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PŮVODNÍ PRÁCE

Prophylactic Cerclage Cabling Decreases the Intraoperative Periprosthetic Fracture Rate during Cement-Less Total Hip Arthroplasty in Patients with Severe Developmental Hip Dysplasia

Profylaktická kabelová cerkláž snižuje četnost intraoperační periprotetické zlomeniny při implantaci necementované endoprotézy kyčle u pacientů s významným stupněm kyčelní dysplazie

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ABSTRACT

PURPOSE OF THE STUDY

Cementless stems in highly dysplastic hips are considered to increase the risk of femoral fracture and associated morbidity. Several authors speculated to use prophylactic cabling in this patient group to prevent intraoperative fractures. This study aims to reveal objective results regarding the perioperative complications in a large and consecutive patient group with respect to use of prophylactic cabling.

MATERIAL AND METHODS

A retrospective comparative study was planned. A total of 122 consecutive patients with dysplastic hips of Crowe type 3 or 4, operated on with total hip arthroplasty (THA) and shortening osteotomy using a rectangular femoral stem were included. Patients were stratified according to use of a diaphyseal prophylactic cerclage cable. Perioperative complications were recorded. Clinical outcome was measured in terms of Harris Hip Score and Visual Analog Scale (VAS) for pain. All results were compared between the groups.

RESULTS

The mean follow-up time was 27 months. Two (2%) versus five (14%) patients had a fracture at the diaphyseal level in cabled versus non-cabled groups. Difference between groups was statistically significant (p=0.01). Relative risk of fracture in case of a non-cabling was 5.8 (p=0.03). Eleven (9%) patients had a non-displaced fracture at the metaphyseal level. No significant differences were detected with respect to preoperative clinical outcome scores or change in these scores between groups.

CONCLUSIONS

Femoral diaphyseal fracture rates are low when cementless, rectangular stems are used in dysplastic high riding hips. Prophylactic cerclage cabling further decreases the fracture risk and eases treatment in case of a fracture without causing additional complications and therefore is recommended.

Key words: intraoperative fracture, periprosthetic fracture, total hip arthroplasty, cerclage cabling, developmental hip dysplasia, transverse shortening osteotomy.

INTRODUCTION

Developmental hip dysplasia related secondary coxarthrosis is associated with diverse anatomical variances of the proximal femur (1). These variations make the bone more susceptible to unintended fractures during the complex surgery. Relatively younger age of patients with dysplastic hips make cementless options more attractive, whereas a higher complication rate with respect to intraoperative fractures have been traditionally postulated (2).

Among cementless options, many authors published their experiences with different kinds of femoral implants. Modular (3), cylindrical (4), conical (5), custom made (6), and rectangular implants (7, 8) have been reported to provide successful results. Various osteotomy techniques were introduced, with different osteotomy shapes and osteotomy handling options (9, 10). Currently, transverse shortening osteotomy is the most commonly used method in this patient group.

Rectangular stems have been reliably used in primary coxarthrosis with solid and successful long term results (11). Same implants have also been shown to provide successful results in dysplastic hips with a transverse femoral shortening osteotomy (7, 8). Main advantages are better rotational support and relatively smaller and non-canal filling design (7). A critical concern is the potentially increased intraoperative fracture risk, whereas several authors found comparable fracture rates with other implants and concluded that fracture risk is dependant on the dysplastic femoral morphology, rather than the rectangular implant (7, 12). A meta-analysis also supported this suggestion, in which the authors analyzed the effect of femoral implant on the intraoperative fracture risk (13).

Intraoperative periprosthetic fractures are reported to be associated with worse functional outcomes and can be troublesome to handle. Therefore, Young et al. reasonably suggested in an editorial, that prevention of these fractures must be the principle aim of the surgeons (14).

