7], and lower morbidity and mortality [8-10] compared to TKR.

The OUKR femoral component is spherical and the bearing has a matching concave surface, the bearing therefore moves with the femoral component. The bearing position within this paper refers to the antero-posterior (AP) location of the centre of the bearing relative to the tibial component, unless stated otherwise. Overhang refers to posterior surface contact of the bearing going beyond the posterior contact surface of the tibial implant, thereby being unsupported. Bearing position in the OUKR during knee flexion has been determined in a number of studies using established fluoroscopic techniques [11-14]. Although the movement profile varies between individual patients, and the exercise undertaken, there is a trend towards posterior movement with increasing flexion, which is similar to known movement profiles in the anatomically normal knee [15-18]. The earliest study with 20 patients [11], showed bearing movements of up to 13.5 mm in the medial compartment. More recent studies have confirmed that the bearing moves posteriorly and established that there can be up to 15 mm difference in bearing position between knees in the medial compartment [12]. There was greater variability in movement in patients that were anterior cruciate ligament (ACL) deficient [13]. In lateral OUKR there is much greater posterior bearing movement than medial, furthermore the lateral bearing moves further posterior with the domed tibia than the flat tibia and the movement is more like that of the normal knee [19]. Cadaveric models have clearly shown the potential for significant overhang in the lateral OUKR, (Figure 1).

While bearing position relative to the metallic components in medial OUKR has been previously reported, the extent to which the polyethylene bearing overhangs the margin of the tibial component depends upon individual component sizes, and in the lateral case involves complex geometry, and thus has never previously been quantified. Anterior, medial or lateral bearing overhang can be seen at operation or assessed on standard radiographs as it tends to occur near extension, whereas posterior overhang cannot be seen at operation and, as it is likely to occur in flexion, cannot be assessed with standard radiographs. Therefore if posterior bearing overhang is occurring it would not be recognised and any consequences would not be attributed to it. Potential consequences which could warrant design modifications include; pain, wear and dislocation.

Marked overhang of the antero-medial corner of the old symmetric bearings was thought to be a possible cause of pain, so when the anatomic bearings were introduced this corner was rounded off. In a similar manner posterior overhang could possibly cause pain.

Bearing dislocation of medial OUKR has always been rare, with an incidence of 0.5% to 2.3% in early studies [20-21], however since the introduction of the Phase 3 the dislocation rate has fallen to about half of a percent (0.6%) [22-23]. In contrast, dislocation is more common on the lateral side. In the first report of lateral OUKR the dislocation rate was about 10% [24]. With improved surgical technique and the increased entrapment, with the domed tibial component and biconcave bearing the dislocation rate has fallen to between 0% and 6.6% [25-29].

Bearing wear in medial OUKR has been studied both in-vivo with radiostereometric analysis (RSA) [30], and in retrievals [31-32], finding wear rates of low wear rates of about 0.02 mm/year for well-functioning components. Bearing wear has not been studied following domed lateral OUKR. Bearing fracture is very rare and tends to occur when the bearings are very worn in situations where they are not functioning normally such as with gross component malposition or with impingement [33-34]. If posterior bearing overhang was found to occur and was related to clinical problems it could possibly be addressed by modifying the surgical technique or implant design.

The aim of the study was to determine if posterior bearing overhang occurred following OUKR. We obtained data from two fluoroscopic studies, which assessed sagittal plane kinematics during step-up and forward lunge exercises for medial [13] (n=32) and lateral [35] (n=20) OUKR. As in the previous medial OUKR study [13], the medial cohort were divided and analysed based on whether the anterior cruciate ligament was intact. We obtained component sizes for these patients and calculated whether posterior overhang occurred during knee flexion. Our null hypothesis was that bearing overhang does not occur in either compartment
during knee flexion.

Methods

Patients

The cohort of medial implants consisted of 26 patients, with 32 separate implants, from operations performed between January 2000 and June 2011. These patients were originally matched cohorts for ACL deficient (n=16) and ACL intact (n=16) [13].

The cohort of lateral implants consisted of 20 patients each with a lateral domed implant. Surgery for all these patients was performed at a single centre between January 2003 and August 2005.

All implants were phase 3 OUKRs, all surgeries were performed for a pre-operative diagnosis of isolated compartmental osteoarthritis (OA), all patients received a standard post-operative rehabilitation, and the study protocols were approved by the relevant local ethics committees.

Data acquisition

All knees were imaged through their full range of active motion, by performing step-up and lunge exercises on a platform, (Figure 2), under continuous fluoroscopic imaging from a fixed position. This allows calculation of location of the midpoint of the bearing along the AP axis of the tibial component, and the flexion angle of the knee, the methods for which are previously published [1; 13; 35], and are also described below.

The sizes for components used for individual patients were obtained from the original records. The relevant bearing and tibial component dimensions required were obtained directly from the manufacturer (Zimmer Biomet, Swindon, UK).

Determination of Knee Flexion Angle (KFA) and Bearing Position (BP)

Briefly, the individual fluoroscopy frames were corrected for distortion for each patient individually using a global correction method, which corrects for the effects of distance from the fluoroscopic source [35]. Points on the images are manually identified using a custom routine in Matlab (Mathworks, USA), which locates the centres of the femoral and tibial components along the anterior posterior axis of the implant, and calculates the Knee Flexion Angle (KFA), and Bearing Position (BP) [1; 13].

The centre of the tibial plates are determined from locating the central keel point. This point is invariant under rotation of the implant relative to the observer, and lies directly underneath the midpoint of the tibial implant surface.

BP is determined, despite the bearing not being visible on the fluoroscopic images, because the thinnest part of the bearing, will always lie under the centre of curvature of the femoral component when under load. The centre of the femoral component is located by fitting a circle to the silhouette and calculating the central point of this circle. The perpendicular line is calculated by taking a normal to points plotted along the keel slot, which is parallel to the tibial implant surface.

The method thus far in calculating BP is the same for both and medial and lateral components, and at this stage represents the AP displacement of the centre of the femoral component. Calculation of Overhang from this BP is different for medial and lateral implants as follows.

