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Original article

Risk factors for unsuccessful acetabular press-fit fixation at primary total hip arthroplasty

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ARTICLE INFO

Article history:
Received 11 April 2017
Accepted 1st June 2017

Keywords:
Total hip arthroplasty
Press fit fixation
Risk factors

ABSTRACT

Background: Surgeon at primary total hip arthroplasty sometimes cannot achieve sufficient cementless acetabular press-fit fixation and must resort to other fixation methods. Despite a predominant use of cementless cups, this issue is not fully clarified, therefore we performed a large retrospective study to: (1) identify risk factors related to patient or implant or surgeon for unsuccessful intraoperative press-fit; (2) check for correlation between surgeons' volume of operated cases and the press-fit success rate.

Hypothesis: Unsuccessful intra-operative press-fit more often occurs in older female patients, particular implants, due to learning curve and low-volume surgeons.

Materials and methods: Retrospective observational cohort of prospectively collected intraoperative data (2009–2016) included all primary total hip arthroplasty patients with implant brands that offered acetabular press-fit fixation only. Press-fit was considered successful if acetabulum was of the same implant brand as the femoral component without additional screws or cement. Logistic regression models for unsuccessful acetabular press-fit included patients' gender/age/operated side, implant, surgeon, approach (posterior $n = 1206$, direct-lateral $n = 871$) and surgery date (i.e. learning curve).

Results: In 2077 patients (mean 65.5 years, 1093 females, 1163 right hips), three different implant brands (973 ABG-II™-Stryker, 646 EcoFit™ Implantcast, 458 Procotyl™ L-Wright) were implanted by eight surgeons. Their unsuccessful press-fit fixation rates ranged from 3.5% to 23.7%. Older age (odds ratio 1.01 [95% CI: 0.99–1.02]), female gender (2.87 [95% CI: 2.11–3.91]), right side (1.44 [95% CI: 1.08–1.92]), surgery date (0.90 [95% CI: 1.08–1.92]) and particular implants were significant risk factors only in three surgeons with less successful surgical technique (higher rates of unsuccessful press-fit with Procotyl™-L and EcoFit™ [$P = 0.01$]). Direct-lateral hip approach had a lower rate of unsuccessful press-fit than posterior hip approach ($P < 0.01$), but there was no correlation between surgeons' volume and rate of successful press-fit (Spearman's $\rho = 0.10$, $P = 0.82$). Subcohort of 961 patients with 5–7-years follow-up indicated higher early/late cup revision rates with unsuccessful press-fit.

Discussion: Success of press-fit fixation depends entirely on the surgeon and surgical approach. With proper operative technique, the unsuccessful press-fit fixation rate should be below 5% and the impact of patients' characteristics or implants on press-fit fixation is then insignificant. Findings of huge variability in operative technique between surgeons of the presented study emphasize the need for surgeon-specific data stratification in arthroplasty studies and indicate the possibility of false attribution of clinically observed phenomena to patient-related factors in pooled data of large centers or hip arthroplasty registers.

Level of evidence: Level III, retrospective observational case control study.

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1. Introduction

Total hip arthroplasty with uncemented acetabular press-fit cementless fixation has become increasingly popular in the

last decades [1]. Initial intraoperative mechanical stability is an essential prerequisite to achieve osteointegration of press-fit acetabular cups [2,3]. Despite excellent long-term outcomes of uncemented fixation [4–6], in some cases the operating surgeon cannot establish initial intraoperative stability of the acetabular component with the intended press-fit implant type and has to use alternative fixation methods with additional screws, cement (i.e. reverse hybrid), threaded cup or press-fit implant from another

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manufacturer [6–8]. Unsuccessful primary fixation of the intended implant prolongs the operation time and represents additional stress for operating surgeon and other medical personnel.

So far, none of the published studies on unsuccessful intraoperative acetabular fixation reported exact rates of unsuccessful press-fit. Only in experimental setting it was shown osteoporosis and segmental acetabular rim defects can jeopardize fixation in extreme cases [9–12], augmentation with screws, pegs, or hydroxyapatite does not bring any significant advantage [13] and excessive macroscopic surface roughness decreases primary acetabular press-fit stability [14]. However, it is not clear what impact these patient-related factors and implant properties actually have on acetabular press-fit fixation in the clinical setting and how they depend on the operative skills of the surgeon.

