Journal of Arthritis

Ajuied et al., J Arthritis 2015, 4:1
DOI: 10.4172/2167-7921.1000144

Research Article | Open Access

Saw Cut Accuracy in Knee Arthroplasty – An Experimental Case-Control Study

Adil Ajuied*, Christian Smith, Adrian Carlos, Diane Back, Peter Earnshaw, Paul Gibb and Andrew Davies

Guy's & St. Thomas Hospitals, Guys Hospital, St Thomas's St, London SE1 9RT, UK

Abstract

Introduction: Navigated TKA (Total Knee Arthroplasty) has heightened awareness of mal-alignment in conventional TKA, as well as providing an accurate means of measuring alignment intra-operatively. Debate as to the importance and significance of alignment versus knee balance continues.

Aim: To assess cutting error, and examine the hypothesises:

- 'Slotted osteotomies are more accurate than non-slotted'
- 'Second pass of the saw blade improves the accuracy of osteotomies'

Method: Three pairs of fresh frozen human knees were prepared, exposed, and positioned as for primary TKA. Standard cutting guides were used in conjunction with a clinical navigation system, and the error (difference between the achieved resection, and the planned resection) in each osteotomy was measured. A second, tidying, pass of the saw blade was made and the error re-measured. Cutting guides were used with a slotted and un-slotted technique in left and right knees respectively. A single experienced surgeon performed all 96 osteotomies.

Results: Slotted tibial osteotomies are significantly more accurate in the sagittal (p=0.01) and coronal (p=0.04) planes. Second pass osteotomies reduce variability in femoral (p=0.07) and tibial (p=0.17) osteotomies.

Discussion: The bone cutting process is prone to high levels of random error that can result in implant mal-alignment, and thus predispose to aseptic loosening. Navigated TKA gives the operating surgeon the opportunity to check each osteotomy, and correct any error where necessary. In conventional TKA the use of dual pass, slotted osteotomies should provide improved accuracy.

Keywords: Bone Cutting Process; Total Knee Arthroplasty; Osteotomy

Introduction

Aseptic loosening following primary total knee arthroplasty (TKA) is the most common reason for revision surgery [1]. The association between limb mal-alignment and early aseptic loosening in TKA is long established and well recognised [2], although recent work has cast questioned this association [3,4)]. There are several factors which potentially contribute to poor implant alignment, such as surgical technique or experience [5)], deviation of the oscillating saw blade [6)], thickness of the saw blade [7,8)], sub-optimal cutting jig stability [9,10)], limited accuracy of jig alignment systems [10)] and uneven cement mantles [11].

Current literature has looked at several of these factors, and in 2002 [4)] found that guide movement contributed 10% to 40% of the total cutting error. Knee prosthesis are predominantly implanted using bone cement. This cement acts as a grout, forming a 1.0 - 1.5 mm mantle upon which the implant lies. This mantel acts as a mechanical couple between the bone and the implant, and transmits stress between the two [12] looked at the degree of implant mal-alignment that is attributable to the process of cementation and impaction, this group reported <1 degree of deviation in the coronal and sagittal planes in less than 33% of cases, and instances of 3 degrees deviation in tibial sagittal alignment. This study highlights that addressing accuracy in the saw cutting process alone can not assure accurate implant position.

The majority of commonly available knee systems have the option of un-slotted or slotted cutting blocks. Published literature suggests variability in cutting error is dependent on surgical experience and independent of the surgical instrumentation used [6,13]. The literature also suggests that slotted cutting blocks improve the accuracy of experienced surgeons but not of trainees [13]. These results have not been consistently reproducible [9].

Peri-operatively, care is taken to accurately align the cutting block relative to the bone being resected, as it is this position that defines the planned saw blade trajectory and hence the planned osteotomy plane. The saw blade must be orientated in such a way as to avoid bending the saw blade thus levering upon the cutting block. This would alter the cutting block position, and the subsequent resection plane.