To overcome the risk of fracture during implantation of the femoral stem, several authors recommended to place a cerclage cable around the femur below the osteotomy level to prevent fractures. Although prophylactic cabling was presumed to decrease the risk of femoral fracture during stem implantation (3, 7, 15), no study selectively investigated the effect of prophylactic cabling in a clinical study. Biomechanical studies using different but similar set-ups, found out that hoop stresses can be decreased and fractures might be prevented, when cabling is performed prophylactically (16, 17). On the other hand, wiring and cabling related complications such as soft tissue injuries, implant failure or irritation constitute a concern when using these implants (18).

This study aimed to document relevant perioperative complications in a large and relatively homogenous patient group with respect to prophylactic use of a cerclage cable around the femoral diaphysis. Secondary aim was to comparatively evaluate the effectiveness of cabling in terms of diaphyseal fracture rate and cabling related complications.

The hypothesis was that cementless, rectangular femoral stems would have a low rate of intraoperative periprosthetic fracture and cabling would further reduce the fracture rate at the diaphyseal level and ease treatment in case of a fracture without causing additional complications.

MATERIAL AND METHODS

An institutional ethical board approval was obtained prior to start of this study. A total of 170 patients were identified. Inclusion criteria were patients with a Crowe type 3 or 4 hip dysplasia, operated on with total hip arthroplasty and transverse shortening osteotomy using a rectangular, tapered femoral component. Exclusion criteria were follow-up time of less than 12 months (n=20), previous femoral or pelvic operations (n=18), and unreachable patients (n=10). A total of 122 patients remained and were included in the study. A single type of femoral component, SL-PLUS Japan (Smith & Nephew, Memphis, TN) was used in all patients. Mean patient age was 42.4±10.3. Six patients (5%) were male, 107 patients (%88) had a Crowe type IV and 15 (%12) had a Crowe type III hip. All patients were operated using the same previously described technique (7). An autologous strut graft was used as per the operating surgeon.

Distal prophylactic cabling was not applied routinely to all patients. One of the surgeons within the same department operated using cables routinely, the other didn't use them unless a fracture occurred (Fig. 1). Metaphyseal cabling proximal to the osteotomy site was never prophylactically performed, but only in case of a crack or fracture. Patients were stratified into two groups according to use of a prophylactic cerclage cable as the cabled group (CG) or the non-cabled group (nCG).

Preoperative and postoperative Harris Hip Score (HHS) and Visual Analog Scale (VAS) for pain was obtained from all patients. Used femoral component size was noted. Perioperative complications such as an intraoperative fracture, its type and location, femoral fractures during the follow-up period, early postoperative dislocation (within 30 days) and amount of bleeding were recorded.

Patients in both groups were compared with respect to the demographical features, Crowe type, preoperative HHS and VAS score.

Bone union was defined as the presence of progressive callus, cortical continuity at the osteotomy site, and painless weight bearing. Bone consolidation time was determined from the serial radiographs of the hip. Stem subsidence amount was measured in early postoperative, at sixth month and final follow-up x-ray images using teardrop and greater trochanter tip as landmarks.

Any complication related to surgery was noted. All results were compared between groups.

The data were analyzed using IBM SPSS 23.0 statistical package software by a certified statistician. Descriptive statistics were used to represent the demographic data. All variables were analyzed for normal distribution using a Shapiro-Wilkinson test. Nominal values between groups were compared using the chi-square test. Independent group variables were analyzed using a Student's *t*-test or Mann-Whitney *U*-test depending on the distribution. The *P* -value was regarded as statistically significant if <.05.

RESULTS

Mean follow-up time was 27.3±15.8 months (med: 24, min: 12, max: 80). A prophylactic cerclage cabling at least one cm distal to transverse osteotomy was performed in 86 (70%) of patients.

