Research Square

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Correlation between Sagittal Plane Deformities of the Hip and Spinopelvic Alignment in Advanced Hip arthritis patients undergoing Total Hip Arthroplasty: A Prospective Observational Study

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Abstract

Purpose

This study evaluated the relationship between Fixed flexion deformity (FFD), hip range of motion (ROM), and dynamic spinopelvic parameters and identified predictors of early postoperative sacral slope (SS) mobility in patients with advanced hip arthritis undergoing total hip arthroplasty (THA).

Methods

In this prospective study, 45 patients with unilateral hip arthritis and FFD undergoing primary THA were evaluated preoperatively and at three months postoperatively. Clinical assessments included the Thomas test, hip ROM, Harris Hip Score (HHS), and Visual Analogue Scale (VAS) for pain. Radiographic measurements in standing and sitting positions included pelvic incidence, sacral slope, pelvic tilt, ante-inclination (AI), and pelvic–femoral angle. Spinopelvic mobility was defined by the change in sacral slope (ΔSS) between standing and sitting positions.

Results

The mean age was 56.2 years. Mean FFD improved from 16.4° preoperatively to 0° postoperatively, while hip flexion increased from 72.5° to 114.1°. Preoperatively, 11% of patients exhibited a stiff spinopelvic pattern, 63% had normal mobility, and 26% were hypermobile. Following THA, spinopelvic mobility shifted toward a more physiological distribution. Preoperative FFD correlated positively with ΔSS ($r = 0.45$, $p = 0.002$). Regression analysis identified preoperative hip ROM ($\beta = -0.35$) and dynamic AI ($\beta = 0.23$) as significant predictors of postoperative ΔSS.

Conclusion

Correction of FFD through THA improves spinopelvic mobility and promotes pelvic realignment. Preoperative hip ROM and dynamic AI predict early postoperative SS mobility, suggesting that acetabular component positioning based solely on preoperative spinopelvic parameters may not accurately reflect postoperative biomechanics in patients with substantial FFD.

Introduction

Total hip arthroplasty (THA) reliably restores function and relieves pain in patients with advanced hip arthritis (1, 2). In India, the epidemiology of hip pathology further underscores the continued need for effective reconstructive interventions (2, 3). However, optimal outcomes following THA depend not only on implant design and surgical technique but also on accurate component positioning within a

dynamically functioning spine–pelvis–hip complex. Abnormal spinopelvic alignment has been associated with instability, impingement, and dislocation after hip arthroplasty (4, 5).

The concept of hip–spine syndrome, described by Offierski and Macnab, highlighted the interdependence of these regions. Subsequent radiographic studies have characterized key pelvic parameters—pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT) - and their variation with posture (5, 6). More recently, the introduction of ante-inclination (AI) has refined the assessment of functional acetabular orientation during positional changes (7–9). Although prior reports emphasize the importance of dynamic spinopelvic evaluation in THA planning (10–11), prospective data specifically addressing patients with clinical fixed flexion deformity (FFD) remain limited.

In patients with FFD, compensatory pelvic adaptations may develop preoperatively and partially reverse following hip arthroplasty. As a result, acetabular component orientation based solely on preoperative spinopelvic measurements may not accurately reflect the postoperative functional state (10–13). We therefore conducted a prospective study to quantify spinopelvic changes following THA in patients with FFD, examine clinical–radiological associations, and develop a predictive model for postoperative SS.

Methods

This prospective observational study was conducted at a tertiary-care university hospital after Institutional Ethics Committee approval. Consecutive patients providing written informed consent were enrolled according to predefined criteria.

45 patients undergoing primary unilateral THA for advanced hip arthritis with clinical fixed flexion deformity (FFD) were included. Indications comprised primary or secondary osteoarthritis, healed tubercular or infective sequelae, and Crowe type I–II dysplasia with FFD. Exclusion criteria included prior hip arthroplasty or arthrodesis, previous spinal fusion, advanced tubercular subluxation/dislocation, limb shortening > 4 cm, and Crowe type III–IV dysplasia.

Preoperative assessment documented the hip FFD using the Thomas test (goniometer) and hip range of motion (ROM). Functional outcomes were recorded using the visual analogue scale (VAS) and Harris Hip Score (HHS). Evaluations were repeated at three months.

Standardized lateral radiographs (L3 to proximal femur) and anteroposterior pelvis views were obtained in standing and sitting positions preoperatively and at three months. PI, PT, SS, AI, and pelvic–femoral angle (PFA) were measured (Fig. 1).