Rhetoric suggests that various surgeons will, following the initial osteotomy, perform a second "trimming" pass of the saw blade in order to complete the osteotomy. There are no published studies assessing the impact of this second pass of the saw blade upon the accuracy of the achieved osteotomy. With this background our study aimed to test the two following hypothesises: To assess cutting error, and examine the hypotheses:

***Corresponding author:** Dr. Adil Ajuied, BSc(Hons) MSc FRCS(Tr&Orth), Consultant Orthopaedic Surgeon, Senior Honorary Clinical lecturer, Guy's & St. Thomas Hospitals, Guys Hospital, St Thomas's St, London SE1 9RT, UK, Tel: +44 7713 399944; E-mail: aajuied@doctors.org.uk

Received November 26, 2014; **Accepted** January 26, 2015; **Published** February 03, 2015

Citation: Ajuied A, Smith C, Carlos A, Back D, Earnshaw P, et al. (2015) Saw Cut Accuracy in Knee Arthroplasty–An Experimental Case-Control Study. J Arthritis 4: 144. doi:10.4172/2167-7921.1000144

Citation: Ajuied A, Smith C, Carlos A, Back D, Earnshaw P, et al. (2015) Saw Cut Accuracy in Knee Arthroplasty–An Experimental Case-Control Study. J Arthritis 4: 144. doi:10.4172/2167-7921.1000144

- Slotted osteotomies are more accurate than non-slotted
- Second pass of the saw blade improves the accuracy of osteotomies

Method

Six paired, cadaveric human fresh frozen knees were dissected, and the soft tissue envelope removed, leaving the bones of the distal femur and proximal tibia skeletonised. These were then positioned in a rigid vice, lined with padding, with the bones orientated as for a primary TKA.

A navigation spatial array was rigidly attached to the specimen being tested. A cutting block was securely fixed to the bone by two 3.2 mm drilled pins. The cutting block could be used to perform both slotted and non-slotted cuts. The block was positioned such that a bone resection of 4 mm was achieved. A second spatial array was then attached to the cutting block, allowing the position of the block to be registered relative to the bone in 3 dimensions. The desired plane of resection according to the navigation software (which we refer to as the zero plane) is defined as the plane of the cutting block slot for slotted cuts and the superior surface of the block for non-slotted cuts.

The osteotomy was performed using a single pass of the saw blade. The second spatial array was reattached after each bony resection to confirm that the cutting block position had not moved (and thus the zero plane had not changed). A third spatial array was attached to the cut bony surface, detecting the difference of the bony resection compared to the zero plane. A second pass of the saw blade was then performed as a trimming or tidying pass. The third spatial array was once again used to assess the resection plane and quantify the impact of the trimming pass.

The osteotomy was performed on the medial and lateral sides of the femur and tibia, with each osteotomy repeated 4 times at 4 millimetre intervals. This resulted in 16 total cuts per knee (i.e. 4 cuts of the medial tibia, lateral tibia, medial femur and lateral femur). The same experienced Orthopaedic surgeon carried out all osteotomies, totalling 96 across all 6 specimens using standardised surgical technique. The difference of the bony resection compared to the zero plane was calculated to the closest 0.1 of a degree in both the coronal and sagittal planes.

Paired knees from donors were used to reduce errors due to bony anatomy. The slotted block was used on the right knee and the un-slotted on the left. Two identical mains powered electrical saws were used at intervals to prevent overheating. A new saw blade was used for each knee in order to reduce potential inaccuracy due to blunting of the cutting edge.

Statistical analysis was performed using the SPSS statistical package (SPSS, Inc, Chicago, Il, USA), with level of significance set at $p<0.05$. The Kolmogorov-Smirnov test was used to ensure the data was parametric. The Student's t-test was used for statistical analysis.

Results

The navigational software calculated coronal and sagittal angular error to within 0.1 degrees. The tibial and femoral cuts were grouped and analysed separately. Figures 1 and 2 show the angular errors recorded for tibial resections in the coronal and sagittal plane using a single pass of the saw. Figures 3 and 4 show similar results for the femoral resections.

It can be seen from the tibial results (Figures 1 and 2) that there is a statistically significant difference in the variance for the slotted and non-slotted cuts. The slotted cuts are more precise with a tighter cluster around the mean, whereas with the non-slotted cuts there were more widely distributed. The femoral cut results (Figures 3 and 4) were not statistically significant when comparing mean or variance. It is interesting to note that all the osteotomies tended towards varus in the coronal plane.

