RANDOMIZED CONTROLLED TRIAL COMPARING THE SHORT COLLUM FEMORIS PROSTHESIS WITH THE CORAIL PROSTHESIS: PRELIMINARY RESULTS

Liesbeth Klein[1], Goran Puretic MD[2], Mazziar Mohaddes PhD[2], Prof. Johan Kärrholm PhD[2]

[1]Master Student Medicine, Radboud University Medical Center, Nijmegen, the Netherlands
[2]University of Gothenburg, Sahlgrenska Academy, Institute of Clinical Science, Department of Orthopaedics, Sweden

ABSTRACT

Randomized Controlled Trial

BACKGROUND: A femoral neck preserving hip replacement is intended for the young and active patients. By preserving proximal bone load, the transmission to the proximal femur is supposed to improve and future revision surgery would be facilitated. We speculated that a more conservative resection of the femoral neck could lead to better clinical outcomes compared to a conventional resection. We therefore compared clinical- and the fixation associated outcomes with the use of a short stem with the outcomes associated with the use of a classic design.
METHODS: 83 patients were included in our randomized controlled trial. Patients either received a Collum Femoris Preserving (CFP) stem or a classic stem (Corail). Clinical outcomes were assessed using several validated scoring systems and stem fixation was determined by studying plain radiographs and using radiostereometric analysis. Follow-up took place after one year.
RESULTS: The clinical outcomes for both groups improved after surgery. The Harris Hip score increased from 52 to 93 in the CFP group and from 52 to 98 in the Corail group ($p < 0.01$). After one year the clinical outcomes (Oxford Hip Score, Harris Hip Score, EQ-VAS, satisfaction VAS and pain VAS) did not differ between the two groups ($p = 0.05 – 1.00$). The magnitude of the stem migration, measured by radiostereometric analysis, was similar in both groups ($p = 0.12$-0.33). The migration pattern however, differed. None of the hips were revised within the first year.
CONCLUSION: Both the clinical and fixation associated outcomes in both groups were good to excellent after one year. In the short time perspective we could not find any difference in clinical outcomes and stem fixation, indicating that there are no obvious advantages to the use of the CFP stem. Long-term follow-up is necessary to determine if the bone preservation associated with use of CFP prosthesis will ease future revision.

KEY WORDS: Collum Femoris Preserving, short stem, surgery, orthopedics

Introduction

It has been estimated that in 2030 the demand for revision surgery for hip replacements will increase by 31% in England [1] and 137% in the United States [2], mostly due to the increased life expectancy and the use of primary hip replacement surgery in younger patients. The stems used most frequently in primary hip replacement surgery have a stem length which could jeopardize future stem removal, should any late infection or instability occur. The concept of femoral neck preserving hip replacement with the use of a short stem was introduced for young and active patients as they, partly as a result of their longer life expectancy, have a higher risk of revision due to aseptic loosening. Preserving the femoral neck could ease future revision due to the higher cervical osteotomy and the more proximal physiological load distribution to the femur. It could also lead to better bone ingrowth due to conservation of the circumflex artery branches.

The Collum Femoris Preserving (CFP) stem was introduced by Pipino and Calderale in the eighties [3] and has been evaluated in multiple studies [4-11]. So far, the clinical documentation of the CFP stem indicates a stable fixation and good short- and intermediate-term results in terms of clinical outcome and durability [4-11]. We speculated that a more conservative resection of the femoral neck, associated with using the CFP stem, would lead to better clinical outcomes compared to a conventional resection, associated with the use of a conventional stem. Therefore we initiated a randomized controlled trial to compare the preserving CFP stem with the conventional Corail stem. Our primary aim was to compare the clinical outcomes between the groups. As a secondary outcome, the difference in fixation between the two prostheses was analysed using radiostereometric analysis (RSA).