Medial OUKR

Bearing overhang is given by a simple subtraction of lengths, (Figure 3):

$$Overhang = Tibial\ Plate - Bearing - Bearing\ Position\ (BP)$$

(Equation 1)

Where: “Tibial Plate” = the length of sliding surface available from midpoint to posterior edge of the tibial implant. “Bearing” = the length of sliding surface available from midpoint to posterior edge of the bearing.

Positive values for overhang represent full contact with the tibial plate, a zero value indicates the most posterior part of the bearing is at the most posterior part of the tibial sliding surface, and negative values represent posterior overhang of the bearing beyond the posterior margin.

Lateral OUKR

While the tibial component for medial OUKR has a flat surface, the domed surface of the lateral tibial component necessitated an alternative calculation for bearing overhang, based on arc lengths, as opposed to straight lines.

The angle, Alpha, is the angle subtended by a normal from the centre of curvature of the tibial component through its own midpoint, and a line linking the centre of curvature of the tibial and femoral components. Alpha is given by:

$$Alpha = \sin^{-1}\left(\frac{BP}{(R1+R2+D)}\right)$$

(Equation 2)

Where: Alpha’s units are Radians
BP = perpendicular distance between the centre of the femoral implant from the vertical.
D = thickness of the bearing (at midpoint, defined as the thinnest coronal slice),
R1 = the radius of the tibial implant domed surface,
R2 = the radius of the femoral component,
X = straight line distance from midline to posterior edge of tibial component sliding surface.

The lateral domed bearing is symmetrical, with each half-length given by W, and lower surface radius matching exactly the dome of the tibial component, R1. Therefore the surface arc from bearing midline to posterior margin, (Figure 4), L1, the longer blue section, can be calculated as;

$$L1 = R1 \sin^{-1}\left(\frac{W}{R1}\right)$$

(Equation 3)

The arc of displacement of the bearing’s mid-point from the midline, (Figure 4) L2, the shorter blue section, runs along the surface of the tibial component. L2 is given by;

$$L2 = R \times Alpha$$

(Equation 4)

The length of sliding surface available from midpoint to posterior edge of the Tibial Implant, shown in (Figure 4) as the green line, and annotated L3 is given by;

$$L3 = R1 \sin^{-1}\left(\frac{x}{R1}\right)$$

(Equation 5)

The overhang arc length was then calculated by subtraction of these arc lengths;

$$Overhang = L3 - (L1 + L2)$$

(Equation 6)

Data Analysis

The tibial component length is taken as the maximum length of the implant, which occurs adjacent to the lateral retaining wall. The posterior margin of the implants then curve to match the natural shape of the tibia, which is not accounted for in this paper. An assumption that, the bearing is travelling whilst fully conforming with the tibial implant surface, adjacently to the retaining wall, without rotation, was also made.

The KFA data was grouped into 10° intervals for analysis, i.e. all values for KFA between 5.0° and 14.9° were assigned to the set covering the 10 degree interval. The mean was calculated using a smoothing function, using weighted datapoints adjacent to the 10° interval, to reflect the fact that physical reality requires a continuous movement of the bearing in space. 95% confidence intervals for the mean were calculated assuming that readings were normally distributed using standard deviation.

There was no missing data in the lateral cohort, however, the medial cohort did contain missing data as follows. The original study on the medial cohort was designed to compare ACL deficient group matched with an ACL intact group [13], only eight of the ACL intact knees could be analysed. These eight ACL intact knees contributed 597 datapoints to the final results, which remained in excess of the 483 datapoints, which the 15 combined ACL deficient knees were able to contribute to the final results. The remaining data was not used, as it could not be related to their original knee fluoroscopy data, and therefore to exact component sizes.

Results

Medial Cohort

Medial OUKR overhang (Figure 5) is found in one datapoint (representing one patient) at 0° of extension, this datapoint is outside the 95% confidence interval for the cohort as a whole at 0°. None of the remaining fluoroscopic images showed overhang, from any of the 26 patients at all flexion angles. In addition, 95% confidence intervals show that overhang would be most likely at the extremes of extension. The confidence interval widens considerably at 130° due to the relatively lower number of datapoints, as only two knees reached this flexion angle. By taking a smoothed average or fitting a polynomial, as shown by the red dashed line, the pattern of most likely movement is determined. Overhang is therefore effectively excluded, to at least 95% confidence, at ranges between 5° and 120° in medial OUKRs, and furthermore if it were to occur would be most likely at either full extension or flexion beyond 120°.

Lateral Cohort

Patients with Lateral OUKR, showed significant overhang (Figure 6). Beyond 60° flexion over half of participants showed bearing overhang. At 130° all lateral implants were overhanging. The largest overhang being 16 mm of bearing surface in a patient with medium sized components. When converted to show overhang length as a percentage of total bearing length, 16 mm represents 51% of this 28 mm long bearing.

Sub-analysis of ACL deficient vs. intact within the medial cohort

Analysis of ACL deficient (Figure 7a) vs. intact (Figure 7b) in the medial cohort showed little difference between the two in terms of average movement profile of the two groups at flexion angles up to 100°, at which point the ACL deficient group bearing average position moves posteriorly. The outlying point at 0 degrees in the ACL deficient group is overhanging, but is beyond the 95% confidence interval for the mean of all knees at 0 degrees. This point represents therefore an outlier, but is significant in demonstrating that some individuals will be capable of posterior overhang at full extension. The comparison between groups shows that the likelihood of an individual knee exhibiting overhang is increased if ACL deficient, and at either full extension or high flexion.

Discussion

The results of this study suggest that all patients that receive a domed lateral OUKR are likely to have posterior bearing overhang at flexion angles above 130° and that half of patients will exhibit bearing overhang at angles of 60° and above. In contrast, patients that receive medial OUKR do not exhibit bearing overhang at knee flexion angles from 5° to 120°. Following medial OUKR a deficient ACL appears to increase the risk of bearing overhang at extremes of joint movement.

