The goal of total knee arthroplasty (TKA) is to provide a knee that has a functional range of motion. Although one of the means to achieving this goal is to bring the knee to full extension (i.e., 0°), postsurgery, the knee can either end up in genu recurvatum or in a fixed flexion deformity (FFD). There is substantial data on the surgical techniques for performing total knee replacement in patients with either a preoperative fixed flexion or genu recurvatum deformity. There is substantial data on the surgical techniques for performing total knee replacement in patients with either a preoperative fixed flexion or genu recurvatum deformity. The natural history of FFD and genu recurvatum after total knee replacement is also well documented. Each deformity has been associated with less than desirable outcomes. FFD causes an increase in the forces across the patellofemoral and tibiofemoral joints as well as an increase in the quadriceps force required to stabilise the knee. On the other hand, genu recurvatum is associated with medial instability. However to date, there is no study comparing clinical outcomes between post-total knee replacement genu recurvatum and FFD. The aim of this study is to provide this knowledge to clinicians which will help in deciding which side (i.e., in recurvatum or in fixed flexion) to err on when neutral extension is not achieved.

**METHODS**

This is a prospective cohort study. Data were collected from the hospital joint registry. All patients in the joint registry who underwent primary TKA from 2004 to 2008 were included in the study. Patients who defaulted from follow-up at 6 months, 2 years, or both were excluded from the study. Patient biodata, post-total knee replacement range of motion as well as clinical scores (Knee Society knee and function scores, Oxford Knee scores, and Short Form 36 [SF-36] scores) were reviewed at 6 months and 2 years postsurgery. We used the Oxford Knee score described by Dawson et al. where a better outcome is denoted by a lower score. This is in contrast to the Knee Society and SF-36 scores, also used here, where a better outcome is denoted by a higher score. All range of motion measurements were performed by 4 experienced therapists, who were blinded to the surgeon or the type of implant used. A goniometer was used to measure the
range of motion, as it is a commonly used instrument and has good to excellent reproducibility.\textsuperscript{12-14} The postoperative rehabilitation protocol comprising range of motion exercise, ambulation on flat ground and stair climbing was performed by the therapists. Most patients were discharged on the fourth to fifth postoperative day, and they were subsequently followed up in the orthopaedic and therapists’ outpatient clinics.

FFD was defined as a flexion deformity of 1° or more, while genu recurvatum was defined as a recurvatum deformity of 1° or more.\textsuperscript{9} All other knees (i.e., knees with less than 1° of either flexion or recurvatum deformity) were grouped into neutral extension. We use positive numerals to denote fixed flexion while negative numerals were used to denote genu recurvatum.

We grouped the type of deformity based on the deformity type (i.e., either FFD or genu recurvatum) at 6 months. The 6-month and 2-year clinical scores and range of motion were then compared between the 2 groups. To negate the effects of extreme deformities, knees in fixed flexion or recurvatum greater than 10° at 6 months post-replacement were excluded from the analysis. The remaining subgroup was then analysed.

IBM SPSS ver. 19.0 (IBM Co., Armonk, NY, USA) was used for data analysis. Nonparametric Kruskal-Wallis test was used to compare patient biodata, i.e., age, weight, height, and body mass index (BMI). Nonparametric Mann-Whitney U test was used to compare the degree of knee flexion, Oxford Knee scores, Knee Society knee and function scores, and SF-36 scores.\textsuperscript{15}

\section*{RESULTS}
A total of 5,383 primary total knee arthroplasties were performed between 2004 and 2008. Of these, 4,471 knees (83.1%) were seen at 6 months postsurgery, and from this group, 3,980 knees (73.9%) were followed up at 2 years postsurgery. Thus, 26.1% of the knees did not have a complete follow-up at 6 months and 2 years. These 3,980 knees (3,884 patients, 96 bilateral arthroplasties) were then analysed in our study as they had a 6-month as well as a 2-year follow-up. Of these, 411 knees were excluded from the data analysis due to severe deformities i.e., > 10° at 6 months. The remaining 3,569 primary total knee arthroplasties (3,473 patients, 96 bilateral arthroplasties) were then analysed. Of these, 1,589 knees (44.5%) were in fixed flexion, 1,752 knees (49.1%) were in neutral extension, and 228 knees (6.4%) were in recurvatum at 6 months. This comprised 79.6% of all fixed flexion deformities and 97.4% of all genu recurvatum deformities at 6 months.

The analysis of patient biodata at 6 months is shown in Table 1, which shows that the weight, height and BMI of the patients with postoperative FFD, genu recurvatum, and knee in neutral extension were statistically similar. Although there was a statistical difference in age among the 3 groups, it was not clinically significant.