Methods

Study Design

We conducted a randomized controlled trial at the Sahlgrenska University Hospital in Mölndal, Sweden. We included 83 patients with a painful hip and radiological evidence of osteoarthritis who were eligible for primary hip arthroplasty. Inclusion criteria were age between 35 and 75 years and hip anatomy suitable for both designs according to preoperative planning. Exclusion criteria were previous treatment with cortisone and low expected activity rate due to other diseases such as generalized joint disease. Patients were recruited between May 2012 and May 2014. 83 patients were randomly divided into two groups, using envelopes which were opened just before surgery. At the time of writing, all patients have been followed for one year. The study was approved by the ethical committee (DNR;243-12). Informed consent was obtained from all patients.

Implants and surgical procedure

The CFP stem (LINK, Germany) is a short, cementless, neck preserving stem. A left and a right CFP stem has been developed and those are available in six sizes with two different stem curvatures and with or without calcium phosphate (HX) coating. Only coated stems were used. The Corail stem (DePuy Synthes, USA) is a conventional, uncemented, hydroxyapatite-coated straight stem. It is available in 11 sizes and is widely used in Sweden. All patients received an uncemented cup (Delta TT or Delta-ONE-TT, LIMA, Italy). Surgery was performed between May 2012 and May 2015 by 14 surgeons. Two of the authors performed over half of the CFP surgeries. All patients were operated using a direct lateral approach with the patient in the lateral decubitus position. Full weight bearing was encouraged directly postoperatively.

Clinical outcome measures
Clinical parameters were measured using different questionnaires. The Oxford Hip Score (OHS), Harris Hip Score (HHS) and University of Los Angeles California Activity Scale (UCLA) were conducted pre-operatively and after 12 months. Quality of life was determined by using the SF-36, EQ-5D and EQ-5D-VAS, which we expanded with a visual analogue scale (VAS) for pain and satisfaction. The Swedish EQ-5D contains an additional question in which patients value their general health in comparison with the last 12 months. This question is scored separately and is not included in the EQ-5D scoring tool. These scores were determined pre-operatively and after 3 and 12 months. All questionnaires used were in Swedish. The EQ-5D was scored according to the new Swedish tariffs. The UCLA questionnaire was scored using the English scoring tool.

Radiography
Post-operatively and after 12 months, standard pelvic, anteroposterior (AP) and lateral radiographs were obtained. We used these radiographs to determine the length of the remaining femoral neck, the inclination-angle of the cup and the position of the tip of the stem in the femoral canal. The remaining neck was measured from the middle of the lesser trochanter to the proximal calcar, the position of the tip was expressed in a ratio (figure 1). Radiolucent lines around stem, which could indicate loosening, were determined according to the method of Gruen [12]. This method divides the perimeter of the stem into 7 zones on the frontal view and into 7 zones on the lateral view. To determine radiolucency around the cup we used the DeLee and Charnley method [13].

Radiostereometric analysis (RSA)
During surgery, 0.8 mm tantalum markers were placed in the femur and acetabulum bone. The Delta cup liner was marked at the time of operation with 5-10 markers. Uniplanar radiographs were taken 2 (range 0-5) days after surgery, using two detectors with an angle of 40° between the x-ray tubes and a cage 77. The post-operative RSA examination was performed after a median of 2 days (range 1-20). Follow-up investigations were performed 3, 6 and 12 months after the operation. To determine the precision of the RSA measurements we conducted double examinations post-operatively of 76 hips and calculated the 99% prediction interval of the precision based on presumption of zero motion between repeated exposures.

