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Original Article

New Instrumentation Improves Patient Satisfaction and Component Positioning for Mobile-Bearing Medial Unicompartmental Knee Replacement

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Abstract

Background: The Oxford unicompartmental knee replacement (OUKR) has achieved excellent functional outcomes and long term survivorship in many single center and single surgeon series. However, in national registries, the failure rates are up to three times higher than total knee replacement. This is at least in part due to difficulty experienced by low-volume surgeons in implanting the prosthesis accurately. A new instrumentation system (Microplasty) was introduced to help surgeons achieve better component positioning, however, it is not known whether the new instruments achieve that goal. This study investigates whether the new system achieves better component positioning and whether it improves the clinical outcomes when compared to the existing instruments. **Materials and Methods:** This retrospective cohort study compared 50 consecutive OUKR implanted using the conventional Phase 3 instrumentation with 100 consecutive OUKR implanted using the new Microplasty instrumentation. Component orientation was measured on postoperative radiographs, and the percentage outside the recommended range was identified. Intraoperative data and retrospectively collected clinical data were also analyzed. **Results:** Femoral component alignment improved significantly, and there were no outliers in the

Microplasty group. Although there were fewer tibial component alignment outliers with Microplasty, the difference was not significant. The intraoperative incidence of tibial recut, patient satisfaction and patient expectations was significantly better in the Microplasty group. The Oxford Knee Scores were also better with Microplasty, however, the difference was not significant. **Conclusion:** Microplasty instrumentation helps the surgeon achieve optimal component positioning and reduces the need for tibial recut. The clinical outcomes are also better with the Microplasty instrumentation.

Keywords: Alignment, Microplasty, outcomes, unicompartmental knee replacement

<H1>Introduction

In patients with symptomatic end-stage anteromedial osteoarthritis (AMOA) or medial osteonecrosis of the knee joint, unicompartmental knee replacement (UKR) is an effective treatment with the advantages of significantly lower morbidity and mortality.[1] A higher percentage of good or excellent patient reported outcomes, and a more rapid recovery is noted, as compared to total knee replacement (TKR).[2]

The Oxford UKR (OUKR), which is the most commonly performed UKR, has demonstrated excellent functional outcomes and long term survivorship similar to that of the best TKR in many single center and single-surgeon series.[3-7] However, this is not reflected in the national registers which typically show a revision rate about three times higher with UKR than TKR. This disparity is at least in part due to lower UKR caseload per surgeon. According to the

National Joint Register (NJR), between 2004 and 2012, users of UKR performed an average of 5.4 UKRs/year, with 25% doing only one UKR/year and this was the most common UKR caseload.[8] Lower case-load contributes to the higher failure rates of UKR seen in various national joint registries.[8] Liddle *et al.* demonstrated that in the NJR of England and Wales, the mean 8-year rate of survival of the UKRs in the hands of surgeons performing <10 UKRs/year was 88.1% (95% confidence interval [CI] = 86.9% to 88.8%) compared with 92.1% (95% CI = 90.9% to 93.6%) for those who performed 30 or more per year.

One of the main reasons why low-volume surgeons have poor results is that they have difficulty accurately positioning the implant. This is particularly a problem when minimally invasive surgical (MIS) techniques are used.[9] Since 1998, the OUKR has been implanted using this technique (Phase 3),[10] which does not require patella eversion and minimizes soft-tissue damage resulting in a faster recovery, less postoperative pain, and better function in the long term.[11,12] However, a MIS approach can make the intraoperative visualization more difficult with fewer surgical landmarks available, and as a result, the surgery may be more difficult.[13] Some publications have highlighted the inability of the surgeons to achieve the recommended implant orientation using Phase 3 instrumentation, as these series demonstrate a substantial population of OUKRs are implanted outside the proposed limits of tolerance.[13-15] This may in part be due to the way the Phase 3 instrumentation works. The surgeon has to judge by eye the height of the tibial cut and the femoral component orientation. As a result,

many surgeons find it necessary to recut the tibia which in turn may weaken the bone or result in damage to the medial collateral ligament (MCL).