At 6 months, the FFD group had a mean 5.78° of fixed flexion (standard deviation [SD], 2.57°; range, 1° to 10°). At 2 years, this group of patients had a mean 2.28° of fixed flexion (SD, 4.08°; range, –19° to 30°). At 6 months, the genu recurvatum group had a mean –4.63° of genu recurvatum (SD, 2.14°; range, –1° to –10°). At 2 years, this group of patients had a mean –3.94° of genu recurvatum (SD, 3.93°; range, –17° to 8°).

At 6 months, we found that the genu recurvatum group did better in terms of the degree of knee flexion (mean 118.16°, SD 15.51° vs. mean 111.90°, SD 14.36°) and Oxford Knee scores (mean 19.53°, SD 5.42° vs. mean 20.52°, SD 6.05°) (Table 2). We went on to analyse the 2-year outcomes based on the deformity at 6 months, by comparing the FFD group against the genu recurvatum group (Table 2). We found that knees in genu recurvatum at 6 months, compared to those in fixed flexion, ended up having a better degree of

\begin{table}[h]
\centering
\caption{Biodata of the Study Population at 6 Months after Total Knee Replacement}
\begin{tabular}{|l|c|c|c|c|}
\hline
Variable & Fixed flexion (n = 1,589) & Neutral (n = 1,752) & Recurvatum (n = 228) & p-value \\
\hline
Knee (male:female) & 330:1,259 & 282:1,470 & 34:194 & - \\
\hline
Mean age (yr) & 67.16 & 66.55 & 65.71 & 0.020 \\
\hline
Mean weight (kg) & 66.38 & 67.12 & 65.71 & 1.000 \\
\hline
Mean height (cm) & 155.17 & 154.57 & 153.90 & 1.000 \\
\hline
Mean body mass index (kg/m\textsuperscript{2}) & 27.82 & 28.21 & 27.86 & 1.000 \\
\hline
\end{tabular}
\end{table}
knee flexion at 2 years (mean 120.76°, SD 14.21° vs. mean 115.99°, SD, 14.20°), and this difference was statistically significant.

However, knees with fixed flexion deformities achieved a better knee score at 2 years compared to knees with recurvatum (mean 84.82°, SD 10.91° vs. mean 82.91°, SD 11.16°).

We categorized Knee Society scores (both knee and function) into excellent (80–100), good (70–79), fair (60–69), poor (< 60) based on the study by Asif and Choon and compared the 6-month and 2-year results (Table 3).

Significantly, at 6 months, 74.1% of knees with fixed flexion deformities had excellent function scores (vs. 39.9% of knees with genu recurvatum, \( p < 0.01 \)). Also, 88.9% of knees with fixed flexion deformities had excellent or good function scores (vs. 54.4% of knees with genu recurvatum, \( p < 0.01 \)). At 2 years, 81.0% of knees with fixed flexion deformities had excellent or good knee scores (vs. 67.1% of knees with genu recurvatum, \( p < 0.01 \)).

Fig. 1 shows how the deformities progressed from 6 months to 2 years. The knees either improved i.e., deformity became less pronounced or neutral, remained the same or worsened, i.e., either the deformity became more