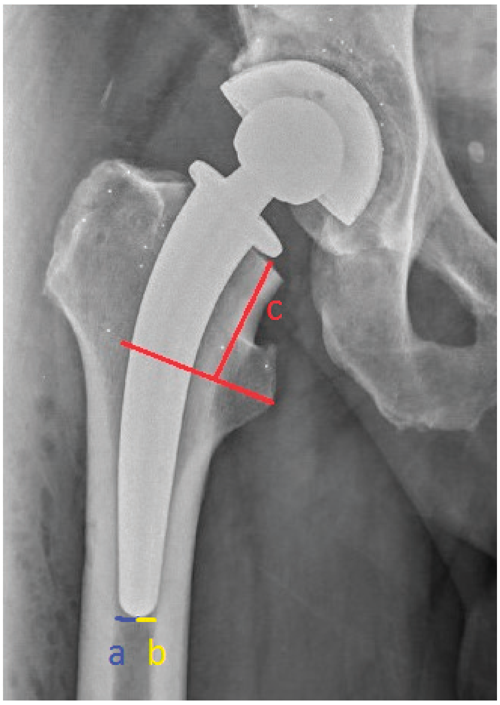

Figure 1: *Method of measuring the remaining neck (c) and the position of tip of the stem. We measured the distance between the tip of the stem and the inner cortex and calculated the ratio between these distances. Ratio between lateral and medial distance is a/b.*

The analysis of movement of the stem and cup was performed using the UMRSA analysis software 6.0 (RSA Biomedical, Umeå, Sweden). Only the center of the femoral head was used to measure translations of the stem, so stem rotations could not be analysed. Translations of the cup were analysed using both marker-based and model-based RSA analysis. Rotations of the cup could only be determined when using marker-based analysis. The mean error of rigid body fitting was accepted was 0.35.

Statistical analysis
The primary outcome of this study was the Oxford Hip Score. The secondary outcome was stem migration measured with RSA. A power analysis indicated that 30 patients in each group would give us the possibility to detect a difference of 4 points on the OHS between the groups with a power of 80%. All outcomes were analysed using IBM SPSS Statistics 23 (IBM SPSS New York, United States). Clinical data did not follow a normal distribution, therefore we used the Mann-Whitney test to compare the clinical outcomes between the Corail and CFP group. P-values less than 0.05 were regarded to represent a significant difference.

Results

41 patients received a CFP, 42 patients received a Corail prosthesis. The characteristics of the groups were comparable at baseline (table 1). There was no significant difference in amount of male and female patients (p=0.94). The majority of patients were diagnosed with primary osteoarthritis (91.6%) the rest of the patients had secondary osteoarthritis due to dysplasia (6.1%), idiopathic femoral head necrosis (1.2%) or trauma (1.2%). One patient dropped-out before surgery because of an unknown reason.

Clinical outcomes
No significant differences were found between the two groups after 3 months in the different questionnaires, except for the additional question in the EQ-5D questionnaire. 83.3% of the patients with a Corail stem valued their general health at the time of measurement to be better than the last 12 months compared to 63.4% with a CFP stem ($p = 0.04$). This result in favor of the Corail stem persisted after one year (table 2). After one year all clinical outcomes improved significantly compared to the pre-operatively measurements (table 2). For example the HHS improved from 52 to 92 in the CFP group and from 52 to 98 in the Corail group ($p < 0.01$). We found no other significant differences between the two groups. The analysis of the EQ-5D and SF-36 is pending.

Radiographic outcomes
The post-operative radiographs showed a mean neck preservation of 37 mm (SD 5.4) in patients with a CFP stem, compared to 28 mm (SD 5.4) in the Corail group (pc< 0.01). In both groups, the length of the remaining neck decreased in the first year (CFP group to 35 mm, the Corail group to 27 mm, $p < 0.01$ and 0.02).

The mean angle of inclination of the cup, in the total study population was 39 degrees (range 23-59) postoperatively. The lateral-medial ratio of the position of the tip after one year was 0.96 in the CFP group and 0.73 in the Corail group ($p = 0.02$). The anterior-posterior ratio of the tip was 1.30 after 1 year in the CFP group and 1.37 in the Corail group ($p = 0.33$).