We therefore conducted a retrospective cohort observational study to (1) identify patient-related (age, gender, operated side), implant-related and surgeon-related risk factors (approach, learning curve) for unsuccessful acetabular press-fit fixation at primary total hip arthroplasty and to (2) check if there exists correlation between surgeons' volume of operated hip arthroplasty cases and the success rate of press-fit fixation. Our hypothesis was that unsuccessful press-fit more often occurs in older female patients, in particular implants, in the beginning of the learning curve and in low-volume surgeons who have less experience with the press-fit technique.

2. Material and methods

2.1. Patients

In a single institution, the intraoperative data on all implanted total hip arthroplasties were being prospectively collected in the period between 1st April 2009 and 31st December 2016, with clinical follow-up of at least 150 days for the entire cohort and minimum 5 years for all patients operated before 1st June 2012. The observational cohort study included all patients who underwent primary total hip arthroplasty with uncemented femoral implant types where acetabular press-fit component was the only available option of the same implant manufacturer. All patients were included in the study regardless of age, gender, diagnosis or possible perioperative/postoperative complications. The main exclusion criterion was previous arthroplasty of the same hip. In addition, the study excluded all patients who were operated by operating surgeons with less than 100 performed hip arthroplasties in the observation period.

2.2. Methods

Primary hip arthroplasties were performed by eight different surgeons through direct lateral transgluteal approach ($n=871$) or posterior surgical approach ($n=1206$) to the hip. Each of the surgeons used only one type of approach and the choice of approach therefore depended entirely on the habit of the operating surgeon, regardless of the patients' characteristics. Patient's gender, date of birth, preoperative diagnosis, operated side, implant brand of the femoral and the acetabular component, operating surgeon, date of surgery (i.e. measure of surgeons' learning curve), surgical approach and successful/unsuccessful press-fit fixation were recorded prospectively at each surgical procedure.

Implanted endoprostheses were produced by 3 different manufacturers – ABG-II™ (Stryker), EcoFit™ (Implantcast), Procotyl™ L (Wright Medical) – and uncemented femoral stems were provided together with press-fit acetabula as the only available acetabular component of these manufacturers. The choice of particular implant depended mainly on the surgery date due

to implant availability in the institution (Procotyl™ L was used 2009–2011 and ABG-II™ 2012–2016, while EcoFit™ was available 2009–2016) and partially on surgeons' personal preference, regardless of the patients' characteristics.

2.3. Methods of assessment

Acetabular press-fit fixation was considered successful if the operating surgeon used press-fit acetabulum of the same implant brand as the femoral component without additional screws. Intraoperative press-fit stability of the acetabular component on a long lever-arm insertion handle was tested by each surgeon manually twice: first with the probe component and finally with the implanted component. The institution policy was not to use metal screws routinely because their presence has been linked to possible formation of retroacetabular lytic granulomas [15]. In case of acetabular cup fixation with additional screws, cement, threaded cup or use of components from different manufacturers, press-fit fixation of the original implant brand (i.e. the brand of the femoral component) was therefore considered unsuccessful.

If a particular femoral stem was chosen due to specific patient's femoral morphology, the operating surgeon was supposed to implant acetabulum of the same brand in accordance with instructions of implant manufacturers. Lack of press-fit was the only reason, why additional screws, cemented components or other implant brands would be used with the chosen cementless femoral stem. The study included all cases with insufficient intraoperative press-fit stability at primary total hip arthroplasty, regardless of the cause of instability (e.g. improper operative technique, insufficient bone stock, intraoperative crack in the acetabular rim).