The extent of the posterior overhang of the lateral bearing in high flexion is marked, being on average 40% of the bearing length in 140 degrees flexion. The extent of the overhang can clearly be seen in cadavers with the domed lateral OUKR implanted (Figure 1), but has not been assessed in vivo before. This extensive posterior movement and overhang is what would be expected considering that, the domed lateral OUKR restores normal knee kinematics and that in the normal knee there is marked lateral roll back in high flexion [17-18]. Indeed in high flexion in the normal knee the lateral femoral condyle articulates with the convex surface of the back of the lateral tibial plateau and the posterior horn of the lateral meniscus subluxes off the lateral tibial plateau [16; 18; 36], in a similar manner to that seen with the lateral OUKRs. In a comparative study we found that following lateral UKR, knees with a convex domed tibia flexed more that with a flat tibia and had both greater and more normal posterior movement of the femoral condyle, presumably because the tightening of the soft tissues laterally with the flat component prevents the normal roll back in high flexion [37]. Therefore the marked posterior overhang in high flexion with the domed lateral OUKR is advantageous as, unlike other designs of knee replacement, it allows normal kinematics in high flexion.

The marked posterior overhang of the domed lateral bearing in high flexion may, potentially, cause problems. If the overhang is greater than 50% there may be edge-loading on the back of the tibial component. The risks of this should be minimised by the surgeon ensuring that the tibial component reaches, or slightly overhangs, the posterior tibial cortex, and that there is no retained posterior cement. There is a potential concern that if the bearing overhangs extensively in high flexion, it might jam and not return to its normal position as the knee extends. This might cause posterior pain or locking, but we are not aware of this ever happening. The extensive overhang may be a risk factor for dislocation. However, if the overhang was to cause a dislocation it would probably be a posterior dislocation, which is very rare [38-39]. The common mode of dislocation occurs when the bearing subluxes medial and superiorly over the tibial vertical wall and ends jammed on top of the wall [39]. It is not clear if posterior overhang would contribute to this mode of dislocation.

With extensive overhang the contact area between the metal and polyethylene would decrease with an associated increase in contact stress and thus potentially more wear. We also know that in high flexion force transmitted across the knee can increase, up to 2.5 times body weight in a squat, however that this load also redistributes with the medial compartment taking a greater share of the load as flexion angle increases [40]. This mixed picture makes it hard to predict the potential stress multiplier caused by overhang in the lateral compartment, and even if this were to be done via computational modelling, or an instrumented prosthesis, we would not know how this would affect wear rates in-vivo. We are not aware of any in vivo wear studies of the domed lateral OUKR, so we cannot be certain that overhang will not cause wear problems. An RSA wear study is needed to investigate this.

With medial OUKR we did not find significant bearing overhang. The main reason for this is that there is much less movement in the medial than the lateral compartment. Although bearing movement was seen in all patients and varied considerably between patients, the movement was limited and posterior overhang did not occur with flexion. Another factor that would decrease overhang is that the medial tibial plateau is longer than the lateral and the medial bearing is shorter. As a result, the proportion of the tibial plateau covered by the bearing is on average 61% for medial components and 71% for lateral components. This means that more movement is required medially to cause overhang. The mobile bearing therefore seems to be ideal for the medial compartment with the large areas of contact minimising wear, the freely moving bearing minimising sheer stress at the bone-implant interfaces and therefore minimising the risk of loosening, and the absence of overhang, which could potentially cause problems.

The ACL tends to hold the femur forward relative to the tibia, and therefore should limit posterior overhang. Occasionally, for example to minimise the risk of medical complications in elderly patients, we would implant OUKR in knees that were ACL deficient but were otherwise appropriate. In our previous study of bearing movement we found that ACL deficient OUKRs had greater variability in kinematics than those with the ACL intact, and we therefore suspected that they might be more likely have posterior overhang [13]. This was found to be true at the extremes of range of movement, however broadly speaking they were both found not to exhibit overhang at normal functional ranges. This would suggest that their neuromuscular control was relatively normal and probably because of this their disease pattern was appropriate for OUKR.

For this study, patients did two exercises: a step up and a forward lunge. The lunge achieved the greatest flexion with the foot being on a step and the patient pushing forward and flexing the knee under load. In this study, following medial OUKR, all patients achieved at least 120° of knee flexion. Up to 120° there was no overhang but the trend was towards increasing posterior bearing movement with increasing flexion. Therefore in higher degrees of flexion some posterior overhang may occur. However, repetitive functional activities tend not be done at these high flexion angles, so this overhang probably would not be associated with increased wear. The situation may be different in countries where high knee flexion is required for cultural and social reasons. It would therefore be important to repeat the study in patients from these countries. In a study of medial OUKR from Korea the bearing dislocation rate was initially high. However, this decreased to an acceptable level, when the new anatomic bearings and Microplasty(®) instrumentation was used suggesting that even if overhang did occur in high flexion it does not contribute to dislocation [41].

The main limitation of the study is that all the assessments were done in two dimensions focusing on antero-posterior (AP) movement not medio-lateral (ML). It was assumed that if the back of the bearing did not extend further back than the back of the tibia there would be no overhang. However, if, with increasing flexion, the bearing tracked postero-medially or externally rotated the bearing might overhang postero-medially even though it was not overhanging posteriorly. It is not possible to determine the ML position of the bearing in flexion with a standard radiograph. This would require either RSA or possibly a CT scan. However, it would be difficult to do this imaging during functional activities. Another limitation is that all the patients assessed had a good clinical outcome and a high level of function. If overhang was occurring and causing problems such as pain, dislocation or wear we would not have identified this as we did not study these type of patients. Further study is needed now we have established the overhang does not occur medially under normal circumstances.

Conclusion

Little is known about posterior overhang of mobile bearings in knee replacement. In particular there is little information about whether it occurs and its consequence, although theoretically it may contribute to dislocation, wear or adverse symptoms. This is the first study of posterior bearing over hang following mobile bearing OUKR. Domed lateral OUKRs exhibit substantial posterior overhang in high flexion in all cases. This occurs because, unlike other types of knee replacement, the domed lateral UKR restores normal lateral roll back in high flexion. In contrast we found that posterior bearing overhang did not occur following medial OUKR during from 5° to 120°, and was less likely to occur in ACL intact knees than ACL deficient knees.

Acknowledgements

The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other non- profit organisation with which one or more of the authors are associated.