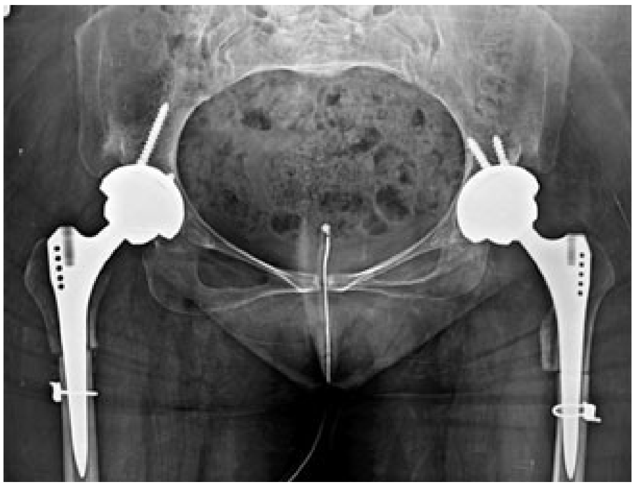

Fig. 1. Prophylactic cabling using a single cable below the osteotomy level around the diaphysis was performed in majority of the patients (70%).

Table 1. Clinical outcome results between the prophylactically cabled and non-cabled patient groups

Clinical outcome measure	Prophylactic cable applied (n=86)	Prophylactic cable not applied (n=36)	p-value
Preoperative HHS	43.6±11	40.4±17.2	0.4
Change in HHS	46.6±12.9	50.4±17.5	0.9
Preoperative VAS score for pain	8.4±1.2	8.2±2.5	0.2
Change in VAS score	6.8±1.8	7.4±2.6	0.1

Table 2. Relevant results between the prophylactically cabled and non-cabled patient groups

	Prophylactic cable applied (n=86)	Prophylactic cable not applied (n=36)	p-value
Diaphyseal fracture	2 (2%)	5 (14%)	0.01
Metaphyseal fracture	8 (9%)	3 (8%)	0.7
Amount of intraoperative bleeding (in mL)	448±170	425±193	0.9
Operating time (in min)	111±29	108±25	0.9
Bone consolidation time (in months)	7.1±2.6	7.1±2.6	0.9
Stem subsidence at the latest follow-up (in mm)	2.1±1.5	2.1±1.2	0.8

No statistically significant differences were detected between patients from both groups with respect to demographical features, Crowe type, preoperative HHS and VAS score.

An autologous strut graft was cabled around the osteotomy site in 28 (23%) of patients. Non-union was observed in two (1.6%) patients, both of which were in the CG. Beside the two patients with a nonunion, clinical and radiological examinations revealed progressive healing of the osteotomy site in all patients and patients were allowed to bear weight at the end of the sixth postoperative week. Mean radiological bony consolidation time at the osteotomy site was 7.1±2.6 months for both groups. Median femoral stem size was -2 for both groups, whereas it was -3 in patients with a diaphyseal fracture of the femur.

Stem subsidence amount was less than 5 mm in all patients. The mean stem subsidence was 1.8±1.1 mm and 1.7±1 mm at the sixth month and 2.1±1.5 and 2.1±1.2 mm at the latest follow-up in CG vs nCG. There were no significant differences between the groups.

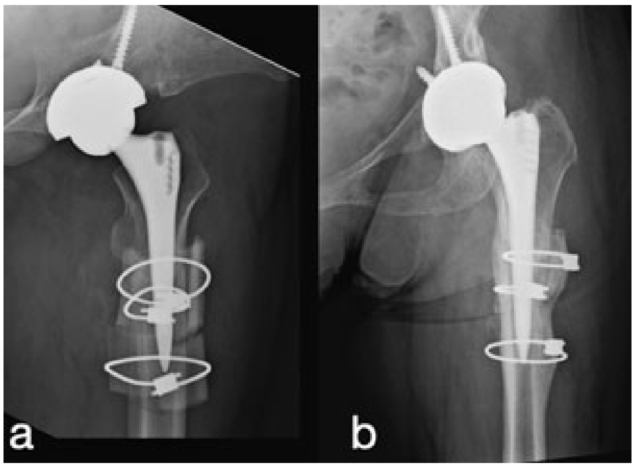

Fig. 2. a – 50-year-old female patient with an intraoperative fracture at the level of diaphysis below the transverse osteotomy level was addressed using three cables during the initial surgery; b – follow-up image of the same patient at 24 months.