Table 1: *Patient characteristics and baseline clinical measurements*

	CFP			Corail	
	Mean	95%-CI of the mean	Mean	95%-CI of the mean	*p*-value
Age in years	**58**	55 – 61	**58**	56 – 61	**0.72**
Harris Hip Score	**52**	47 – 58	**52**	46 – 58	**0.82**
Oxford Hip Score	**22**	19 – 25	**21**	18 – 23	**0.57**
EQ-VAS	**60**	52 – 68	**55**	47 – 62	**0.36**
Pain VAS	**65**	60 – 70	**63**	53 – 68	**0.58**
UCLA score*	**4**		**4**		**0.54**
General health**	**2/14/22 (3)**			**0/12/28 (2)**	**0.21**

**UCLA-score is in median and range*
***Number of patients that valued their general health as better / the same / worse than the last 12 months (missing answers)*
EQ-5D and SF-36 are not presented due to difficulties with the converting values

Table 2: *Clinical outcomes after one year*

		CFP	Corail	
		Mean (95%-CI of the mean)	Mean (95%-CI of the mean)	*p*-value
Harris Hip score (0-100)	*after 1 year*	**92** (88 – 96)	**98** (97 – 99)	**0.05**
	delta 0-12 m	**40** (31 – 49)	**45** (39 – 51)	**0.52**
Oxford Hip score (0-48)	*after 1 year*	**41** (39 – 44)	**43** (42 – 45)	**0.64**
	delta 0-12 m	**20** (17 – 23)	**23** (20 – 25)	**0.15**
EQ-VAS (0-100)	*after 1 year*	**78** (72 – 85)	**81** (77 – 85)	**0.87**
	delta 0-12 m	**17** (8 – 26)	**27** (18 – 35)	**0.14**
Pain VAS (0-100)	*after 1 year*	**13** (8 – 19)	**11** (7 – 15)	**0.97**
	delta 0-12 m	**-52** (-59 – -45)	**-52** (-58 – -46)	**0.81**
Satisfaction VAS (0-100)	*after 1 year*	**80** (73 – 88)	**88** (83 – 93)	**0.17**
	delta 3-12 m	**0.4** (-9 – 10)	**1.5** (-4 – 7)	**0.84**
UCLA-activity score (0-10)	*after 1 year**	**6** (2 – 10)	**6** (2 – 10)	**0.89**
	*delta 0-12 m**	**1** (-3 – 7)	**2** (-7 – 6)	**0.93**
General health	*after 1 year***	**28/8/3** (2)	**36/3/1** (2)	**0.04**
	*delta 0-12 m**	**-1** (-2 – 1)	**-2** (-2 – 0)	**0.02**

** Score is in median and range*
*** Number of patients that valued their general health as better / the same / worse than the last 12 months (missing answers)*

Table 3: *Mean translation of the center of the femoral head in milimeters at one year*

	CFP		Corail		
	Mean	Range	Mean	Range	*p*-value
Medial (+) – lateral (-) translation	**0.35**	-0.27 – 1.88	**0.27**	-0.76 – 3.76	**0.40**
Proximal (+) – distal (-) translation	**-0.51**	-6.59 – 0.30	**-0.48**	-5.37 – 0.32	**0.27**
Anterior (+) – posterior (-) translation	**-0.07**	-1.67 – 2.33	**-0.76**	-13.91 – 0.74	**0.02**

There was a significant change in lateral-medial ratio between the postoperative ratio and the ratio after 1 year in the Corail group (0.88 to 0.73, p<0.001), meaning the tip moved more lateral. No significant changes were seen over time in the CFP group.

Seven Corail stems showed radiolucent lines at one year follow-up in Gruen zones 1, 7 and 8. Less than 15% of the stem-bone interface was involved. Four CFP stems showed radiolucency in Gruen zones 1, 2 and 8 (8-31% of the interface). Postoperative radiographs showed radiolucent lines around the cup in 45% of the hips (range 1-74%) of the total study group. At one year follow-up, the radiolucent lines had disappeared in 20 hips, decreased with 4-37% in 4 hips and increased with 1-55% in 15 hips. None of the cups had been revised at the one year follow-up.

RSA results
The medial-lateral, proximal-distal and anterior-posterior translation could be measured with a precision of 0.18, 0.18 and 0.45 mm respectively. RSA analysis regarding the stem was performed in 81 patients. One patient had unstable bone markers. RSA analysis regarding the cup was performed in 78 patients due to poor bone marking in four patients.