References

[1] Price AJ, Rees JL, Beard DJ, et al. 2004. Sagittal plane kinematics of a mobile-bearing unicompartmental knee arthroplasty at 10 years: a comparative in vivo fluoroscopic analysis. The Journal of arthroplasty 19:590-597.
[2] Burn E, Sanchez-Santos MT, Pandit HG, et al. 2018. Ten-year patient-reported outcomes following total and minimally invasive unicompartmental knee arthroplasty: a propensity score-matched cohort analysis. Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA 26:1455-1464.
[3] Willis-Owen CA, Brust K, Alsop H, et al. 2009. Unicondylar knee arthroplasty in the UK National Health Service: an analysis of candidacy, outcome and cost efficacy. The Knee 16:473-478.
[4] Liddle AD, Pandit H, Judge A, et al. 2015. Patient-reported outcomes after total and unicompartmental knee arthroplasty: a study of 14,076 matched patients from the National 381 Joint Registry for England and Wales. The bone & joint journal 97-B:793-801.
[5] Von Keudell A, Sodha S, Collins J, et al. 2014. Patient satisfaction after primary total and unicompartmental knee arthroplasty: an age-dependent analysis. The Knee 21:180-184.

[6] Duchman KR, Gao Y, Pugely AJ, et al. 2014. Differences in short-term complications between unicompartmental and total knee arthroplasty: a propensity score matched analysis. The Journal of bone and joint surgery American volume 96:1387-1394.
[7] Lombardi AV, Jr., Berend KR, Walter CA, et al. 2009. Is recovery faster for mobile-bearing unicompartmental than total knee arthroplasty? Clinical orthopaedics and related research 467:1450-1457.
[8] Brown NM, Sheth NP, Davis K, et al. 2012. Total knee arthroplasty has higher postoperative morbidity than unicompartmental knee arthroplasty: a multicenter analysis. The Journal of arthroplasty 27:86-90.
[9] Liddle AD, Judge A, Pandit H, et al. 2014. Adverse outcomes after total and unicompartmental knee replacement in 101,330 matched patients: a study of data from the National Joint Registry for England and Wales. Lancet 384:1437-1445.
[10] Morris MJ, Molli RG, Berend KR, et al. 2013. Mortality and perioperative complications after unicompartmental knee arthroplasty. The Knee 20:218-220.
[11] Bradley J, Goodfellow JW, O'Connor JJ. 1987. A radiographic study of bearing movement in unicompartmental Oxford knee replacements. Journal of Bone and Joint Surgery - Series B 69:598-601.
[12] Pegg EC, Baré J, Gill HS, et al. 2015. Influence of consciousness, muscle action and activity on medial condyle translation after Oxford unicompartmental knee replacement. The Knee 22:646-652.
[13] Pegg EC, Mancuso F, Alinejad M, et al. 2016. Sagittal kinematics of mobile unicompartmental knee replacement in anterior cruciate ligament deficient knees. Clinical Biomechanics 31:33-39.
[14] Wahal N, Gaba S, Malhotra R, et al. 2018. Reduced Bearing Excursion After Mobile-Bearing Unicompartmental Knee Arthroplasty is Associated With Poor Functional Outcomes. The Journal of arthroplasty 33:366-371.
[15] Pinskerova V, Iwaki H, Freeman MAR. 2000. The shapes and relative movements of the femur and tibia at the knee. Der Orthopäde 29:S3-S5.
[16] Freeman MA, Pinskerova V. 2003. The movement of the knee studied by magnetic resonance imaging. Clin Orthop Relat Res:35-43.
[17] Hill PF, Vedi V, Williams A, et al. 2000. Tibiofemoral movement 2: the loaded and unloaded living knee studied by MRI. The Journal of bone and joint surgery British volume 82:1196-1198.
[18] Galvin CR, Perriman DM, Newman PM, et al. 2018. Squatting, lunging and kneeling provided similar kinematic profiles in healthy knees—A systematic review and meta-analysis of the literature on deep knee flexion kinematics. The Knee.
[19] van Duren BH, Gallagher J, Pandit H, et al. 2009. A New Domed Tibial Lateral Component Provides Improved Range Of Movement & Retains Normal Kinematics for The Oxford UKR. Orthopaedic Proceedings 91-B:47-48.
[20] Svard UC, Price AJ. 2001. Oxford medial unicompartmental knee arthroplasty. A survival analysis of an independent series. The Journal of bone and joint surgery British volume 83:191-194.
[21] Murray DW, Goodfellow JW, O'Connor JJ. 1998. The Oxford medial unicompartmental arthroplasty: a ten-year survival study. The Journal of bone and joint surgery British volume 80:983-989.
[22] Pandit H, Jenkins C, Gill HS, et al. 2011. Minimally invasive Oxford phase 3 unicompartmental knee replacement. The Journal of bone and joint surgery British volume 93-B:198-204.
[23] Alnachoukati OK, Barrington JW, Berend KR, et al. 2018. Eight Hundred Twenty-Five Medial Mobile-Bearing Unicompartmental Knee Arthroplasties: The First 10-Year US Multi-Center Survival Analysis. The Journal of arthroplasty 33:677-683.
[24] Gunther TV, Murray DW, Miller R, et al. 1996. Lateral unicompartmental arthroplasty with the Oxford meniscal knee. The Knee 3:33-39.
[25] Marson B, Prasad N, Jenkins R, et al. 2014. Lateral unicompartmental knee replacements: early results from a District General Hospital. European Journal of Orthopaedic Surgery & Traumatology 24:987-991.
[26] Schelfaut S, Beckers L, Verdonk P, et al. 2013. The risk of bearing dislocation in lateral unicompartmental knee arthroplasty using a mobile biconcave design. Knee Surgery, Sports Traumatology, Arthroscopy 21:2487-2494.
[27] Altuntas AO, Alsop H, Cobb JP. 2013. Early results of a domed tibia, mobile bearing lateral unicompartmental knee arthroplasty from an independent centre. The Knee 20:466-470.
[28] Pandit H, Jenkins C, Beard DJ, et al. 2010. Mobile bearing dislocation in lateral unicompartmental knee replacement. The Knee 17:392-397.