Clinical outcome related results are represented in Table 1. There were no significant differences between the corresponding outcome scores of both groups. Change in HHS and VAS score was non-significantly greater in nCG compared to CG. Patients with any intraoperative periprosthetic fracture had a non-significantly different clinical outcome scores at the latest follow-up compared to patients with no fractures (HHS change of 48 vs 48.3 and VAS score change of 7 vs 6.7).

No patients had an early dislocation. Two (2%) versus four patients (14%) had a fracture at the diaphyseal level in cabled versus non-cabled femurs. Type of the periprosthetic fracture at the diaphyseal level was Vancouver type B1 in all cases. Difference between groups was statistically significant (p=0.01). Relative risk of fracture in case of a non-cabling was 5.8 (p=0.03). Three (8%) patients in the nCG and eight (9%) patients in the CG had a metaphyseal crack proximal to the osteotomy level. Difference between groups was not significant.

Amount of perioperative bleeding consisting of intraoperative and postoperative drainage was non-significantly different between groups. Mean operating time was non-significantly longer in the CG vs nCG, 111 vs 108 min. An overview of cases with respect to compared findings are represented in Table 2.

Cases without a prophylactic cable required three cables each to fixate the fracture (Figs. 2 and 3), whereas distal fractures in PC group with a single cable weren't cabled additionally (Fig. 4).

DISCUSSION

This study showed that prophylactic cerclage cabling decreases diaphyseal fractures rates. Furthermore, cabling wasn't associated with an increased amount of complications.

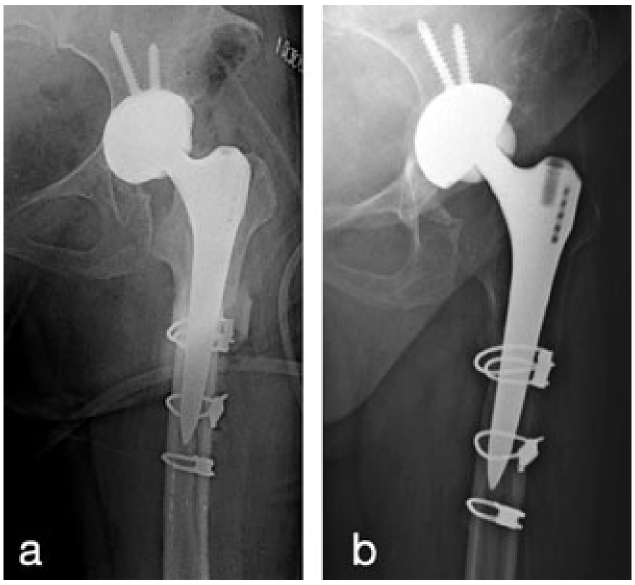

Fig. 3. a – a 65-year-old female with an long intraoperative diaphyseal fracture was fixed using three cerclage cables; b – follow-up image of the same patient at 24 months.

One of the most commonly reported complications in patients with high riding hips is intraoperative fractures. Various reasons were held responsible. First, dysplasia related morphological changes in Crowe type 3 and 4 hips are more prominent compared to milder forms (1, 19) and a shortening osteotomy causes the stem to be placed in a relatively narrower diaphysis of femur (7). Second, use of a cementless femoral component due to younger age of patients. To decrease the fracture risk, some authors used modular or custom-made components, whereas others speculatively used cerclage cabling at the distal femoral region. Although a review article on primary THA revealed that fit-without-fill femoral components such as the rectangular component were associated with a decreased rate of intraoperative fracture compared to fit-and-fill ones (13), no study comparatively investigated the effect of different femoral components on fracture rates in high riding dysplastic hips.