Spinopelvic mobility was categorized by ΔSS (standing SS − sitting SS): stiff < 10°, normal 10–30°, hypermobile > 30° (7–9). All THAs were performed via a standard lateral approach. No Iliopsoas release was done in any case. Acetabular components were positioned within the Lewinnek safe zone (40–45° inclination; 15–20° anteversion) (14). Early mobilization and structured physiotherapy commenced on postoperative day one.

Data were analyzed using SPSS v26. Parametric and nonparametric tests were applied as appropriate. Correlations were assessed using Pearson or Kendall-tau methods. Multiple linear regression evaluated predictors of postoperative ΔSS. Significance was set at p value < 0.05.

Results

45 patients (26 females + 19 males) were included in the study. Table 1 contains the various etiologies present in the study population and the demographic details.

Table 1
Demographic and clinical characteristics of the study population

Parameters	Mean ± SD	Range	95% Confidence intervals
Age (Years)	56.2 ± 11.3	34–78	52.8–59.6
Body mass index (BMI) (kg/m²)	28.3 ± 4.1	21.7–33.4	25.4–30.7
Duration of symptoms (Months)	29.3 ± 19.8	5–84	11.8–36.7
Side of involvement	27 right + 18 left		
Etiology	Advanced arthritis following osteonecrosis of femoral head	21 patients	
	Inflammatory arthritis	13 patients	
	Healed tubercular arthritis	4 patients	
	Sequelae of infective arthritis	3 patients	
	Dysplasia with advanced arthritis	3 patients	

Clinical outcomes

Mean FFD improved from 16.4° (range 5–38°) preoperatively to complete correction postoperatively. Hip flexion increased from 72.5° (95% CI 68.1–76.9) to 114.1° (95% CI 111.2–117.0). The mean preoperative VAS score was 7.96 which improved to 1.24 postoperatively ($p < 0.001$). The Harris hip score improved from a preoperative mean of 48.1 to 90.1 postoperatively ($p < 0.001$).

Spinopelvic parameter changes

Preoperatively, mean standing SS was 40.5°, while sitting SS was 16.7°, yielding mean ΔSS of 23.9°. Postoperatively, mean standing SS decreased slightly to 38.8° and mean sitting SS increased slightly to 18.4°, with mean ΔSS reducing to 20.9°. PT and AI showed corresponding postural adjustments. PI

remained constant overall (54.2° ± 6.4°). Spinopelvic mobility distribution shifted towards normalization: preoperatively 11% stiff, 63% normal, 26% hypermobile; postoperatively 11% stiff, 76% normal, 13% hypermobile (Fig. 2).

Subgroup Analysis by Mobility group

Preoperative standing PFA differed significantly across mobility groups, with median values of 160.8° in the hypermobile group and 172.9° in the stiff group (*p = 0.01*). Preoperative sitting PFA also showed significant variation among groups (*p = 0.02*) (Table 2; Fig. 3 & Fig. 4). Postoperatively, PFA values converged across groups, suggesting restoration of normal pelvic–hip biomechanics following correction of FFD. These findings indicate that recovery of hip ROM after THA leads to normalization of compensatory spinopelvic adaptations. Apparent preoperative hypermobility often reflects hip-driven compensatory pelvic motion.

Table 2
Comparison of preoperative and postoperative AI & PFA across spinopelvic mobility groups

Parameters	**Median**			**p value**
	Hypermobile	**Stiff**	**Normal**	
Preoperative AI standing	28.3°	41.2°	31.3°	0.07
Preoperative AI sitting	61.8°	50.7°	53.7°	0.06
Preoperative PFA standing	160.8°	172.9°	170.2°	*0.01*
Preoperative PFA sitting	136.6°	120.1°	126.1°	*0.02*
Postoperative AI standing	31.2°	27.9°	31.7°	0.10
Postoperative AI sitting	56.6°	48.3°	50.6°	*0.04*
Postoperative PFA standing	180.9°	181.5°	186.3°	0.70
Postoperative PFA sitting	131.2°	118.0°	127.9°	0.10

Clinical–radiological associations

Clinical FFD correlated positively with preoperative ΔSS (*r = 0.45, p = 0.002*) (Fig. 5) and negatively with standing pelvic–femoral angle (PFA) (*r = − 0.61, p < 0.001*) (Table 3). Reduced preoperative ROM was associated with larger preoperative ΔSS (*r = − 0.33, p = 0.02*). These findings suggest that postoperatively PFA values converged across mobility groups, indicating normalization of spinopelvic mechanics after correction of hip FFD.