[29] Walker T, Zahn N, Bruckner T, et al. 2018. Mid-term results of lateral unicondylar mobile bearing knee arthroplasty. The bone & joint journal 100-B:42-49.
[30] Altuntas AO, Alsop H, Cobb JP. 2013. Early results of a domed tibia, mobile bearing lateral Price AJ, Short A, Kellett C, et al. 2005. Ten-year in vivo wear measurement of a fully congruent mobile bearing unicompartmental knee arthroplasty. The Journal of bone and joint surgery British volume 87:1493-1497.
[31] Kendrick BJ, Longino D, Pandit H, et al. 2010. Polyethylene wear in Oxford unicompartmental knee replacement: a retrieval study of 47 bearings. The Journal of bone and joint surgery British volume 92:367-373.
[32] Teeter MG, Howard JL, McCalden RW, et al. 2017. Comparison of articular and backside polyethylene wear in mobile bearing unicompartmental knee replacement. Knee 24:429-433.
[33] Pegg E, Pandit H, Gill HS, et al. 2011. Examination of ten fractured Oxford unicompartmental knee bearings. The Journal of bone and joint surgery British volume 93:1610-1616.
[34] Pegg E, Pandit H, Gill HS, et al. 2011. Examination of ten fractured Oxford unicompartmental Lim HC, Shon WY, Kim SJ, et al. 2014. Oxford phase III meniscal bearing fracture: case report. Knee 21:340-342.
[35] B.H. vD, J. G, H. P, et al. 2009. A New Domed Tibial Lateral Component Provides Improved Range Of Movement & Retains Normal Kinematics For the Oxford Unicompartmental Knee Replacement. Orthopaedic Proceedings 91-B:47-48.
[36] Nakagawa S, Kadoya Y, Todo S, et al. 2000. Tibiofemoral movement 3: full flexion in the living knee studied by MRI. The Journal of bone and joint surgery British volume 82:1199-1200.
[37] Bare JV, Gill HS, Beard DJ, et al. 2006. A convex lateral tibial plateau for knee replacement. Knee 13:122-126.
[38] Gulati A, Weston-Simons S, Evans D, et al. 2014. Radiographic evaluation of factors affecting bearing dislocation in the domed lateral Oxford unicompartmental knee replacement. Knee 21:1254-1257.
[39] Weston-Simons JS, Kendrick BJ, Mentink MJ, et al. 2014. An analysis of dislocation of the domed Oxford Lateral Unicompartmental Knee Replacement. Knee 21:304-309.
[40] Weston-Simons JS, Kendrick BJ, Mentink MJ, et al. 2014. An analysis of dislocation of the Mundermann A, Dyrby CO, D'Lima DD, et al. 2008. In vivo knee loading characteristics during activities of daily living as measured by an instrumented total knee replacement. J Orthop Res 26:1167-1172.
[41] Koh IJ, Kim JH, Jang SW, et al. 2016. Are the Oxford((R)) medial unicompartmental knee arthroplasty new instruments reducing the bearing dislocation risk while improving components relationships? A case control study. Orthop Traumatol Surg Res 102:183-187.

Figures

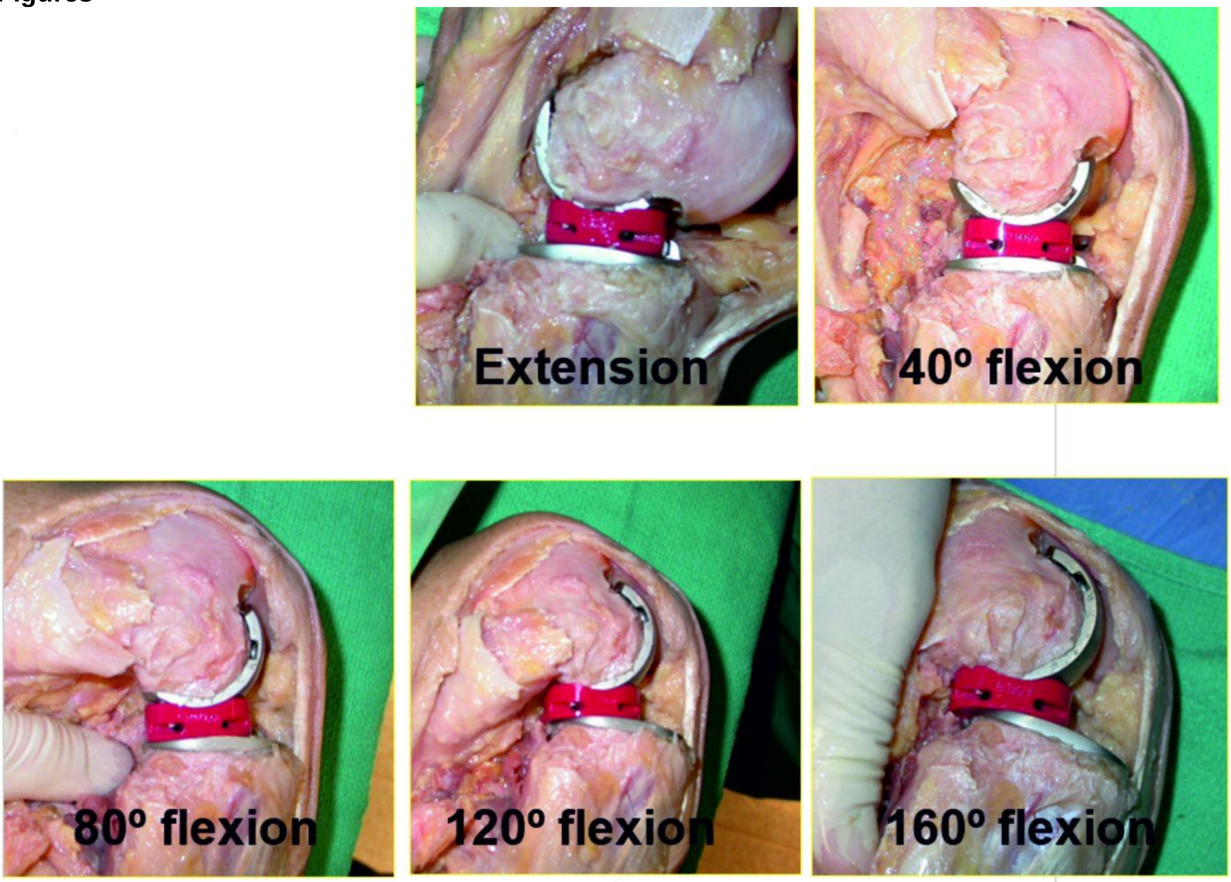

Figure 1: Lateral domed OUKR cadaveric model showing posterior overhang at high flexion angles.