New instrumentation known as Microplasty (Zimmer Biomet, Bridgend, United Kingdom) was introduced in 2011 to make the surgery easier and to improve the reproducibility of component positioning. The instrumentation has a stylus system to ensure a more consistent tibial resection level, a femoral drill guide linked to an intramedullary rod to improve femoral orientation, and slotted saw guides[16,17] [Figures 1-3]. Although in theory, these changes should make the surgery more reproducible, limited data exist in the literature comparing the old and new instrumentation. In addition, it is not known whether these changes have resulted in better functional outcome. It is important to establish if there are any real advantages with the new instrumentation as any change in surgical technique introduces a learning curve possibly with associated harmful effects and increased costs.

<H2>Purpose and hypothesis

The aim of this single-center, two-surgeon retrospective cohort study was to answer three key questions: Does the new instrumentation improve component alignment; does it reduce the risk of tibial recut during surgery, and does it improve the clinical outcome? The study compares intraoperative findings, postoperative clinical and radiological outcomes in patients with AMOA undergoing cemented medial OUKR using either the Phase 3 or Microplasty instrumentation.

<H1>Materials and Methods

Following institutional ethical approval, we analyzed the radiographs and retrospectively collected clinical outcome data on two consecutive cohorts with a total of 150 cemented medial OUKRs implanted in 150 patients with bone-on-bone AMOA. All surgeries were performed by either of two senior surgeons (RM, VK) under spinal anesthetic with recommended indications,[10] described surgical technique and standardized physiotherapy regime postoperatively.[18] All patients were contacted within the last 12 months.

The first cohort consisted of the first consecutive 50 minimally invasive implantations of the Oxford UKR (OUKR) using the conventional Phase 3 instrumentation (Zimmer Biomet UK Limited, Swindon, UK) between August 2008 and July 2013 (Group A). The second cohort consisted of a consecutive series of the 100 minimally invasive OUKR with the new Oxford Microplasty instrumentation between August 2013 and May 2015 (Group B).

Operative data were collected using a standard form, which recorded surgical findings including the status of the ACL and the cartilage in the involved and the retained compartments. In addition, data on need for tibial recut, and the thickness of tibial bearing were recorded. The clinical outcome was assessed using the Oxford Knee Score (OKS), a validated patient-based questionnaire.[19] We used this score with a minimum of 0 (worst outcome) and maximum of 48 (best outcome).[20] Based on established criteria, patients were classified into those with excellent (OKS > 41), good (OKS 34–41), fair (OKS 27–33), and

poor (OKS < 27).[21] The American Knee Society Score (AKSS) was also used including assessment of patient expectations and patient satisfaction.[22,23] Each patient's level of activity was recorded with the Tegner score.[24] At the time of last followup, all patients underwent radiographic assessment in addition to detailed clinical assessment including careful recording of any perioperative complications encountered.

<H2>Radiographic assessment

In all patients, anteroposterior (AP) radiographs aligned on the tibial component and lateral radiographs aligned on the femoral component were taken under fluoroscopic guidance.[25] Weight-bearing long leg limb alignment radiographs were obtained preoperatively as well as postoperatively to assess overall limb alignment.

<H2>Femoral component varus/valgus

Measured as the acute angle between the femoral component and the femoral diaphyseal axis in the coronal plane on the screened short leg X-rays (Figure 4). The diaphyseal axis was drawn from the femoral notch to a point bisecting the cortex at a point 10 cm proximal to the notch. A 7° subtraction was made from the measured angle to make the reported angle representative of the mechanical axis. The aim is for the femoral component to be aligned parallel to the mechanical axis. Thus, an angle of 0° was seen as neutral with a range of tolerance of ±10°.[17]

<H2>Flexion/extension of femoral component

Measured as the acute angle between a line through the center of the femoral peg and the femoral axis in the lateral short leg screened view (Figure 5). The diaphyseal axis was measured using the posterior cortical line as described by Rees *et al*.[26] The accepted range is 0° to 20° from the intramedullary rod, with an aim to flex the component 10°. As there is a femoral bow of about 5° relative to the distal femur, a 5° addition was made to the measured angle to make the reported angle representative of the mechanical axis. Thus, an angle of 10° flexion was seen as optimal, with a range of tolerance of ±10° (accepted range of 0° to 20° flexion).