Table 3
Correlation between spinopelvic parameters and hip FFD or Range of flexion (ROF)

Preop change in SS	**Clinical FFD by Thomas test**	**Preop PFA standing**	**Preop ROF**	**Postop ROF**
	r = 0.45, p = 0.002	***r = -0.48, p = 0.001***	***r = -0.33, p = 0.02***	**r = -0.22, p = 0.14**
Postop change in SS	*r = 0.32, p = 0.029*	*r = -0.45, p = 0.002*	*r = -0.46, p = 0.001*	r = -0.20, p = 0.06
Postop Standing PFA	*r = -0.60, p < 0.001*	r = 0.15, p = 0.14	r = 0.28, p = 0.06	*r = 0.36, p = 0.01*
Postop Sitting PFA	r = 0.26, p = 0.09	r = -0.06, p = 0.56	r = -0.15, p = 0.33	*r = -0.40, p = 0.005*
Postop Standing AI	r = 0.09, p = 0.55	r = -0.02, p = 0.80	r = 0.08, p = 0.54	r = -0.06, p = 0.69
Postop Sitting AI	r = 0.15, p = 0.33	r = -0.13, p = 0.38	r = 0.05, p = 0.74	r = -0.19, p = 0.20

Predictive model

Multiple linear regression identified preoperative hip ROM (β ≈ -0.35) and preoperative ΔAI (β ≈ 0.23) as independent contributors to postoperative ΔSS (Table 4). Greater hip ROM predicted smaller postoperative ΔSS, whereas larger dynamic ΔAI predicted greater postoperative ΔSS. The model explained approximately 30% of variance ($R^2 \approx 0.30$). Neither predictor reached statistical significance, likely due to limited sample size.

Table 4
Results of linear regression

	R^2	adjusted R^2	beta	t score	p value
Preoperative ROM	0.30	0.27	-0.35	-2.62	0.12
Preoperative change in AI (Sitting-standing)			0.31	2.30	0.23

Discussion

This prospective study demonstrates that THA in patients with advanced hip arthritis and FFD results in significant clinical improvement alongside measurable changes in spinopelvic mechanics. Correction of FFD was associated with substantial gains in ROM, pain relief, and functional recovery. Greater preoperative FFD and restricted hip motion correlated with larger preoperative changes in sacral slope (ΔSS) and altered PFA, suggesting that apparent spinopelvic hypermobility is often a compensatory response to hip contracture. Following THA, spinopelvic mobility patterns converged across subgroups, indicating reduced reliance on pelvic compensation after restoration of hip motion.

These findings have important implications for acetabular component planning. Dynamic spinopelvic assessment has been emphasized in prior literature (5–11), and abnormal alignment has been linked to instability and impingement (10–13). Our results suggest that reliance on static preoperative spinopelvic parameters in patients with significant hip FFD may be misleading, as pelvic alignment frequently readjusts after deformity correction. Consequently, component positioning based solely on preoperative measurements may not accurately reflect the postoperative functional state.

The predictive model incorporating preoperative hip ROM and dynamic ante-inclination (ΔAI) provides a clinically meaningful framework for anticipating postoperative ΔSS. While the model demonstrated biologically plausible and directionally consistent associations, the predictors did not reach statistical significance, most likely due to the limited sample size. Nonetheless, the observed trends suggest that restricted preoperative motion and greater dynamic acetabular adaptation may influence postoperative spinopelvic behavior. Further studies with larger cohorts are required to validate and refine this predictive model.

Our findings are consistent with previous reports demonstrating that spinopelvic parameters may evolve after THA and influence functional acetabular orientation (15–18). However, unlike patients with intrinsic spinal stiffness or prior lumbar fusion—where compensatory mechanisms may persist (19–21)—the hypermobility observed in this cohort appeared predominantly hip-driven and reversible following correction of deformity.

The strengths of this study include its prospective design and standardized radiographic assessment in both standing and sitting positions. Limitations include a modest sample size and short-term follow-up.

In conclusion, FFD-related spinopelvic hypermobility appears largely compensatory and reversible following THA. The proposed predictive model highlights the potential role of preoperative range of motion and dynamic AI in anticipating postoperative pelvic realignment. Preoperative planning should therefore account for these dynamic changes, particularly in patients with significant contracture, to optimize functional cup positioning and minimize instability risk.