After one year, the mean proximal-distal translation of the center of the femoral head was similar in both groups (p=0.27). The femoral head center showed a mean medial translation in both groups during the first year (table 3). Looking at the movement along the anterior-posterior axis, the Corail stem showed an increased mean posterior displacement compared to the CFP stem (p=0.02). However, taking out the vector of the movement, the mean absolute movement in the anterior-posterior direction (0.41 mm in the CFP group and 0.58 mm in the Corail group) did not differ (p=0.12). This indicates that the CFP stem moved both posterior and anterior (figure 2).

Separate evaluation of each individual stem revealed that translations below the detection level along any of the 3 axes postoperatively to one year were measured in 8 (19.5%) patients in the CFP group and 13 (33.3%) patients in the Corail group. 19 (47.86%) patients in the CFP group and 19 (48.76%) patients in the Corail group only showed movement during the first 6 months. 13 (32.6%) of the patients in the CFP group and 7 (17.9%) in the Corail group had detectable movements between 6 months and 1 year. One patient was not examined at 6 months due to unknown reason. The individual evaluation didn't reveal any significant differences between the two groups.

RSA analysis regarding the cup was performed in 78 patients due to poor bone marking in four patients. Analysis of the movement of the cups at one year showed no differences between the groups (table 4).

Revisions and complications
One patient who received a Corail stem had an intraoperative fissure which was treated with cerclage wires. Within the one year prospective there were no dislocations or infections.

Conclusion

The clinical outcomes were considered good to excellent after one year, with no significant difference between the groups. The magnitude of the stem migration was similar in both groups, but the pattern of stem migration differed. The femoral head center of the Corail stems was more frequently displaced posteriorly whereas the CFP stems showed a more equal distribution between anterior and posterior displacement. From a clinical perspective the use of a short stem and allowing preservation of the femoral neck did not result in better short-term clinical outcomes than the use of a conventional stem.

Discussion

Previous reports regarding the CFP stem showed good short- and mid-term results [4-11]. Whether the CFP stem improves the outcome in terms of hip function and patient satisfaction compared to a conventional stem, has not been investigated in previous studies. This has been investigated for an ultra-short stem. Thomaszeweski compared the clinical outcomes of patients with an ultra-short stem (Proxima) with a control group who received a classic design. He concluded that patients in the Proxima group had a better clinical status and a greater quality of life [14].

Although our findings indicate improved clinical outcomes, however we did not find any evidence that the patients in the CFP group had better outcomes in terms of hip function nor patient satisfaction.

We note several limitations. First, the follow-up time was limited to one year and even though the data of the RSA looks quite promising, several stems showed migration up to one year. Two of these stems proceeded to clinical loosening but it requires 2 year data on the entire cohort to make any more definite conclusions. Also, a follow-up of several years is necessary to draw conclusions about long-term function. Second, multiple surgeons operated patients included in our study. The CFP stem was implanted by 11 different surgeons, meaning some of them only inserted a few CFP stems. In these cases they were assisted by more experienced colleagues. Since the Corail stem is often used, all surgeons are experienced in the use of the Corail stem. Third, due to the lack of markers on the Corail stem it was impossible to measure rotations of the femoral head. With the center of the head of the prosthesis as only reference, we can only assume the direction of movement of the stem by using the possibilities of movement of the stem in the femoral bone. With that in mind, distal and medial translation of the head center can be interpreted as varus tilt and posterior translation as retroversion or posterior tilt of the stem. It is not possible to convert the observed head translation to magnitude of rotation in a more accurate way. Finally, not all patients completed all clinical questionnaires, reaching a maximum of 10% missing answers. Although this study has some limitations, the strength is the randomized design and the inclusion of comparatively many patients. Several outcomes were used and both stem and cup fixation was monitored with RSA analysis.