### Table 2. Comparison of FFD and Genu Recurvatum of 10° or Less at 6 Months and 2 Years

| Variable                  | FFD 1 to 10 (SD) | Recurvatum –1 to –10 (SD) | \( p \)-value |
|---------------------------|------------------|---------------------------|---------------|
| Degree of flexion (°)     |                  |                           |               |
| 6 Months                  | 111.90 (14.36)   | 118.16 (15.51)*           | 0.000         |
| 2 Years                   | 115.99 (14.20)   | 120.76 (14.21)*           | 0.000         |
| Oxford knee score         |                  |                           |               |
| 6 Months                  | 20.52 (6.05)     | 19.53 (5.42)*             | 0.049         |
| 2 Years                   | 18.68 (5.75)     | 18.78 (5.64)              | 1.000         |
| Function score            |                  |                           |               |
| 6 Months                  | 65.88 (19.25)    | 68.11 (17.08)             | 0.293         |
| 2 Years                   | 70.29 (19.94)    | 72.06 (18.04)             | 0.587         |
| Knee score                |                  |                           |               |
| 6 Months                  | 82.23 (11.45)    | 80.44 (11.97)             | 0.065         |
| 2 Years                   | 84.82 (10.91)*   | 82.91 (11.16)             | 0.032         |
| SF 36-1 (physical function)|                  |                           |               |
| 6 Months                  | 61.36 (21.00)    | 63.93 (18.70)             | 0.249         |
| 2 Years                   | 65.14 (21.24)    | 66.21 (21.13)             | 1.000         |
| SF 36-2 (role function)   |                  |                           |               |
| 6 Months                  | 69.07 (41.80)    | 70.72 (41.92)             | 1.000         |
| 2 Years                   | 75.36 (38.78)    | 77.52 (36.88)             | 1.000         |
| SF 36-3 (bodily pain)     |                  |                           |               |
| 6 Months                  | 65.20 (24.59)    | 66.34 (25.16)             | 1.000         |
| 2 Years                   | 69.57 (25.38)    | 69.82 (25.30)             | 1.000         |
| SF 36-4 (general health)  |                  |                           |               |
| 6 Months                  | 69.92 (20.44)    | 68.30 (19.79)             | 0.775         |
| 2 Years                   | 68.76 (21.04)    | 68.45 (21.97)             | 1.000         |
| SF 36-5 (vitality)        |                  |                           |               |
| 6 Months                  | 70.08 (20.47)    | 70.44 (18.33)             | 1.000         |
| 2 Years                   | 71.32 (19.84)    | 71.84 (19.56)             | 1.000         |
| SF 36-6 (social function) |                  |                           |               |
| 6 Months                  | 83.43 (28.44)    | 87.23 (26.09)             | 0.181         |
| 2 Years                   | 87.92 (26.65)    | 87.66 (26.20)             | 1.000         |
| SF 36-7 (role function)   |                  |                           |               |
| 6 Months                  | 91.02 (26.83)    | 93.27 (22.64)             | 0.686         |
| 2 Years                   | 93.98 (22.43)    | 91.08 (27.16)             | 0.246         |
| SF 36-8 (mental health)   |                  |                           |               |
| 6 Months                  | 80.52 (16.25)    | 80.79 (15.13)             | 1.000         |
| 2 Years                   | 81.99 (15.27)    | 81.46 (15.39)             | 1.000         |

### Table 3. Comparison of the Percentage of Excellent and Excellent/Good Knee & Function Scores at 6 Months and 2 Years

| Variable                  | FFD 1 to 10 (%) | Recurvatum –1 to –10 (%) | \( p \)-value |
|---------------------------|-----------------|---------------------------|---------------|
| Knee score                |                  |                           |               |
| Excellent                 | 6 Months         | 1,178 (74.1)              | 158 (69.3)    | 0.122 |
| 2 Years                   | 1,287 (81.0)*    | 111 (48.7)                | \( < 0.01 \)  |
| Excellent/good            | 6 Months         | 1,413 (88.9)              | 200 (87.7)    | 0.59  |
| 2 Years                   | 1,464 (92.2)*    | 153 (67.1)                | \( < 0.01 \)  |
| Function score            |                  |                           |               |
| Excellent                 | 6 Months         | 1,178 (74.1)*             | 91 (39.9)     | \( < 0.01 \) |
| 2 Years                   | 740 (46.6)       | 111 (48.7)                | 0.55          |
| Excellent/good            | 6 Months         | 1,413 (88.9)              | 124 (54.4)    | \( < 0.01 \) |
| 2 Years                   | 980 (61.7)       | 153 (67.1)                | 0.13          |

FFD: fixed flexion deformity, SD: standard deviation.

*Data indicate statistically significantly better outcomes.
Knees with fixed flexion deformities tended to show an improvement in the deformity over time (70.4%). Knees with recurvatum did not show a similar improvement (50.4%), and the deformity tended to worsen (39.0% vs. 22.0% for fixed flexion).

**DISCUSSION**

The effects of fixed flexion in comparison to those of genu recurvatum post TKA have not been studied in detail. To the best of our knowledge, this is the first article that directly compares post-total knee replacement fixed flexion and genu recurvatum deformities.

We found that at 6 months, a significantly higher proportion of knees with fixed flexion deformities had excellent and excellent/good function scores. Knees with recurvatum deformity, however, did better in the degree of knee flexion and Oxford scores.

However, at 2 years, knees with fixed flexion deformities did better than knees with recurvatum deformity in knee scores and showed a greater improvement in deformity compared to knees with recurvatum deformity. A significantly higher proportion of knees with fixed flexion deformities had excellent and excellent/good knee scores. However, knees with recurvatum deformity continued to have a greater degree of knee flexion.

The finding that recurvatum deformity tends to worsen (39.0%) is also consistent with the study by Siddiqui et al., who found that patients with hyperextension at 6 months are 6.5 times more likely to have recurvatum at 2 years versus those with no hyperextension at 6 months.