Conclusion

In this prospective study, THA in patients with advanced hip arthritis and FFD resulted in marked clinical improvement and normalization of spinopelvic mobility in most cases. Preoperative hip ROM and dynamic ante-inclination (AI_sitting_preop − AI_standing_preop) were associated with postoperative sacral slope behavior and informed a predictive model for ΔSS. Many patients categorized as hypermobile preoperatively (7–9) demonstrated postoperative normalization, indicating that hypermobility was often hip-driven and compensatory. Planning acetabular orientation solely on preoperative spinopelvic parameters may therefore be misleading, and dual mobility bearings should be reserved for patients with fixed spinal pathology.

Declarations

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Competing Interests: The authors have no relevant financial or non-financial interests to disclose.

Ethical Approval: This study was performed in line with the principles of the Declaration of Helsinki. The institutional ethical clearance was taken for the study and paper publication.

Consent to participate: Written and informed consent was obtained from patients before enrolment.

Consent to publish: The authors affirm that human research participants provided informed consent for the publication of the images.

Author Contribution

S.P., R.B.K, U.C., Q.A. - Conceptualisation and Project administrationS.P., A.C., A.G. - Data curation, Formal analysis, Original draft preparationA.C., A.G. - Review & EditingS.S., A.M. - Tables & Figures, ResourcesAll authors reviewed the manuscript.

Data Availability

The reserach data generated during the study is availabe on request from the corresponding author.

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Figures

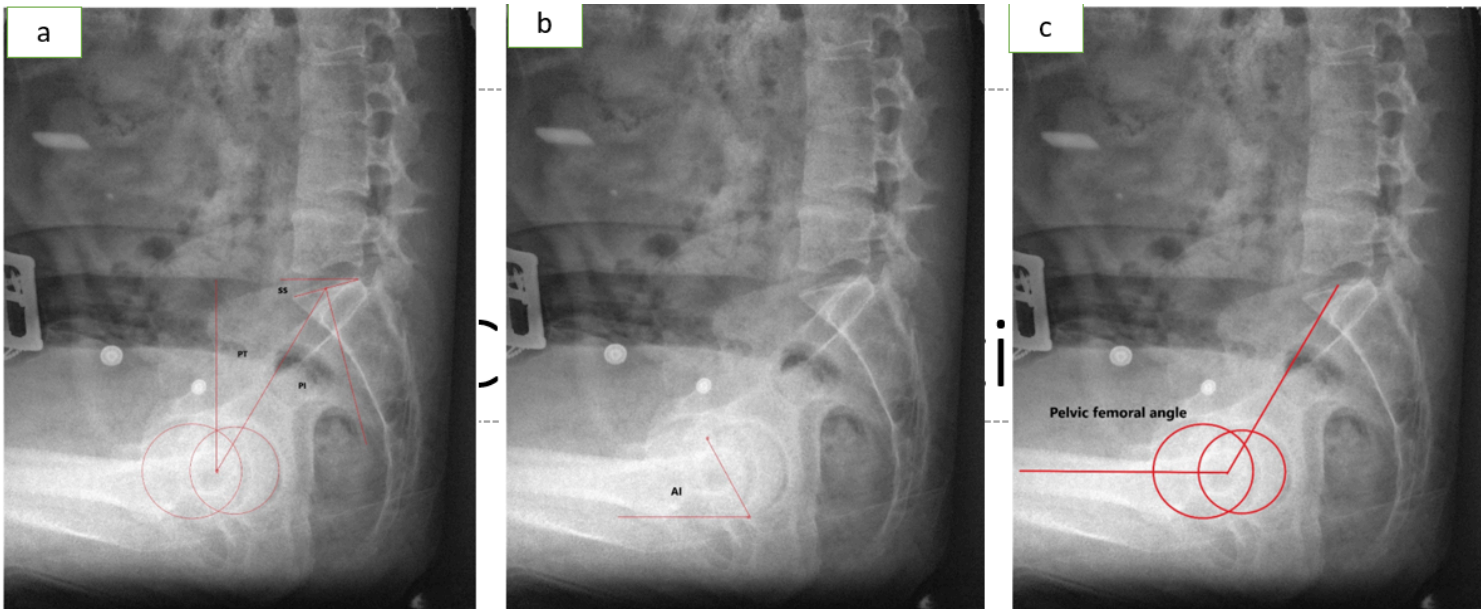


Figure 1

(a) Depicts the measurements of Pelvic incidence (PI), Pelvic tilt (PT), and Sacral slope (SS); (b) Depicts the measurement of Ante-inclination (AI); (c) Depicts the measurement of Pelvic-femoral angle (PFA)