2.4. Statistical analysis

Differences in proportions were computed with two-tailed chi-square test (implants, surgeons' approach) or Fisher's exact test (comparison successful/unsuccessful press-fit). Correlation between surgeons' volume and successful press-fit rate was evaluated with the Spearman's rank correlation coefficient. The entire patient cohort was first analyzed with a logistic regression model for unsuccessful press-fit and the input variables of patients' age, gender, operated side (right/left), learning curve (represented by surgery date as a five-digit serial date integer), and surgeon. Subsequent analysis was done separately for each operating surgeon with eight binary logistic regression models for unsuccessful press-fit fixation as the outcome and input variables of patients' gender, age (numerical variable), operated side, surgery date (five-digit serial date integer) and implant type. Statistical significance of the P -values was set at 0.05. Statistical calculations were performed with SPSS (version 23.0; SPSS Inc, Chicago, IL, USA) and Microsoft Excel (Office 2016 Microsoft Inc., Redmond, WA, USA). Ethical consideration: The study protocol was approved by the National Medical Ethics Committee of the Republic of Slovenia on June 26, 2015, case No.# 87/06/15.

3. Results

In the period between April 1, 2009 and December 31, 2016, the eight included operating surgeons operated 3063 total hip arthroplasties; therefrom implant brands which exclusively offered press-fit acetabula were used in 2077 patients (1093 females and 1163 right hips) with the mean age of 65.5 ± 10.8 years (range 22–89 years). Direct lateral approach was used in 871 operative procedures; posterior approach in 1206 cases and each of the surgeons used only one type of approach in all surgical procedures. Implanted endoprostheses were produced by 3 different

Table 1

Preoperative diagnoses and postoperative cup-removal rates, stratified according to the three implant groups and success of press-fit. P-values were computed with two-tailed chi-square test (comparison between implants) or Fisher's exact test (comparison successful/unsuccessful press-fit).

Implant	ABG-II [®] (Stryker)	EcoFit [®] (Implantcast)	Procotyl [®] -L (Wright Medical)	P value
Diagnosis				
Idiopathic osteoarthritis	827	539	391	0.61
Avascular necrosis	53	43	22	0.39
Rheumatic diseases	16	15	9	0.62
Dysplasia/Perthes/SCFE	51	28	22	0.71
Post-traumatic osteoarthritis	27	21	14	0.86
Cup revision within 150 days after primary implantation	<i>P</i> = 0.28	<i>P</i> = 0.49	<i>P</i> = 0.31	
Successful press-fit	9/881 (1.0%)	4/565 (0.7%)	1/380 (0.3%)	0.36
Unsuccessful press-fit	2/92 (2.1%)	1/81 (1.2%)	1/78 (1.3%)	0.85
Cup revision within 5–7 years after primary implantation ^a	<i>P</i> = 0.46	<i>P</i> = 0.11	<i>P</i> = 0.08	
Successful press-fit	2/141 (1.4%)	3/290 (1.0%)	1/380 (0.3%)	0.30
Unsuccessful press-fit	1/32 (3.1%)	2/40 (5.0%)	2/78 (2.6%)	0.78

^a Subcohort of 961 patients, operated in the period 2009–2012.

Table 2

Binary logistic regression model shows the impact of patients' age, gender, operated side, surgery date and surgeon on the risk for unsuccessful press-fit (*n* = 2077). Total model value Nagelkerke $R^2 = 0.18$; *P* < 0.01. Statistically significant results are marked with an asterisk (*).

Risk factor	B	SE	Exp(B) and 95% CI	P-value
Age (year)	0.01	0.01	1.01 (95% CI: 0.99–1.02)	0.15
Gender (female)	1.05	0.16	2.87 (95% CI: 2.11–3.91)	0.01*
Operated side (right)	0.36	0.15	1.44 (95% CI: 1.08–1.92)	< 0.01*
Surgery date (year)	–0.11	0.03	0.90 (95% CI: 1.08–1.92)	< 0.01*
Surgeon				
Surgeon 1	–0.67	0.3	0.51 (95% CI: 0.28–0.93)	0.03*
Surgeon 2	–1.04	0.31	0.35 (95% CI: 0.19–0.64)	< 0.01*
Surgeon 3	–1.06	0.29	0.35 (95% CI: 0.20–0.61)	< 0.01*
Surgeon 4	–0.4	0.22	0.67 (95% CI: 0.44–1.02)	0.07
Surgeon 5	–2.19	0.36	0.11 (95% CI: 0.06–0.22)	< 0.01*
Surgeon 6	–2.13	0.34	0.12 (95% CI: 0.06–0.23)	< 0.01*
Surgeon 7	–1.8	0.28	0.17 (95% CI: 0.10–0.29)	< 0.01*
Surgeon 8 ^a				

B: regression line coefficient; SE: Standard Error, Exp (B): 95% odds ratio; CI: confidence interval.