The results from the single versus double pass saw cuts were divided into the same four groups by tibia or femur and coronal or sagittal cut variance. Although it can be observed from Figures 5-8 that the means are brought closer to zero by perfoming a second pass, and that the number of outliers appears reduced, none of these results were statistically significant.

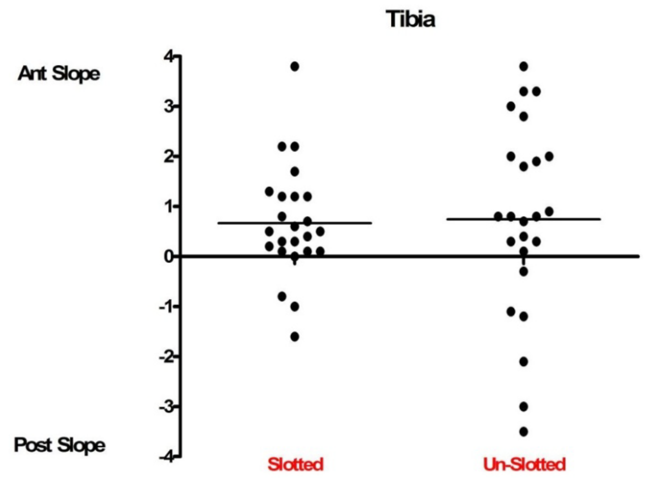

Figure 1: The difference between predicted and actual cuts in slotted versus un-slotted osteotomies in the sagittal plane. Results are shown in degrees; n=48 for each group. Mean cutting error: Slotted=0.67 (+/- 0.23); Un-Slotted=0.74 (+/- 0.40) Statistical difference between slotted and non-slotted: Mean p=0.87, variance=0.01.

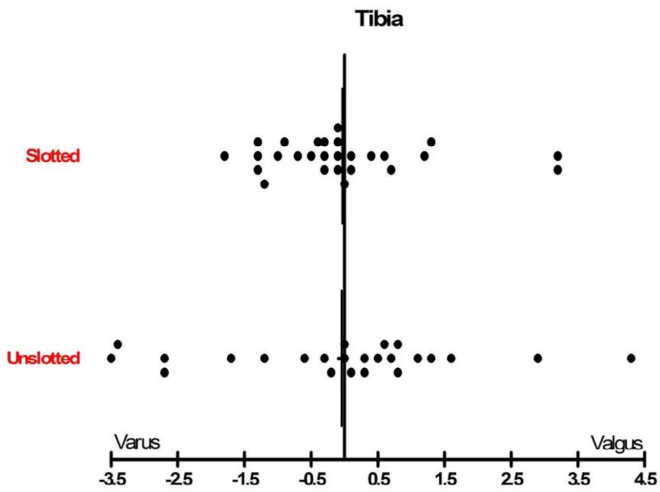

Figure 2: The difference between predicted and actual cuts in slotted versus un-slotted osteotomies in the coronal plane. Results are shown in degrees; n=48 for each group. Mean cutting error: Slotted=-0.03 (+/- 0.23); Un-Slotted=-0.04 (+/- 0.38). Statistical difference between slotted and non-slotted: Mean p = 0.98, variance=0.04.

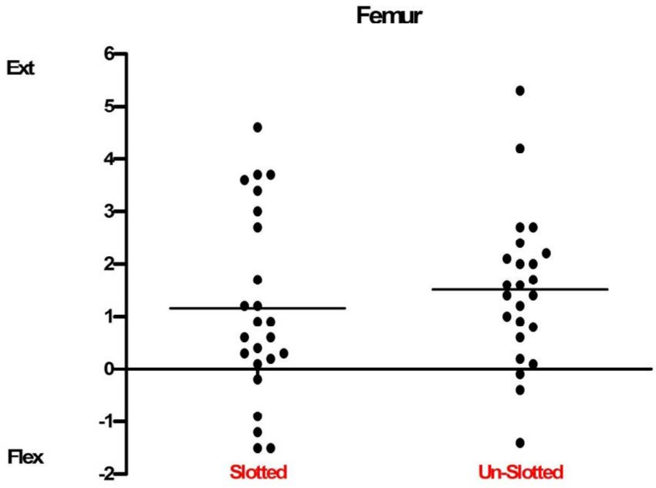

Figure 3: The difference between predicted and actual cuts in slotted versus un-slotted osteotomies in the sagittal plane. Results are shown in degrees; n=48 for each group. Mean cutting error: Slotted=1.20 (+/- 0.36); Un-Slotted=1.50 (+/- 0.29). Statistical difference between slotted and non-slotted: Mean p=0.46, variance=0.31.