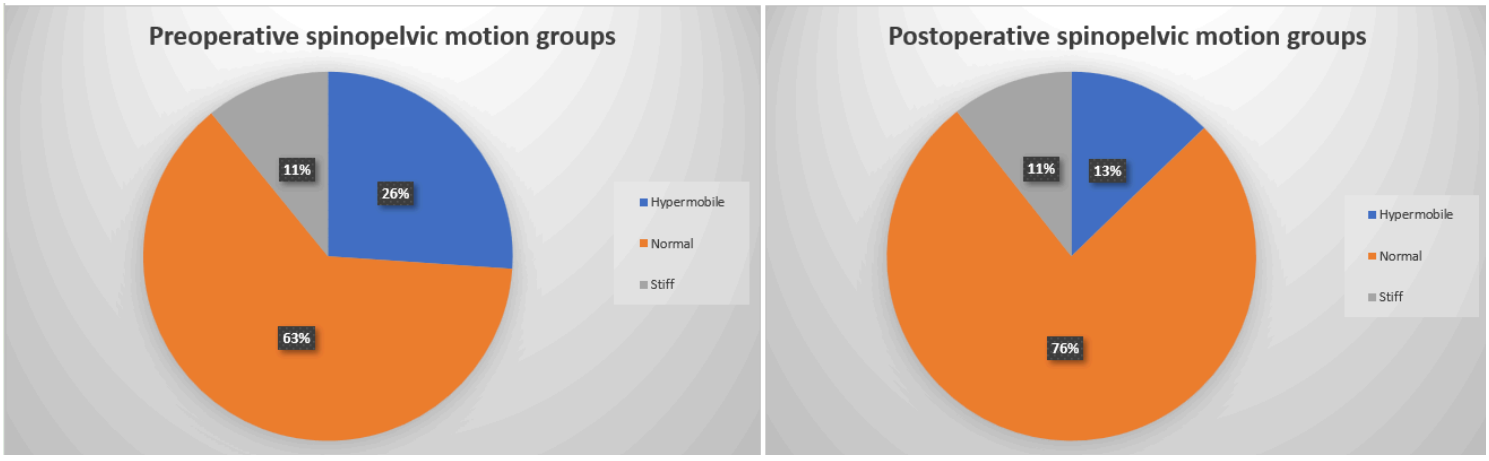


Figure 2

Distribution of preoperative and postoperative spinopelvic motion groups

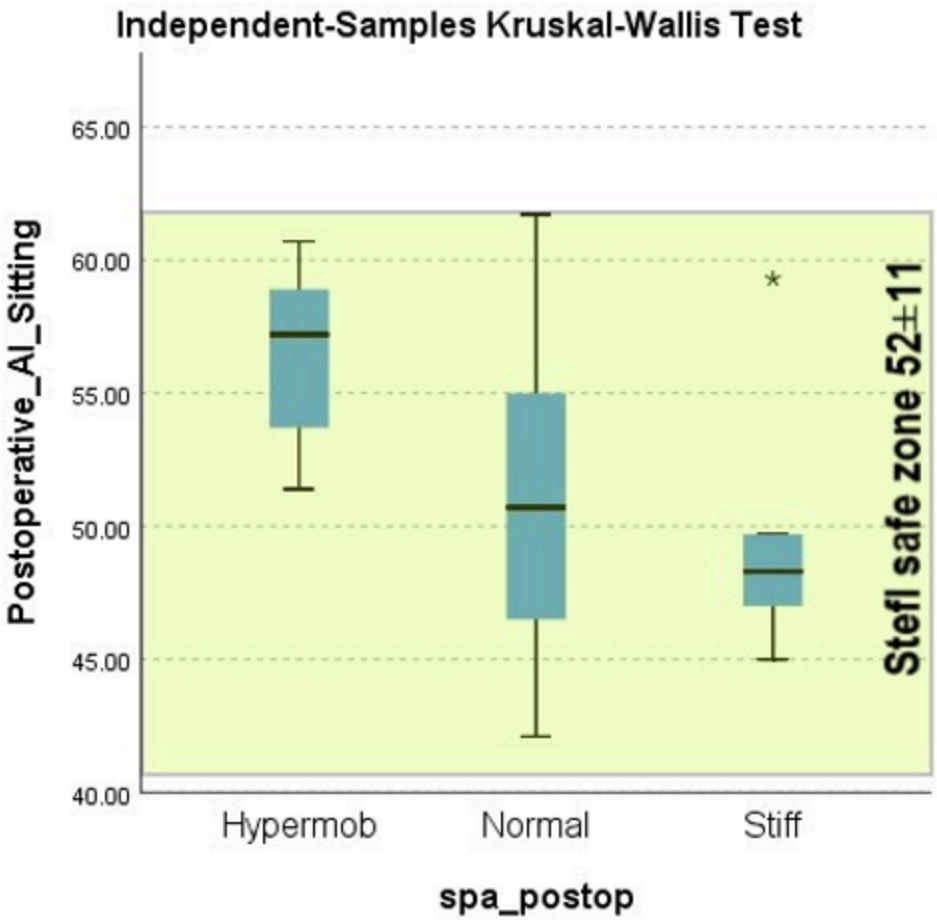


Figure 3

Distribution of sitting postoperative ante-inclination in hypermobile, normal, and stiff groups. There was a significant difference (*p=0.04*) in postoperative sittingante-inclination betweenthegroups.