<H2>Tibial component varus/valgus

Measured as the acute angle between a line perpendicular to the tibial axis and a line drawn across the tibial tray in the coronal plane on a short-leg screened X-ray (Figure 4). The axis was drawn between a point at the midpoint of the spines, and a point bisecting the cortex 10 cm distal to this point. The accepted range was 0° ± 5°.[17]

<H2>Tibial component-anteroposterior slope

Measured as the acute angle between a line drawn along the tibial tray and a line perpendicular to the tibial axis in the lateral short-leg screened view (Figure 5). The axis was drawn as per the proximal anatomical axis (diaphyseal) described by Yoo *et al*. with a line

drawn to connect mid cortical points at 5 cm and 15 cm distal to the joint space.[27] A slope of 7.5° was seen as optimal with a range of tolerance of ±5° (thus giving an accepted range of 2° to 13°).[17]

<H2>Leg alignment

The hip-knee-ankle angle was measured on the standing long leg film by drawing tibial and femoral mechanical axes (Figure 6). The acute angle subtended between the two was recorded as the leg alignment angle.

If for any of the measures femoral component, varus/valgus or flexion/extension of the femoral component, the component was outside the recommended range, the knee was considered as an outlier for femoral component positioning. Similarly, if for any of the measures tibial component, varus/valgus or AP slope of the tibial component the component was outside the recommended range, the knee was considered as an outlier for tibial component positioning A knee was considered an outlier if either the femoral or tibial component were outliers.

<H2>Intraoperative findings

For the purpose of this study comparing old with new instrumentation, two key aspects were assessed. The incidence of tibial recut and thickness of the meniscal bearing. Tibial recut introduces error and ideally should not be performed if the instrumentation is reliable in

168 predicting correct level of horizontal tibial cut. The mobile-bearing thickness was used as an
169 indicator for the height of the resection of the tibial plateau. A bearing size of 3 or 4 mm
170 suggests an appropriate level of resection, whereas a bearing size of 5 mm or more indicates a
171 level of resection too far distally, resulting in unnecessary bone loss.

172 **<H2>Statistical analysis**

173 The quantitative variables are expressed by mean ± standard deviation (SD) and range; and
174 were analyzed by a Student *t*-test or a Mann–Whitney U-test in the case of unequal variance.
175 Categorical variables are expressed as counts and percentages and were compared by Fisher's
176 exact test or a Z-test. Categorical data are expressed as counts and percentages. Quantitative
177 data are expressed by mean ± SD or range. Statistical significance was set for $P \leq 0.05$.
178 Statistical evaluation was performed using XLStat™ v.2015 (AddInsoft, Paris, France) and
179 Stata version 14 (STATA Corp., Texas, USA).

180 **<H1>Results**

181 None of the patients died as a result of surgery and none were lost to follow up. The mean
182 age at the time of surgery for the entire cohort was 58.8 years (SD 8.3, range 41–79). There
183 were 32 males (21%) and the mean body mass index (BMI) for the entire cohort at the time
184 of surgery was 28.9 (SD 3, range 23–36). The mean followup was 27 months (SD 17.3, range
185 12–88).

The mean age for Group A was 59.8 years (SD: 8.4, range 41–79) and for Group B was 58.3 years (SD: 8.2, range 44–79). Nearly 28% of patients in Group A and 18% patients in Group B were male. The mean BMI for Group A was 29.3 (SD 2.8, range 23–35.6) and mean BMI for Group B was 28.7 (SD 3.1, range 23–36). The mean followup for Group A was 45 months (SD 17.2, range 18–88) and the mean followup for Group B was 18 months (SD 4.6, range 12–30).

<H2>Clinical outcomes

The mean OKS at the time of last followup was 38.1 (SD 5.2, range 11–47, Table 1) for Group A and 39.2 (SD5.5, range 22–48) for Group B. The difference between the two was not statistically significant ($P = 0.96$). According to criteria proposed by Kalairajah *et al.* ,[21] 38% of cases in Group A and 45% cases in Group B had excellent outcome ($P = 0.41$). A small proportion had poor outcome in both the groups (2% in each). The differences were not statistically significant although it showed a trend toward better outcome with the new instrumentation.

The mean AKSS Functional was 69.9 (SD 9.9, range 15–83) for Group A and was 70.8 (SD 9.4, range 21–85) for Group B. The difference between the two was not significant ($P = 0.61$). The mean AKSS Satisfaction was 29.7 (SD 4.0, range 10–38) for Group A and was 32.8 (SD 4.5, range 12–40) for Group B. The difference between the two was statistically significant ($P = 0.01$). The mean AKSS Expectation was 10.6 (SD 2.5, range 0–14) for Group

A and was 11.8 (SD 1.5, range 5–15) for Group B. The difference between the two was statistically significant (P = 0.03). The median activity score for Group A was 3 (range 0–4) and the median activity score for Group B was 3 (range 0–4). The difference between the two was not statistically significant.