^a Surgeon with the largest number of implanted cases used as benchmark.

manufacturers: ABG-IITM (Stryker), EcoFitTM (Implantcast), ProcotylTM L (Wright Medical). There was no significant difference between the three implant groups in the proportion of preoperative diagnoses, early cup-revision rates within 150 days after implantation or late cup-revision rates in the subcohort of 961 (46.3%) patients with 5–7 years of clinical follow-up (Table 1). All implant groups indicated the trend of higher early/late cup-revision rates with unsuccessful press-fit, but the trend was not statistically significant (Table 1).

Analysis of the entire cohort in a single logistic regression model indicated risk factors for unsuccessful press-fit with older age (odds ratio 1.01 [95% CI: 0.99–1.02]), female gender (odds ratio 2.87 [95% CI: 2.11–3.91]), operated right hip (odds ratio 1.44 [95% CI: 1.08–1.92]), learning curve (odds ratio 0.90 [95% CI: 1.08–1.92] for each year) and particular surgeons whose unsuccessful press-fit fixation rates differed considerably (Table 2). However, separate multivariate binary logistic regression for each surgeon (Table 3) revealed older age, female gender, right side, surgery date (i.e. measure of learning curve) and particular implants were important risk factors only in a few surgeons with less successful surgical technique. None of these factors was significant for the three surgeons with most successful press-fit results (Table 3).

Further data stratification in Table 3 showed direct-lateral hip approach was more successful in press-fit fixation than posterior hip approach (unsuccessful rates 3.5%–4.6% versus 9.8%–23.7%, *P* < 0.01). There was no significant correlation between surgeons' volume of operated cases and the success of the press-fit (Spearman's $\rho = 0.10$, *P* = 0.82).

4. Discussion

Cementless press-fit fixation in primary total hip arthroplasty has many advantages [16,17], but in some cases the operating surgeon cannot achieve intraoperative mechanical stability of the acetabular component and must resort to the use of screws, cement, threaded cups or use of components from other manufacturers [7,8]. We asked whether patients' characteristics, implant type and surgeons' skills had significant impact on intraoperative acetabular press-fit stability and whether there existed correlation between surgeons' volume of operated hip arthroplasty cases and successful press-fit rate. Multivariate analyses of the analyzed data have shown surgeon was the main independent risk factor for unsuccessful intra-operative press-fit fixation regardless of his yearly hip arthroplasty volume. Press-fit results were less successful in surgeons with posterior hip approach while female gender, higher age, right hip, learning curve and particular implants were independent risk factors only in particular individual surgeons with less successful operative technique.

The current study has limitations: (1) the retrospective design, but the data were collected in a prospective database in a continuous design; (2) lack of radiological analysis of acetabula and therefore uncontrolled variable of acetabular shape which could influence press-fit fixation [10]; (3) all cases with insufficient intra-operative press-fit stability at primary total hip arthroplasty were taken into account, regardless of the cause of instability. While the study cannot differentiate between possible causes that may have appeared during surgery (e.g. improper operative technique, insufficient bone stock, intraoperative crack in the acetabular rim), it does take into account all the factors that were known preoperatively; (4) another limitation is also the fact that each of the analyzed surgeons used only one surgical approach (either posterior or direct lateral approach) in primary total hip arthroplasty and had personal preferences for one particular implant type over another. This is why it is statistically impossible to separate the variables of surgical approach and surgeon (i.e. it could be a coincidence that all surgeons who used posterior approach were less skilled in press-fit) and the finding of less successful press-fit with posterior approach should therefore be interpreted with caution. To some extent it could be explained by the fact that posterior approach demands slightly more anteversion to prevent dislocation after total hip arthroplasty [18,19] and with increased anteversion press-fit is more difficult to achieve.