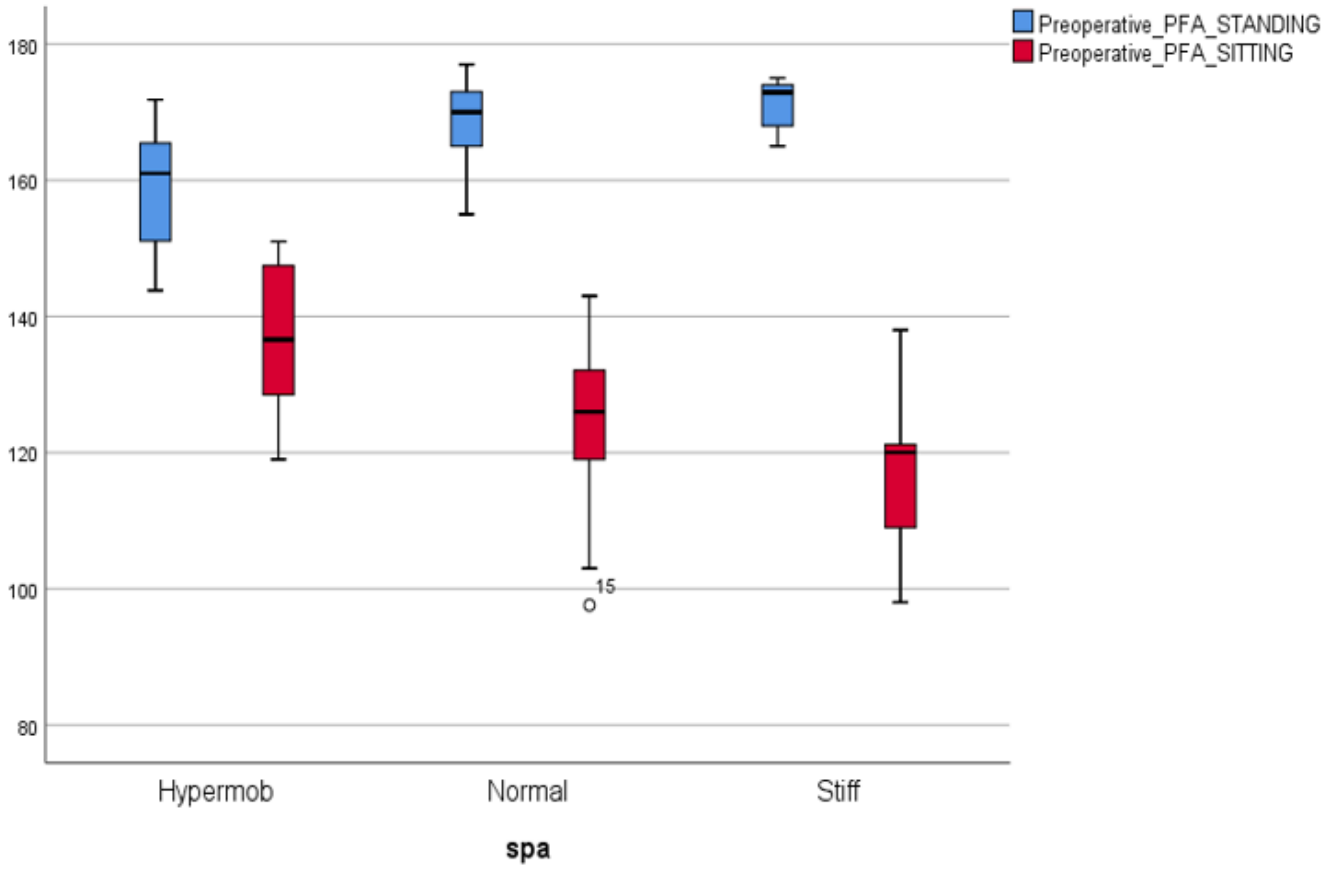


Figure 4

Distribution of standing preoperative pelvic-femoral angle (in blue) and sitting preoperative pelvic-femoral angle (in red) in hypermobile, normal, and stiff groups. There was a significant difference in preoperative