Table 4: *Mean translations and rotations of the cups after one year*

	CFP			Corail			
	n	Mean	Range	*n*	Mean	Range	*p*-value
Medial (+) – lateral (-) translation	39	**0.13**	-0.24 – 0.95	39	**0.10**	-0.85 – 1.15	**0.29**
Proximal (+) – distal (-) translation	39	**0.16**	-0.22 – 0.85	39	**0.58**	-0.15 – 0.78	**0.70**
Anterior (+) –posterior (-) translation	39	**0.11**	-0.94 – 1.00	39	**-0.03**	-0.57 – 1.03	**0.09**
Anterior (+) – posterior (-) rotation	33	**0.18°**	-2.54 – 3.98	31	**0.60°**	-0.76 - 4.93	**0.12**
Ante- (+) – retroversion (-)	33	**0.61°**	-1.98 – 4.17	31	**0.58°**	-1.61 – 6.46	**0.76**
Decreased (+) – increased (-) inclination	33	**0.11°**	-1.71 – 4.06	31	**-0.03°**	-1.47 – 2.54	**0.24**

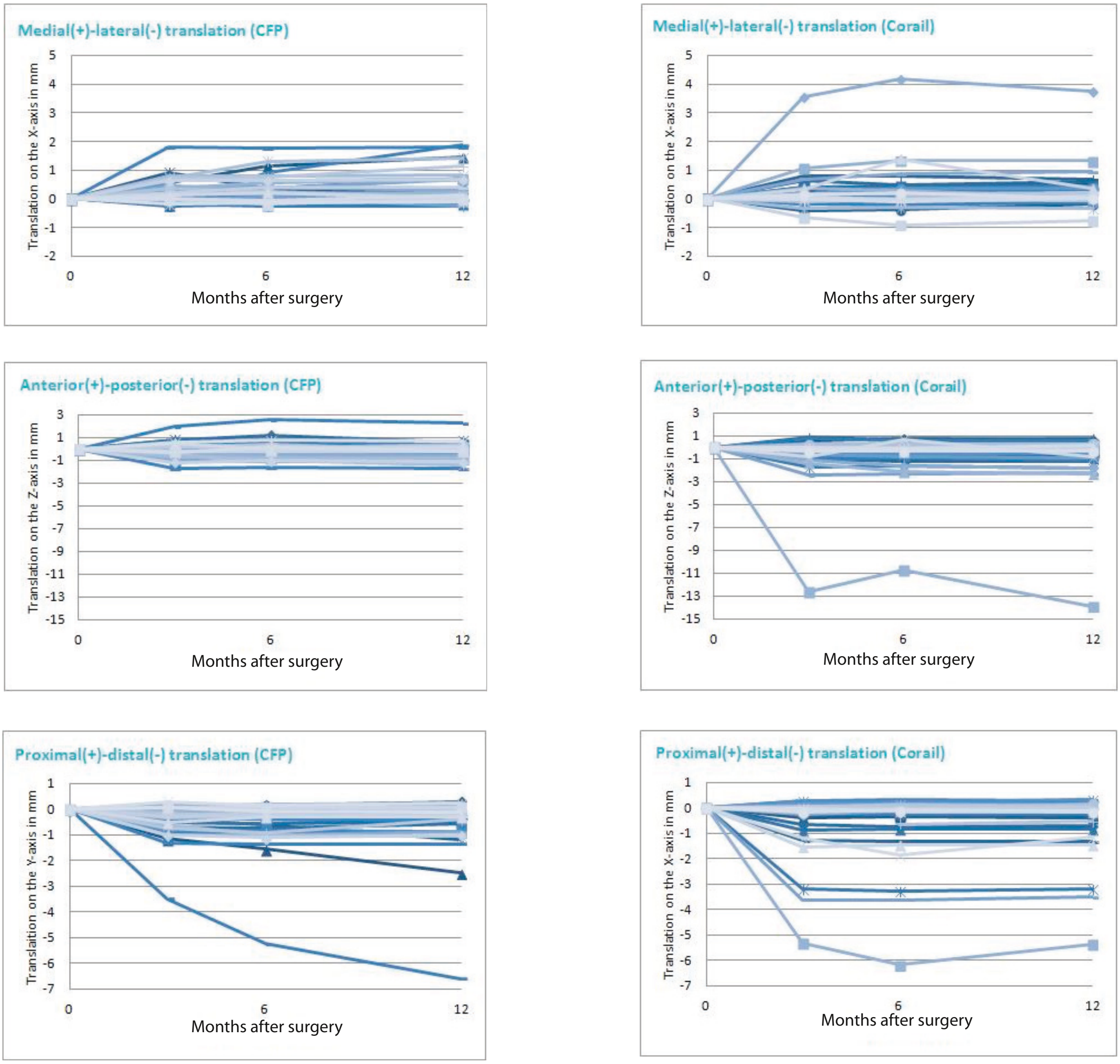

Figure 2: *Migration of each individual stem along the three different axis, divided in the two groups.*