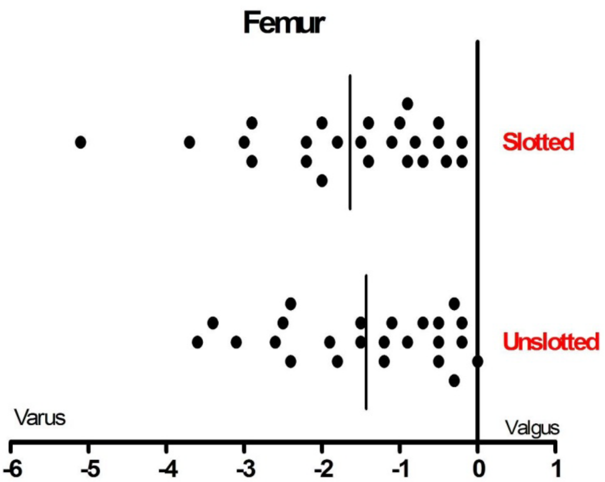

Figure 4: The difference between predicted and actual cuts in slotted versus un-slotted osteotomies in the coronal plane. Results are shown in degrees; n=48 for each group. Mean cutting error: Slotted=-1.64 (+/- 0.25); Un-Slotted=-1.43 (+/- 0.22). Statistical difference between slotted and non-slotted: Mean p=0.54, variance=0.61.

Discussion

This study aimed to compare the accuracy of osteotomies when using a slotted and non-slotted cutting block. The results show the slotted cutting block is favourable when compared with the non-slotted block for reducing cutting errors. Tibial osteotomies are significantly more accurate in the sagittal (p=0.01) and coronal (p=0.04) planes (Figures 1 and 2). Femoral resections showed no significant difference when comparing slotted and non-slotted cutting blocks.

The reciprocal thickness of the slot and blade leave minimum clearance space, helping reduce leverage with slotted cutting blocks. This reduction in the propensity to use the saw blade as a lever reduces the phenomenon of posterior lift off which can be seen when using an non-slotted cutting block. The working length of the blade is also reduced, preventing the blade from bending or deviating when it initially comes into contact with the bone during cutting.

This study also looked into whether a second pass of the saw blade improved the accuracy of the final resection. The second pass osteotomy produced a reasonably strong trend towards reduced variability in femoral (p=0.07) and tibial (p=0.17) osteotomies, but the results were significant. It is interesting to note that angular deviation of the cuts in the sagittal plane were generally towards the joint line, with increased tibial slope and extension of the femur. It can be hypothesised that the cause for the deflection towards the joint line is due to mobility of the resected bone fragments. As the saw progresses through the bone, the resection fragment becomes progressively more mobile. This results

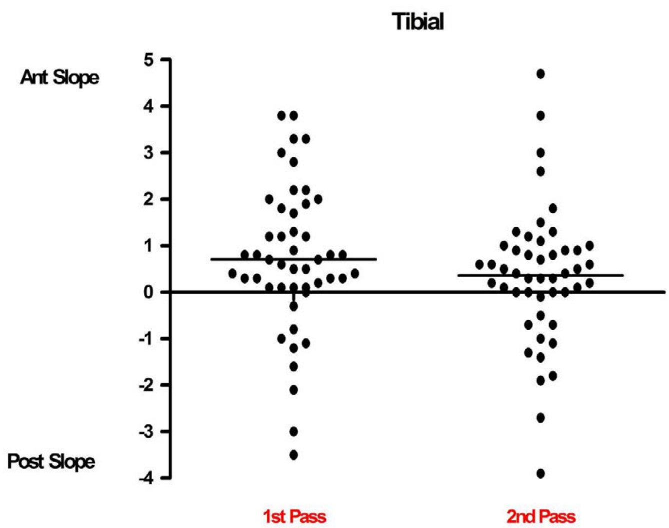

Figure 5: The difference between single and double pass cutting errors in the sagittal plane. Results are shown in degrees; n=96 for each group. Difference of average angular error for 1st and 2nd cut: 1st Pass=0.70 (+/- 0.23); 2nd Pass=0.36 (+/- 0.21). Statistical difference between 1st and 2nd cut: Mean p=0.27, variance=0.68