The femoral component used in this study had been in use since decades in primary hip arthroplasty with successful long-term results (11). Numerous articles also showed successful mid- and long-term results of these implants in dysplastic hips with a shortening osteotomy (12, 20). Cementless implants in general have been reported to cause an intraoperative fracture rate of up to 43% of patients in dysplastic hips operated on using THA and a shortening osteotomy (21). Among these, studies reporting on rectangular implants stated a fracture rate of 0 to 28% (7, 12). Of many cementless femoral implants, several different types have been shown to provide successful outcome following THA in this patient group. Regarding the intraoperative fracture rate, a modular stem was reported to cause a fracture rate of 6 to 46% (3, 15), a cylindrical stem 10 to 21% (22), an anatomic or straight custom-made stem 17% (6), a Wagner cone stem 1 to 13% (5). Some studies did not report on the used femoral component and some studies used various femoral components within the same study cohort. Overall, fracture rate results in the literature indicated a relatively higher rate of fractures in primary THA in dysplastic hips compared to primary coxarthrosis (13). However, inhomogenous study cohorts, different study designs, implants and operation techniques make it impossible to draw clear conclusions with respect to the effect of femoral component on the fracture risk.

A clear overview of similar studies involving patients with Crowe type 3 or 4 hip dysplasia and operated on using a rectangular cementless femoral component, with respects to prophylactic use of a cable and intraoperative fracture rate and location, is represented in Table 3. Studies with a cementless femoral implant other than the rectangular component are represented in Table 4.

Summative results from relevant studies in the literature, i.e. with a similar patient group and surgical treatment, showed that intraoperative fracture rates were similar between the groups stratified according to use of a rectangular or other cementless femoral components. The fracture rate from the current study (13%) was comparable with the overall fracture rates from studies with rectangular (12%) or other type of implants (11%). In all groups, as in the current study, prophylactic cabling was associated with a decreased overall fracture rate compared to non-cabled cases, 6% vs 21% with rectangular implants, 5% vs 13% with other femoral implants, 12% vs 17% in the current study. Non-union and early dislocation rates were similar between all groups (Table 5). The relatively higher fracture rate in the subgroup of patients with PC in the current study comprises mostly of proximal metaphyseal cracks (80%). None of these cracks were displaced and none was detectable on postoperative x-rays but they were all recognized intraoperatively and

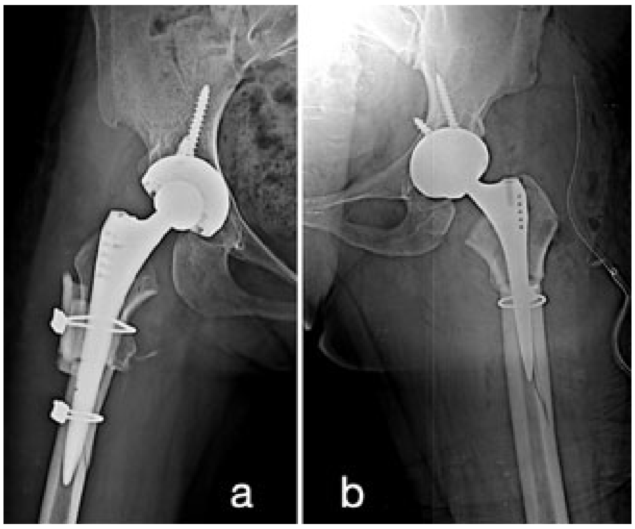

Fig. 4. a – a 23-year-old patient with a prophylactically cabled diaphysis had a nondisplaced fracture, which occurred during placement of the femoral component. A graft was also cabled around the osteotomy line during the operation; b – a 42-year-old patient with a prophylactically placed cable had an intraoperative fracture extending distal to the femoral component.