<H2>Intraoperative findings

<H3>Tibial recut

The incidence of tibial recut was 22% for Group A and 5% for Group B. The difference between the two groups was statistically highly significant (P = 0.001).

<H3>Bearing size

The median bearing thickness was 3 mm (range 3 to 6) for Group A and was 3 mm (range 3–6) for Group B. In 90% cases in Group A and 96% in Group B, a size 3 or 4 bearing was used. The difference between the two groups was not statistically significant.

<H2>Radiographic assessment

<H3>Femoral component varus/valgus

The mean femoral component inclination (in the coronal plane: Varus being given negative value) was 2.5° (SD 7.5, range −12 to 12) for Group A and −0.6° (SD 4.0, range -7–8) for Group B (Table 2). The difference between the two groups was statistically significant (P = 0.001). Fifteen (30%) femoral components in Group A and no components in Group B were

found to be outside the recommended range. The difference between the two groups was statistically significant ($P < 0.001$).

<H3>Flexion/extension of femoral component

The mean femoral component inclination (in the sagittal plane: extension being given negative value) was 5.3° (SD 3.6, range 1–16) for Group A and 7.5° (SD 4.5, range 0–18) for Group B. The difference between the two groups was statistically significant ($P = 0.002$). One (2%) femoral component in Group A and no components in Group B were found to be outside the recommended range. The difference between the two groups was not statistically significant ($P = 0.33$)

<H3>Tibial component varus/valgus

The mean tibial inclination (in the coronal plane–varus being given negative value) was 0° (SD 3.4, range -7 to 8) for Group A and −1.5° (SD 3.9, range -10-6) for Group B ($P = 0.02$). Nine (18%) tibial components in Group A and 13 (13%) components in Group B were found to be outside the recommended range. The difference between the two groups was not statistically significant ($P = 0.42$).

<H3>Tibial component-anteroposterior slope

The mean tibial slope was 7° (SD 3.9, range 2–17) for Group A and 6.6° (SD 3.2, range 0-14) for Group B. The difference between the two groups was statistically not significant ($P =$

241 0.48). Three components (6%) in Group A and five components in Group B (5%) were found
242 to be outside recommended range, the difference between the two groups was not statistically
243 significant ($P = 0.54$).

244 **<H3>Overall components out of range**

245 Fifteen (30%) knees had femoral components out of range for Group A, while no femoral
246 components were out of range for Group B ($P < 0.001$; Table 3). Twelve (24%) knees had
247 tibial components out of range in Group A compared with 18 (18%) in Group B ($P = 0.39$).
248 In total, 22 (44%) knees had components out of range in Group A, while 18 (18%) knees had
249 components out of range for Group B ($P = 0.001$).

250 **<H3>Limb alignment**

251 The mean hip-knee-ankle angle was 5° of varus (SD 3.1, range 0–15) for Group A and 5° of
252 varus (SD 3.2, range 0–14) for Group B. The difference between the two groups was
253 statistically not significant ($P = 0.94$).

254 **<H2>Radiolucency**

255 Partial or complete radiolucency around the tibial component was present in 64% cases in
256 Group A and in 59% cases in Group B. The difference was not statistically significant.

257 **<H1>Discussion**

This study demonstrates that the Microplasty instrumentation decreases the numbers of radiographic outliers for the femoral component, reduces the need for tibial recut and most importantly improves the clinical outcome of the medial Oxford UKR compared to Phase 3 instrumentation. Although previous studies have shown improvement in radiographic findings,[28,29] this is the first study that has shown improvement in all three areas. The design aims of Microplasty instrumentation were to simplify the operation, to improve its reproducibility and, consequently, to improve outcomes. This study suggests that these outcomes have been achieved.