Previous studies investigating the CFP stem showed an improvement of the HHS to at least 82 points [11], but mostly above 90 points [4-10] in the first year after hip replacement surgery. The HHS in the CFP patients improved to 92 in our study. The difference we found between the two groups in the additional question to the EQ-5D is difficult to value since it is only one question. We would like to analyze the outcomes of the SF-36 and EQ-5D to make a reliable comparison between the two groups.

Previous studies evaluating the CFP stem indicate a stable fixation and good short- and intermediate-term results on durability [4,6-11]. Hutt et al. showed a survivorship of 100% after a mean follow-up of 9.3 years [5]. Survivorship of the CFP stem in our study was 100% after one year. We found radiolucent lines in Gruen zones 1, 7 and 8 in several patients in both groups which is comparable to what others describe [9-11].

Using the RSA techniques, we did not find any differences in the absolute motion on the axes between the groups. However, we found a significant difference between the mean anterio-posterior motion after one year. We noticed that the centre of the femoral head in the Corail group moved posteriorly in most cases, while the centre of the femoral head in the CFP group moved both posteriorly and anteriorly. We assume that this translation is a result of the rotation of the stem into retro- or anteversion. Two studies, investigating the CFP stem using RSA, both showed retroversion of the stem using the mean translation and rotation [7,10]. The range of the data, published by Lazarinis (-0.26 – 0.55 mm) suggest that the CFP stem moves both in retro- as in anteversion [7].

At one year follow-up, the mean proximal-distal translation was 0.48 mm in the CFP group. We assume this to be the subsidence of the prosthesis. The other RSA studies regarding the CFP stem showed a mean subsidence of 0.05 and 0.13 mm [7,10]. This difference could be explained by the fact that the patients in the study by Röhrl et al. were advised to only partially bear weight in the first 6 weeks, whereas in this study full weight bearing was encouraged directly postoperatively [10]. A RSA study concerning the Fitmore short stem showed a mean subsidence of 0.39 mm. [15].

The migration of the Corail stem along the three different axes that was found in this study, is in line with other another RSA study regarding the Corail stem [16]. RSA studies show that early micromotion is a good predictor for future revision [17,18]. Lazarinis et al showed that only 1 CFP stem subsided after two years. Röhrl et al described little migration in the first two years. It requires two year results to determine primary stem fixation [7].

The use of a short stem and preservation of the femoral neck did not result in any short-term advantages compared to a standard stem. Two year data should help to draw more definitive conclusions.

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CORRECT ANSWERS TO THE EXAM QUESTIONS

Answer question 1: A. Only histone peptides
During the exam, 27% of the participants answered this question correctly.

B cells can receive help from Tfh cells by presentation of peptide fragments in the MHC class II of the T cells. Other molecules than peptides, such as DNA, cannot be presented in the MHC class II. Thus, anti-DNA-specific autoreactive B cells in Systemic Lupus Erythematosus (SLE) can only receive help from Tfh cells by presentation of histone peptides in their MHC class II.

Question 2: A. Immunoglobulins
During the exam, 43% of the participants answered this question correctly.

Immunoglobulins are important for the immune defence against pathogens in the respiratory tract such as *Streptococcus pneumoniae and Pneumocystis jirovecii*. Respiratory tract infections are therefore often seen in patients with deficient immunoglobulin production. Macrophages are important in phagocytosis, immune regulation and wound healing. Deficiencies in T cells often lead to an increased susceptibility to intracellular pathogens.

The exam questions can be found back on page 6 in this journal.