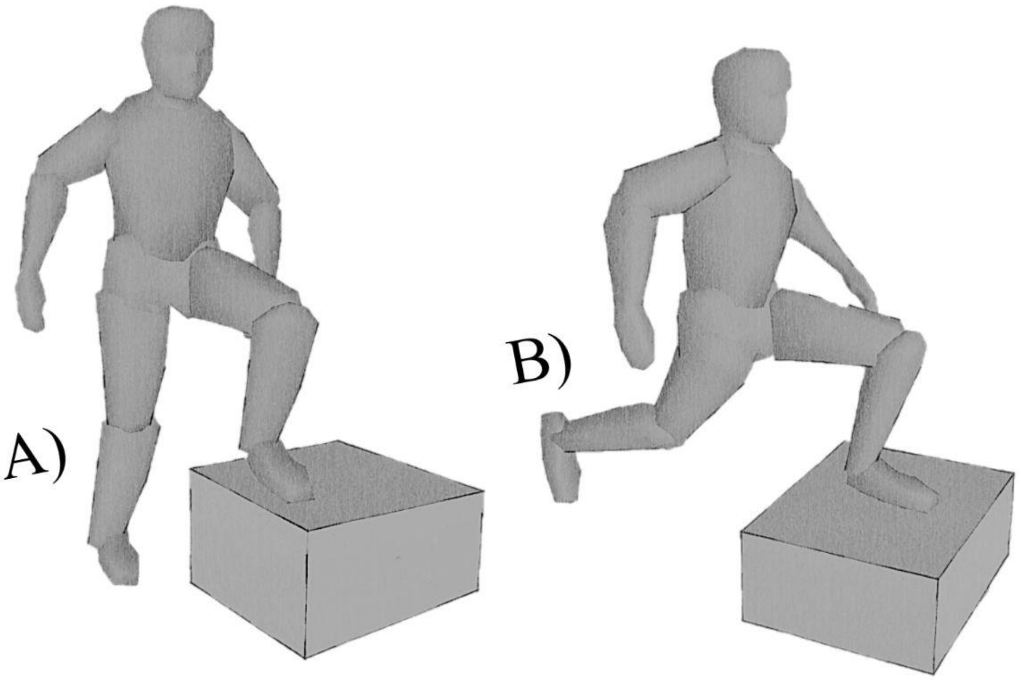

Figure 2: Patient movements; A) Step and B) Lunge.

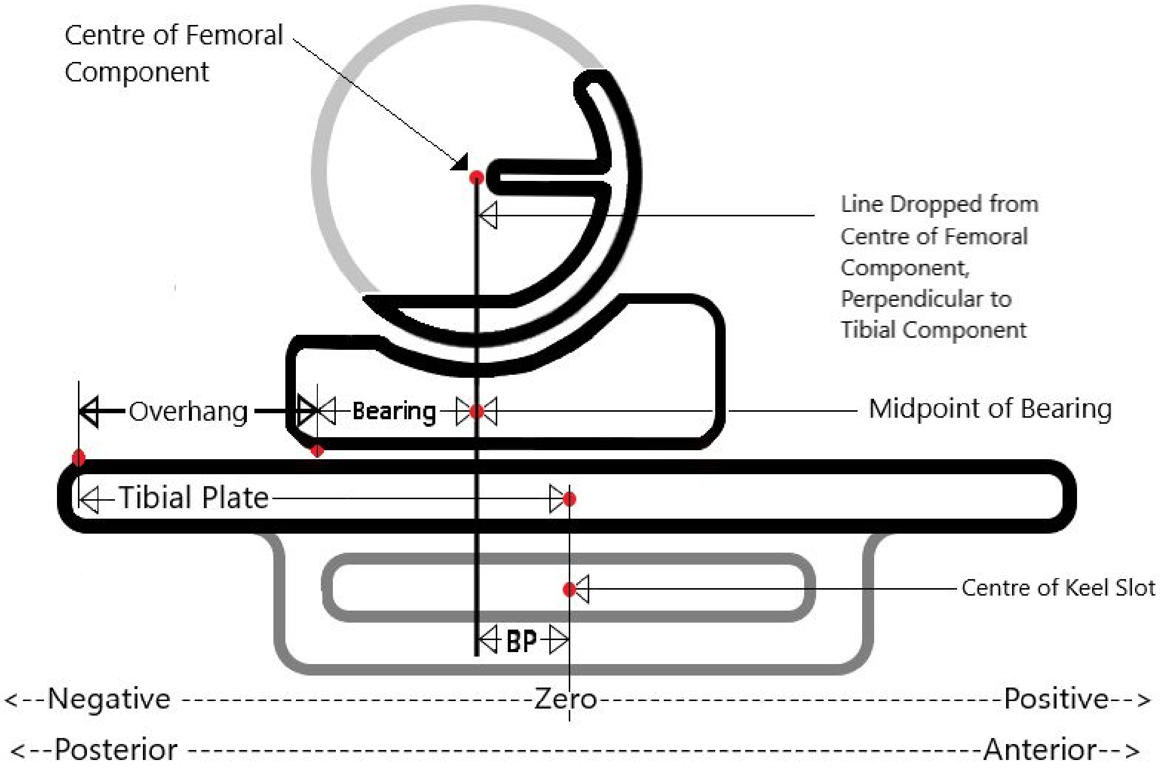

Figure 3: Diagrammatic representation of the geometry of the medial OUKR, with dimensions and orientations required for calculation of bearing overhang.