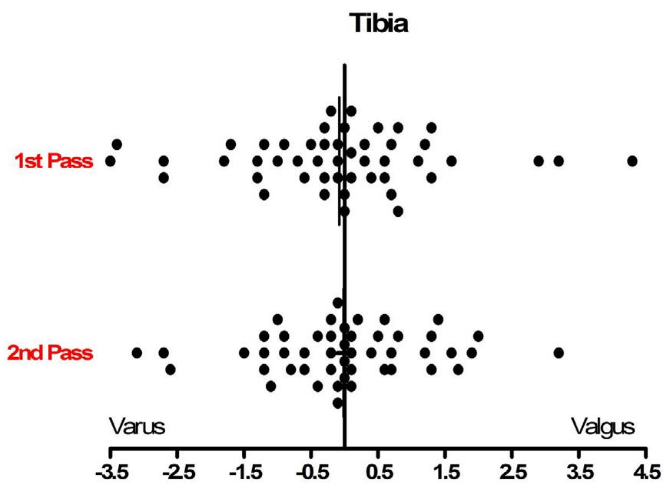

Figure 6: The difference between single and double pass cutting errors in the coronal plane. Results are shown in degrees; n=96 for each group. Difference of average angular error for 1st and 2nd cut: 1st Pass -0.70 (+/- 0.18); 2nd Pass=-0.08 (+/- 0.21). Statistical difference between 1st and 2nd cut: Mean p=0.83, variance=0.17

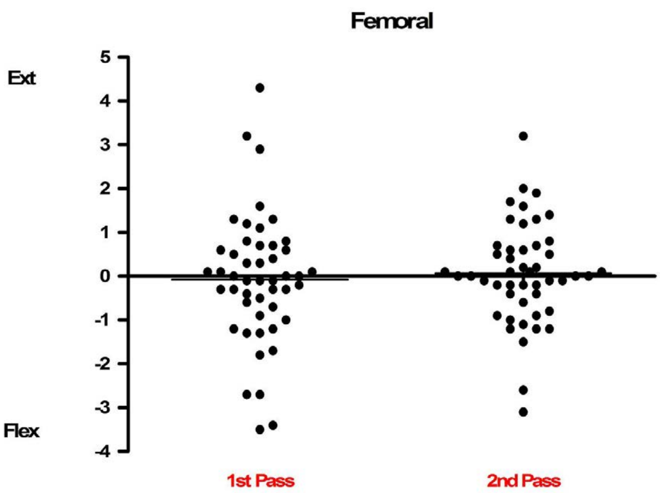

Figure 7: The difference between single and double pass cutting errors in the sagittal plane. Results are shown in degrees; n=96 for each group. Difference of average angular error for 1st and 2nd cut: 1st Pass -0.08 (+/- 0.21); 2nd Pass=0.07 (+/- 0.16). Statistical difference between 1st and 2nd cut: Mean p=0.60, variance=0.07