Meding et al. concluded that in the absence of neuromuscular disease, hyperextension deformity tends not to recur after total knee replacement and that presence of preoperative genu recurvatum does not preclude a well-functioning total knee replacement. However, neither of these studies compared the results against fixed flexion deformities.

At 6 months, we postulate that the type of deformity is reflective of intraoperative deformity post-replacement (after pain and swelling during the immediate postoperative phase has subsided); thus we performed our comparative analysis based on the deformity at 6 months. Of course, this is only a logical assumption. Thus, lack of a more accurate proxy for intraoperative deformity is a limitation of our study.

By extrapolation, based on the 6 month deformity (i.e., intraoperative deformity), knees with fixed flexion deformities show a better improvement in the degree of deformity as well as a higher knee score at 2 years. A significantly higher proportion of knees with fixed flexion deformities had excellent and excellent/good function scores at 6 months and knee scores at 2 years.

Knees with recurvatum deformity achieved a better range of motion at 6 months and 2 years. Knees with recurvatum deformity also achieved a better Oxford score at 6 months, although due to a score difference of 0.99 and a p-value of 0.049, the clinical significance of this result is doubtful.

Thus, based on the results of this prospective cohort study, we conclude that it is better to err on the side of FFD rather than genu recurvatum if neutral alignment cannot be achieved.

**CONFLICT OF INTEREST**

No potential conflict of interest relevant to this article was reported.
REFERENCES

1. Whiteside LA, Mihalko WM. Surgical procedure for flexion contracture and recurvatum in total knee arthroplasty. Clin Orthop Relat Res. 2002;(404):189-95.

2. Meding JB, Keating EM, Ritter MA, Faris PM, Berend ME. Genu recurvatum in total knee replacement. Clin Orthop Relat Res. 2003;(416):64-7.

3. Scuderi GR, Kochhar T. Management of flexion contracture in total knee arthroplasty. J Arthroplasty. 2007;22(4 Suppl 1):20-4.

4. Krackow KA, Weiss AP. Recurvatum deformity complicating performance of total knee arthroplasty: a brief note. J Bone Joint Surg Am. 1990;72(2):268-71.

5. Lam LO, Swift S, Shakespeare D. Fixed flexion deformity and flexion after knee arthroplasty: what happens in the first 12 months after surgery and can a poor outcome be predicted? Knee. 2003;10(2):181-5.

6. Aderinto J, Brenkel IJ, Chan P. Natural history of fixed flexion deformity following total knee replacement: a prospective five-year study. J Bone Joint Surg Br. 2005;87(7):934-6.

7. Quah C, Swamy G, Lewis J, Kendrew J, Badhe N. Fixed flexion deformity following total knee arthroplasty: a prospective study of the natural history. Knee. 2012;19(5):519-21.

8. Meding JB, Keating EM, Ritter MA, Faris PM, Berend ME. Total knee replacement in patients with genu recurvatum. Clin Orthop Relat Res. 2001;(393):244-9.

9. Siddiqui MM, Yeo SJ, Sivaiah P, Chia SL, Chin PL, Lo NN. Function and quality of life in patients with recurvatum deformity after primary total knee arthroplasty: a review of our joint registry. J Arthroplasty. 2012;27(6):1106-10.

10. Perry J, Antonelli D, Ford W. Analysis of knee-joint forces during flexed-knee stance. J Bone Joint Surg Am. 1975;57(7):961-7.

11. Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br. 1998;80(1):63-9.

12. Lavernia C, D’Apuzzo M, Rossi MD, Lee D. Accuracy of knee range of motion assessment after total knee arthroplasty. J Arthroplasty. 2008;23(6 Suppl 1):85-91.

13. Mayerson NH, Milano RA. Goniometric measurement reliability in physical medicine. Arch Phys Med Rehabil. 1984;65(2):92-4.

14. Edwards JZ, Greene KA, Davis RS, Kovacik MW, Noe DA, Askew MJ. Measuring flexion in knee arthroplasty patients. J Arthroplasty. 2004;19(3):369-72.

15. Petrie A. Statistics in orthopaedic papers. J Bone Joint Surg Br. 2006;88(9):1121-36.

16. Asif S, Choon DS. Midterm results of cemented Press Fit Condylar Sigma total knee arthroplasty system. J Orthop Surg (Hong Kong). 2005;13(3):280-4.

17. Cheng K, Ridley D, Bird J, McLeod G. Patients with flexion deformity after total knee arthroplasty do just as well as those without: ten-year prospective data. Int Orthop. 2010;34(5):663-7.