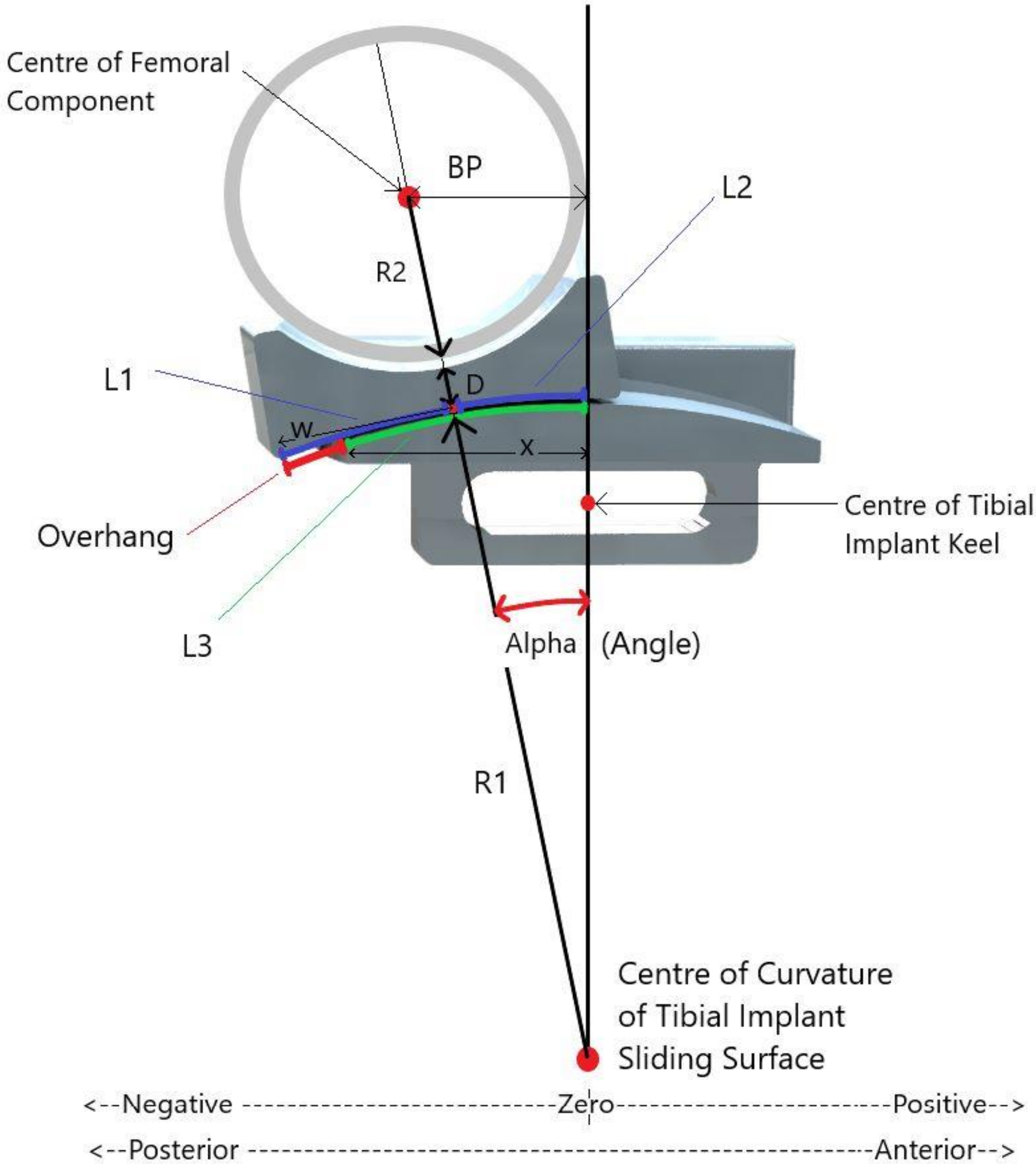

Figure 4: Diagrammatic representation of the geometry of the lateral domed OUKR, with dimensions and orientations required for calculation of bearing overhang.

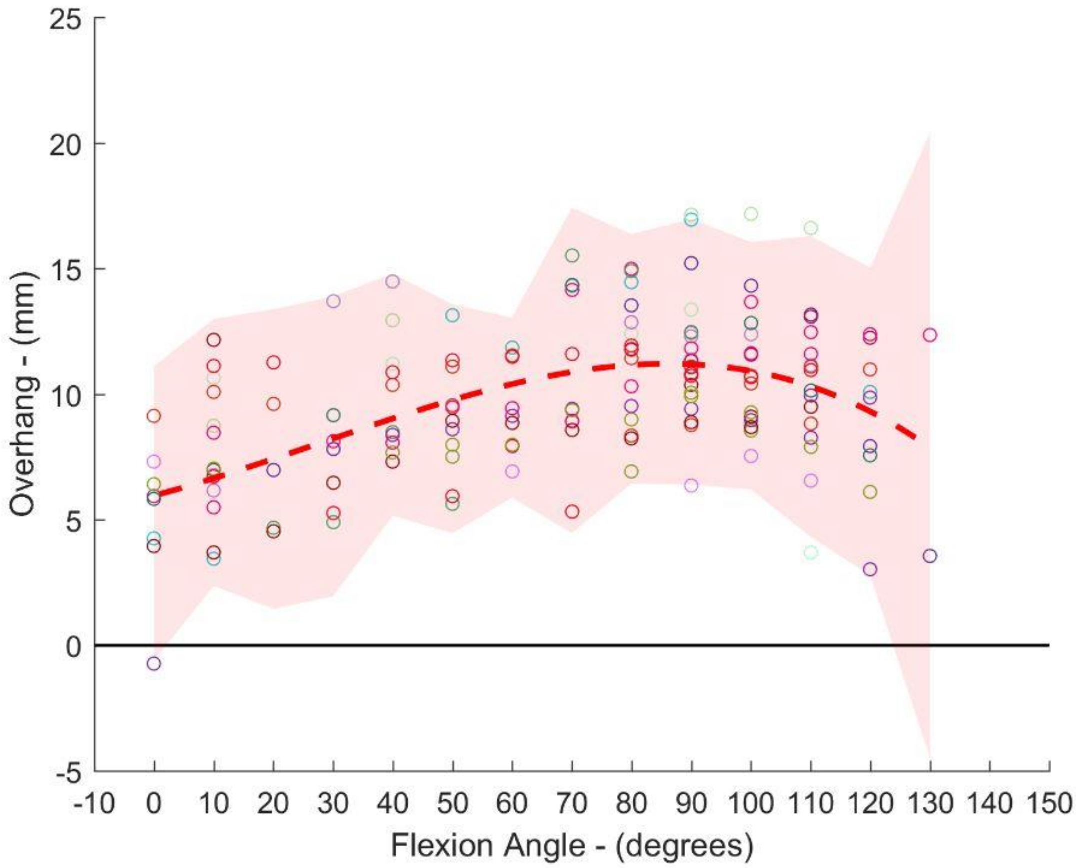

Figure 5: Overhang vs. flexion for medial OUKR.