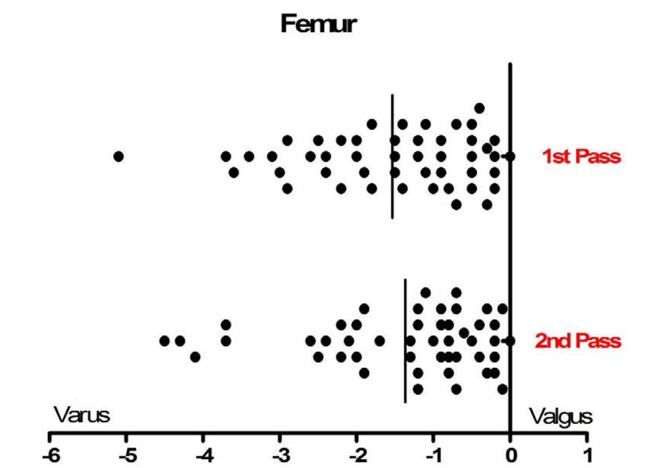

Figure 8: The difference between single and double pass cutting errors in the coronal plane. Results are shown in degrees; n=96 for each group. Difference of average angular error for 1st and 2nd cut: 1st Pass -1.53 (+/- 0.17); 2nd Pass=-1.36 (+/- 0.17). Statistical difference between 1st and 2nd cut: Mean p=0.48, variance=0.90

in the blade travelling through the bone with one surface opposed to fixed bone and the other loosely opposed to the mobile surface. This combined with the increased working length of the saw blade will cause an increased chance of deviation towards the mobile surface. Kim et al. also comment on this phenomenon, adding that the posterior parts of the proximal tibia and distal femur are typically harder than the anterior portions which lead to more deflection of the saw blade [14]. Upon performing a second pass of the saw blade, the blades tip restarts at the border of the bone at the correct resection level, helping remove the excess bone remaining following the first pass.

This study attempted to apply maximal control over the environment and the interventions within our paradigm, with minimal bias. This study was carried out on three pairs of young knees without classical osteoarthritic changes. Although bone quality will obviously differ, the cutting errors are likely to be analagous. Using a single surgeon to perform the osteotomies reduces variabilty, however the results record only one individual's method of performing the cuts.

Table 1 compares the results from our study with those in the current literature. It can be seen that, other than in the femoral coronal plane, our study yielded comparable results with regards to a reduction in cutting error. Other studies assessing *in vivo* saw cutting accuracy have solely used slotted blocks. This may be explained by our study being performed by a single operator and under controlled laboratory conditions. Other studies were performed *in vivo* over many weeks, with multiple operators, variable bone quality and other associated confounding factors.

The relationship between mal-alignment in TKA and early aseptic loosening has been well described [12,15,16] and is now broadly accepted. It has been suggested that greater than 3 degrees of coronal mal-alignment is associated with a higher risk of early failure. Interest and focus in coronal limb alignment has grown following the advent of navigation. The significance of three degrees of malalignment was made by [15], as it was said to approximately correlate with the Maquet line [17] intersecting the joint line within the middle third of the tibial tray.

From our results we found 11 cuts were beyond the recommended 3 degree limit in the coronal plane, representing 11.5% of all cuts. They were more common in the non-slotted cuts (4 tibial and 3 femoral) compared to the slotted cuts (2 tibial and 2 femoral). The greatest tibial cutting error was 4.3 degrees of valgus angulation made with an non-slotted cutting block. The greatest femoral deviation was 5.2 degrees made using a slotted cutting block.

The advent of computer navigation has given researchers the tools for intraoperative measurement and assessment of resection planes. There have been several studies looking at intraoperative cutting errors in TKA, with an emphasis upon comparing results from conventional versus navigated arthroplasty. Recent literature has centred on human factors such as surgeons experience [11] and comparing automated guide positioning with conventional freehand computer-navigated guide positioning [9]. There has been little work to assess the impact of saw blade deflection, cutting block type or stability upon saw cut accuracy.

When assessing the stability of the cutting block it was found that a deviation of +/-2 degrees was possible after applying maximal pressure to the block. Review of the results demonstrates outliers of over five degrees angular deviation. All osteotomies were performed using standard surgical techniques with neutral blade orientation. Cutting block instability can not account for all cutting errors beyond 3 degrees, therefore they must be attributed to the saw blade as is passes through the bone.