The Oxford UKR has a femoral component which is part of a sphere. It is, therefore, very forgiving of femoral malalignment. A clinical study has shown that ±10° of malalignment in any direction of the femoral component does not compromise the outcome.[30] During the time that patients were recruited it was recommended that the femoral component should be flexed about 10° to improve the congruity of the knee in high flexion, With Phase 3 instrumentation, the orientation of the femoral drill guide which sets the component orientation was judged by eye relative to an intramedullary rod whereas with the Microplasty instrumentation the femoral drill guide is linked to an intramedullary rod so as to improve the accuracy of implantation. This study has shown that there has been marked improvement in the reproducibility of femoral component orientation with 30% of Phase 3 being outliers and none of the Microplasty being outliers. In addition, the femoral component flexion has increased with Microplasty to an average of 7.5° flexion. Ideally, this should be higher. To

obtain optimal flexion when using the drill guide with Microplasty, the surgeon should aim to flex the knee to about 110° which would minimize any bending or distortion in the IM rod or linkage.

With unicompartmental replacement, it is advantageous to remove as little of the tibia as possible. Indeed, best results with the Oxford UKR are achieved when the thinnest bearings, which are 3 or 4 mm thick, are used. At 15 years, the survival with 3 or 4 bearings is 94%.[11] It is therefore reassuring that in this study almost all the bearings used were 3 or 4. The bearing size is selected to restore the MCL tension and thus the predisease alignment. As the overall alignment of the leg is similar in both groups, it suggests that bearing size selection and preservation of the ligaments were similar with both instrumentation systems. With the Phase 3 instrumentation, surgeons judge by eye the height of the tibial cut. To avoid excess resection, surgeons tend to do conservative cuts and recut if necessary. Recuts often result in an irregular surface and may result in damage to the tibia or MCL. They are therefore best avoided. The stylus system was therefore introduced for the Microplasty instrumentation. This stylus system has decreased the need for recuts to a very low level which is a major advantage. If, with the Microplasty, the gap made following the tibial cut is slightly narrow, it can be increased by removing a small amount of cartilage from the back of the posterior part of the femur, before femoral preparation, which will further decrease the need for a recut.

With the Oxford UKR, due to the fully congruent bearing, some malalignment of the tibial component is acceptable. It has previously been shown that within the range of ±5° of either varus or valgus or posterior slope there is no difference in results.[30] For both the Microplasty and Phase 3, the average slope and varus/valgus were satisfactory. There were less outliers for tibial alignment with the Microplasty instrumentation than Phase 3; however, the difference was not significant. Despite this 13% of the Microplasty, tibial components were outliers for varus/valgus and 5% for tibial slope, which is higher than expected. The main difference between the Microplasty and the Phase 3 tibial guide is that the Microplasty guide has a slot for the saw blade which should minimize the outliers. The slot was not always used; had it been used always the alignment might have been better. Other factors that could have contributed to the outliers are poorly aligned X-rays, incomplete seating of the component and tibia vara. Further study is needed to improve tibial alignment.

The most important finding of this study is that the clinical results of Microplasty were better than those of Phase 3: With Microplasty, there were significantly better levels of patient satisfaction (AKSS Satisfaction), and patient expectations (AKSS Expectation) were also met significantly more often. Although there was no statistically significant difference in the OKS, Microplasty patients did have a higher OKS than Phase 3 and a higher proportion of patients had excellent OKS. It is not clear why the clinical results were better with Microplasty, but it is likely to be multifactorial. Clearly reducing the number tibial recuts and the number of radiographic outliers will help. However, as the positioning of the components

316 is much simpler with Microplasty, surgeons can focus on what really matters, which is
317 accurate soft-tissue balancing.

318 There are limitations to our study. Patients were not randomized and part of the improvement
319 in component alignment may be due to surgeons' experience increasing with time. However,
320 the results are important as there are no randomized trials. The study was retrospective so we
321 did not have preoperative OKS. As preoperative OKS influences postoperative scores, it is
322 difficult to interpret postoperative scores without knowing that the preoperative scores were
323 the same for both groups. However, satisfaction and achieved expectation do not require
324 preoperative scores, so perhaps are the most relevant scores, and these showed significant
325 improvements. The followup is relatively short particularly for the Microplasty group, so
326 there is no information about long term revision rate.

327 In summary, the new Microplasty instrumentation for the Oxford UKR gives better clinical
328 results than the Phase 3 instrumentation. In addition, as component positioning is better and
329 tibial preparation is more accurate we would expect the long term implant survival to be as
330 good or better with Microplasty. We, therefore, recommend that surgeons use the
331 Microplasty rather than the Phase 3 instrumentation.