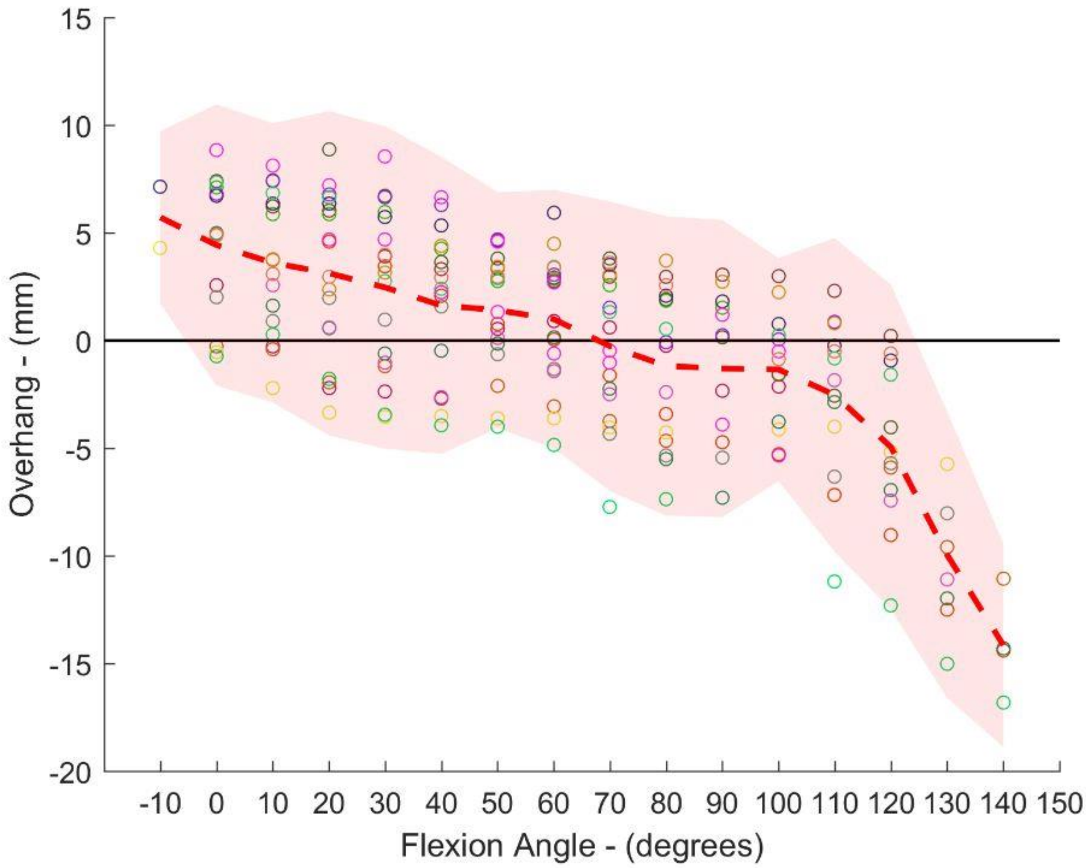

Figure 6: Overhang vs. flexion for lateral domed OUKR.

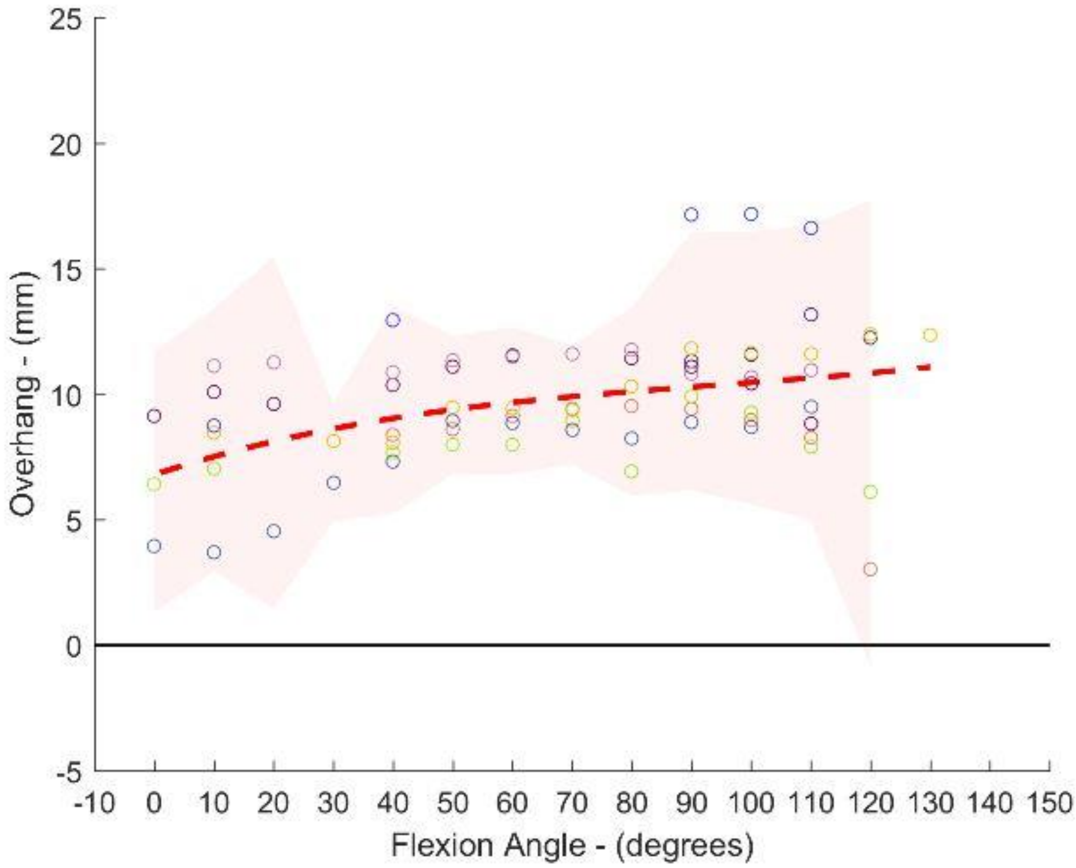

Figure 7: Overhang vs. flexion angle within the anterior cruciate ligament intact (A) and deficient (B) knees respectively from the medial OUKR cohort.