There is certainly potential for further research in this area, looking at other variables contributing to poor implant alignment such as

Angular Error	This study	Bathis et al. [7]	Belvedere et al. [9]	Yau et al. [10]
Sample size	48	50	25	40
Tibial Sagittal	0.7 +/- 0.2	1.0 +/- 0.9	2.2 +/- 2.9	1.5 +/- 0.8
Tibial Coronal	0.0 +/- 0.2	0.5 +/- 0.5	0.2 +/- 1.3	1.3 +/- 0.7
Femoral Sagittal	1.2 +/- 0.4	1.4 +/- 1.3	2.8 +/- 2.0	1.6 +/- 1.3
Femoral Coronal	-1.6 +/- 0.3	0.6 +/- 0.5	0.7 +/- 1.6	0.7 +/- 0.5

Table 1: Comparing mean and standard deviation of slotted tibial and femoral cutting errors in both the coronal and sagittal planes with previous studies.

comparing different types of saw blade. The cutting aggression of the saw teeth has an effect on the bone cut and establishing an industry standard against which saw blades could be measured is an interesting area for future research.

With respect to slotted versus non-slotted osteotomies, we can conlcude that the bone cutting process is prone to high levels of random error. Slotted cutting blocks produced a significantly improved resection for tibial osteotomies.

With regards to single versus double pass osteotomy, double pass osteotomy showed a trend for reduced variability in femoral and tibial osteotomies although these results are not statistically significant.

References

1. Lützner J, Hübel U, Kirschner S, Günther KP, Krummenauer F (2011) Long-term results in total knee arthroplasty. A meta-analysis of revision rates and functional outcome. Chirurg 82: 618-624.
2. Lotke PA, Ecker ML (1977) Influence of positioning of prosthesis in total knee replacement. J Bone Joint Surg Am 59: 77-79.
3. Biant LC, Yeoh K, Walker PM, Bruce WJ, Walsh WR (2008) The accuracy of bone resections made during computer navigated total knee replacement. Do we resect what the computer plans we resect? Knee 15: 238-241.
4. Plaskos C, Hodgson AJ, Inkpen K, McGraw RW (2002) Bone cutting errors in total knee arthroplasty. J Arthroplasty 17: 698-705.
5. Macdonald W, Styf J, Carlsson LV, Jacobsson CM (2004) Improved tibial cutting accuracy in knee arthroplasty. Med Eng Phys 26: 807-812.
6. Minns RJ (1992) Surgical instrument design for the accurate cutting of bone for implant fixation. Clin Mater 10: 207-212.
7. Bäthis H, Perlick L, Tingart M, Perlick C, Lüring C, et al. (2005) Intraoperative cutting errors in total knee arthroplasty. Arch Orthop Trauma Surg 125: 16-20.
8. Otani T1, Whiteside LA, White SE (1993) Cutting errors in preparation of femoral components in total knee arthroplasty. J Arthroplasty 8: 503-510.
9. Belvedere C, Ensini A, Leardini A, Bianchi L, Catani F, et al. (2007) Alignment of resection planes in total knee replacement obtained with the conventional technique, as assessed by a modern computer-based navigation system. Int J Med Robot 3: 117–124.
10. Yau WP, Chiu KY (2008) Cutting errors in total knee replacement: assessment by computer assisted surgery. Knee Surg Sports Traumatol Arthrosc 16: 670-673.
11. Schnurr C, Eysel P, König DP (2011) Do residents perform TKAs using computer navigation as accurately as consultants? Orthopedics 34: 174.
12. Catani F, Biasca N, Ensini A, Leardini A, Bianchi L, et al. (2008) Alignment deviation between bone resection and final implant positioning in computer-navigated total knee arthroplasty. J Bone Joint Surg Am 90: 765-771.
13. Manzotti A, Cerveri P, De Momi E, Pullen C, Confalonieri N (2010) Relationship between cutting errors and learning curve in computer-assisted total knee replacement. Int Orthop 34: 655-662.
14. Kim TK, Chang CB, Kang YG, Chung BJ, Cho HJ, et al. (2010) Execution accuracy of bone resection and implant fixation in computer assisted minimally invasive total knee arthroplasty. Knee 17: 23-28.
15. Jeffery RS, Morris RW, Denham RA (1991) Coronal alignment after total knee replacement. J Bone Joint Surg Br 73: 709-714.
16. Parratte S, Pagnano MW, Trousdale RT, Berry DJ (2010) Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. J Bone Joint Surg Am 92: 2143-2149.
17. Maquet P (1972) Biomechanics of gonarthrosi]. Acta Orthop Belg 38 Suppl 1: 33-54.