ante-inclination between thegroups which is evident by the widespread medians in the chart.

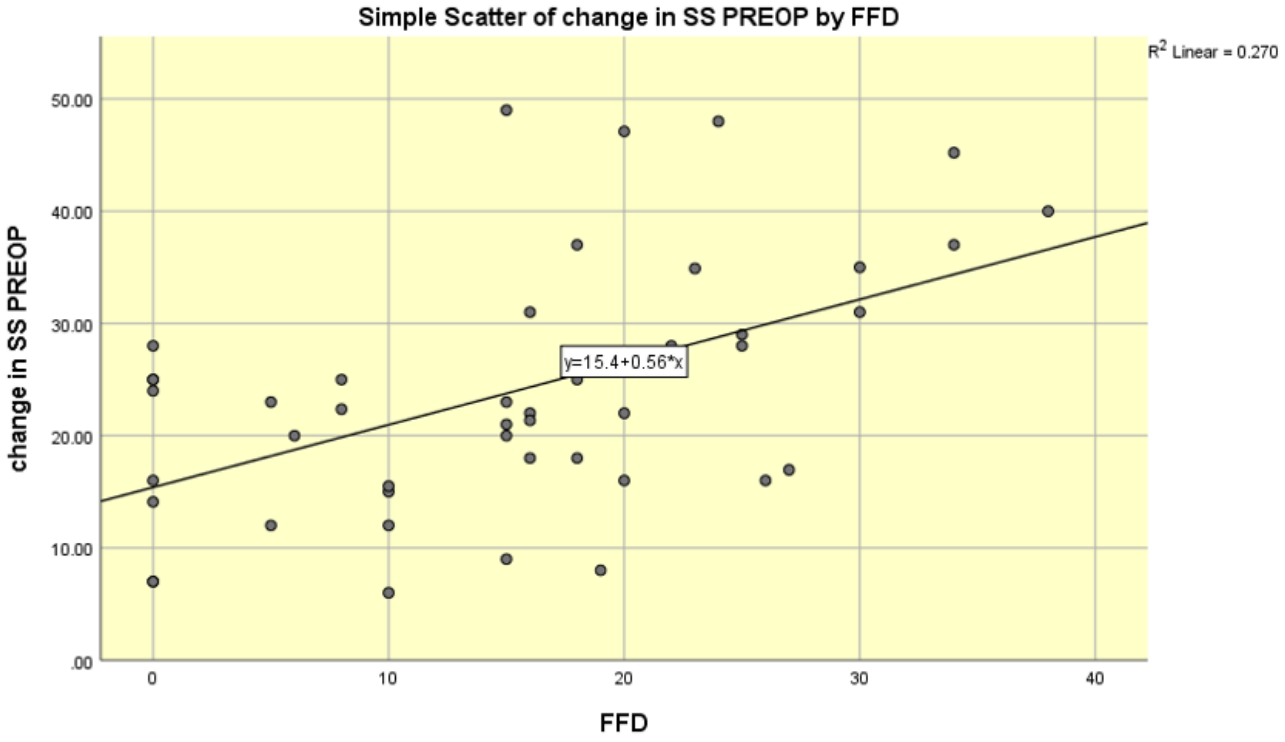


Figure 5

Scatter plot demonstrating a strong positive correlation between change in preoperative SS and clinically measured FFD