Similarly to Garcia-Rey et al. [20], in some surgeons we found less successful intraoperative mechanical stability of uncemented acetabulum in female patients. Although osteoporosis itself has not been proven risk factor for worse press-fit stability in laboratory biomechanical measurements on macerated bone [9], in the clinical setting the combination of degenerative sclerosis and

Table 3
Stratified data according to eight surgeons and corresponding separate binary logistic regression models with unsuccessful acetabular press-fit fixation as the outcome variable and input variables: patient's gender, age, operated side, implant type and surgery date. Statistically significant results are marked with an asterisk (*).

Surgeons	Mean No. THA/year	Unsuccessful press-fit rate	App	Odds-ratios of statistically significant risk factors for unsuccessful press-fit	N-R ²	Model (P-value)
Surgeon 1	29.3	15/119 (12.6%)	P	None	0.14	0.17
Surgeon 2	36.4	14/142 (9.9%)	P	None	0.09	0.30
Surgeon 3	34.6	16/164 (9.8%)	P	Female (3.36 [95% CI: 0.91–11.8]) Right side (3.82 [95% CI: 1.02–14.3])	0.15	0.03*
Surgeon 4	43.3	35/208 (16.8%)	P	ProcotyI™-L (2.17 ^a [95% CI: 2.05–2.31]) EcoFit™ (1.52 ^a [95% CI: 1.09–12.1])	0.18	0.01*
Surgeon 5	49.0	9/254 (3.5%)	L	None	0.07	0.61
Surgeon 6	62.6	10/279 (3.6%)	L	None	0.13	0.15
Surgeon 7	88.3	16/338 (4.6%)	L	None	0.09	0.11
Surgeon 8	89.3	136/573 (23.7%)	P	Female (3.22 [95% CI: 2.07–5.00]) Older age (1.03 [95% CI: 1.01–1.06]) Surgery date (0.99 [95% CI: 0.99–1.00])	0.15	<0.01*

Mean No. THA/year: mean yearly number of all total hip arthroplasty surgeries 2009–2016; App: Approach; L: direct lateral approach; P: posterior approach; N-R²: Nagelkerke's R squared; 95% CI: confidence interval of 95%.

^a Implant with the largest number of implanted cases ABG-II[®] (Stryker) used as benchmark.

osteoporotic bone might explain less successful acetabular press-fit fixation in females [21–24]. The potential influence of implant coating on press-fit has been studied previously [25] and plasma-sprayed acetabular cups have demonstrated superior results. While implant properties with plasma-sprayed coating seem to be an important factor of press-fit fixation only in less skilled operating surgeons (better results of ABG-II[™] Stryker in Tables 1 and 2), its influence on the long-term bone ingrowth and endoprosthesis survival are beyond the scope of this study.

The presented paper provides one of the rare analyses of clinically achieved intraoperative press-fit success rates in the clinical setting. This issue has been grossly overlooked in the scientific literature because it has no direct influence on clinical outcome of the patients in the first years after the implantation. Findings of huge variability in operative technique between surgeons of the presented study emphasize the need for surgeon-specific data stratification in arthroplasty studies [26,27] and indicate the possibility of false attribution of clinically observed phenomena to patient-related factors in pooled data of large centres or hip arthroplasty registers. Success rate of press-fit fixation could be considered as one of objective surgeon-related quality measures in the field of total hip arthroplasty instead of the volume of operated patients alone.

5. Conclusion

Intraoperative mechanical stability of cementless press-fit acetabular components at primary total hip arthroplasty depends entirely on the operative technique of the operating surgeon and is not directly related to the volume of operated arthroplasty cases. In surgeons with excellent surgical technique the rates of unsuccessful press-fit fixation do not exceed 5% and the impact of patient's characteristics or implant type is insignificant. Direct lateral approach tends to show better press-fit results than posterior approach. Female gender, higher age, right-sided hip and non-plasma-sprayed implants might only be significant risk factors of unsuccessful press-fit in individual surgeons with less skilled operative technique.

Funding

No financing was received for the presented study.

Disclosure of interest

The authors declare that they have no competing interest.

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