332 ## Declaration of patient consent

333 The authors certify that they have obtained all appropriate patient consent forms. In the
334 form the patient(s) has/have given his/her/their consent for his/her/their images and other
335 clinical information to be reported in the journal. The patients understand that their names

and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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<H2>Conflicts of interest

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, education institution, or other nonprofit organization with which one or more of the authors are associated.

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Tables

Table 1: Clinical outcomes after Oxford unicompartmental knee replacement in Phase 3 and Microplasty groups

Clinical outcome	Phase 3, mean (SD), range	Microplasty, mean (SD), range	*P*
Oxford Knee Score	38.1 (5.2), 11–47	39.2 (5.5), 22–48	0.96
Knee Society Score (functional)	69.9 (9.9), 15–83	70.8 (9.4), 21–85	0.61
Knee Society Score (expectation)	10.6 (2.5), 0–14	11.8 (1.5), 5–15	0.03
Knee Society Score (satisfaction)	29.7 (4.0), 10–38	32.8 (4.5), 12–40	0.01

SD=Standard deviation

Table 2: Radiographic parameters after Oxford unicompartmental knee replacement in Phase 3 and Microplasty groups

Radiographic criteria	Accepted range	Phase 3, Mean (SD), range	Microplasty, mean (SD), range	*P*
Femoral component	0°±10	2.5° (7.5), −12–12	−0.6° (4.0), −7–8	0.001

varus/valgus				
Femoral component flexion/extension	10°±10	5.3° (3.6), −1–16	7.5° (4.5), 0–18	0.002
Tibial component varus/valgus	0°±5	0° (3.4), −7–8	−1.5° (3.9), −10–6	0.02
Tibial slope (antero-posterior)	7.5°±5	7° (3.9), 2–17	6.6° (3.2), 0–14	0.48
Hip-knee-ankle angle (long leg films)	Not applicable	5° varus (3.1), 0–15	5° varus (3.2), 0–14	0.94

434 SD=Standard deviation

Table 3: Radiographic outliers after Oxford unicompartmental knee replacement in Phase 3 and Microplasty groups

Radiographic outlier	**Phase 3, proportion (%) (number varus or flexed/number valgus or extended if applicable)**	**Microplasty, proportion (%) (number varus or flexed/number valgus or extended if applicable)**	***P***
Femoral component	15/50 (30%) (5/10)	0/100	<0.001

varus/valgus			
Femoral component flexion/extension	1/50 (2%) (1/0)	0/100	0.33
Tibial component varus/valgus	9/50 (18%) (2/7)	13/100 (13%) (9/4)	0.42
Tibial component slope (antero-posterior)	3/50 (6%) (3/0)	5/100 (5%) (1/4)	0.54
Femoral component outliers	15/50 (30%)	0/100	<0.001
Tibial component outliers	12/50 (24%)	18/100 (18%)	0.39
Overall component outliers	22/50 (44%)	18/100 (18%)	0.001

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438 **Figure Legends**

Figure 1: Microplasty instrumentation tibial resection guide with spoon/stylus and "G-clamp" for setting resection depth: lateral view. (Reproduced courtesy of Zimmer Biomet, Inc.)

Figure 2: Microplasty instrumentation tibial resection guide with spoon/stylus and "G-clamp" for setting resection depth: Anteroposterior view. (Reproduced courtesy of Zimmer Biomet, Inc.)

Figure 3: Microplasty intramedullary linked femoral alignment guide: lateral view (Reproduced courtesy of Zimmer Biomet, Inc.)

Figure 4: Accepted coronal alignment of tibial and femoral components. Femoral component coronal alignment: 10° varus to 10° valgus (black dashed arrow); Tibial component coronal alignment: 5° varus to 5° valgus (yellow dashed arrow)

Figure 5: Accepted sagittal alignment of tibial and femoral components. Femoral component sagittal alignment: 5° extension to 15° flexion (black dashed arrow); Tibial component sagittal alignment: 7.5° ± 5° (posterior tibial slope = 90° - α). The red line represents the intramedullary rod, and angle β is between the posterior cortical line and this line (β = 5°)

455 **Figure 6:** Measuring lower limb alignment by tibiofemoral angle, which is the angle between
456 femoral and tibial mechanical axis. β represents the measured angle, and this case
457 demonstrates postoperative varus alignment

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