Table 3. Overview of different studies in a similar patient group using a cementless, rectangular femoral component

Author, year	Number of hips	Number of fractures	Fracture rate	Fracture location in relation to the osteotomy (% to fracture cases)	Non-union	Early dislocation	Prophylactic cabling
Gotze, 2007	7	0	0	n/a	none	none	no
Chen, 2011	17	1	6%	n/a	none	1	no
Neumann, 2012	13	0	0	n/a	none	none	yes
Mu, 2016	71	20	28%	distal: 4 (20%) proximal: 15 (75%)	2	none	no
Can, 2018	69	2	3%	proximal: 2 (100%)	none	1	yes
Erdem, 2019	26	0	0	n/a	none	none	yes
Kayaalp, 2020	50	7	14%	proximal: 7 (100%)	1	none	yes

Table 4. Overview of different studies in a similar patient group using a cementless component other than a rectangular femoral component

Author, year	Femoral stem	Number of hips	Number of fractures (fracture rate)	Fracture location	Non-union	Early dis-location	Prophylactic cabling
Decking, 2003	standard anatomical or custom made	12	2 (17%	trochanteric: 2 (100%)	none	none	yes
Erdemli, 2005	several different types	22	3 (14%)	distal: 3 (100%)	none	1	no
Onodera, 2006	modular	13	6 (46%)	distal: 2 (33%) proximal: 4 (66%)	1	1	no
Eskelinen, 2006	CDH and other types	68	4 (6%)	proximal: 4 (100%)	none	2	no
Park, 2007	modular	24	3 (13%)	proximal*: 3 (100%)	3	1	no
Nagoya, 2009	cylindrical	20	2 (10%)	proximal: 2 (100%)	none	none	yes
Krych, 2010	several different types	24	5 (21%)	distal: 5 (100%)	2	none	no
Takao, 2011	modular	33	8 (24%)	distal: 4 (50%) proximal: 4 (50%)	none	2	no
Kılıçoğlu, 2013	cylindrical	20	3 (15%)	trochanteric: 3 (100%)	1	1	no
Hua, 2015	conical	24	3 (13%)	n/a	none	none	no
Ozan, 2016	n/a	32	5 (16%)	distal: 5 (100%)	none	none	no
Ollivier, 2016	several different types	28	5 (18%)	n/a	none	1	no
Wang, 2017	modular	72	4 (6%)	distal: 1 (25%) proximal: 3 (75%)	none	3	yes
Rollo, 2017	modular or rectangular	17	1 (6%)	medial femoral wall	none	none	no
Wang, 2017	modular	56	4 (7%)	distal*: 2 (50%) proximal: 2 (50%)	none	3	yes
Grappiolo, 2018	conical	102	1 (1%)	trochanteric: 1 (100%)	4	4	no

* fracture location in relation to the osteotomy level

cabled after they have been detected. It might be speculated, that some studies might have failed to recognize these fissures, as previously postulated (16, 17).

Fracture rates below the osteotomy level were of interest because of its morbidity caused by displacement of fragments at this level due to a very narrow intramedullary canal. Overall distal femoral fracture rates from all the analyzed studies showed similar rates of 2% with rectangular, 3% with other implants and 5% within the current study. Cases without a PC had a significantly higher rate of distal femoral fracture, in particular with the use of a rectangular stem. The overall decrease in rates of distal fractures when a cable is used, was less prominent in other implants with 2% vs 1% than in the rectangular implants with 20% vs 2% (Table 6). This finding might reflect the importance of prophylactic cabling when rectangular components are used in dysplastic hips. However, more studies on the rectangular component are necessary to more clearly deduce conclusion by decreasing the effect of confound-

Table 5. Overview of relevant results from similar articles on high riding hips operated using total hip arthroplasty with a cementless femoral component grouped as per the use of either rectangular or other type of femoral component and the current study. All groups are subgrouped as per the use of a prophylactic cabling

Study groups	Femoral stem	Number of hips	Fracture rate	Non-union	Early dislocation
Rectangular implants	total	253	12%	1%	1%
	cases with prophylactic cabling (PC)	158	6%	1%	1%
	cases without PC	98	21%	2%	1%
Other femoral implants	total	809	11%	1%	2%
	cases with PC	225	5%	1%	3%
	cases without PC	584	13%	2%	2%
Current study	total	122	13%	2%	none
	cases with PC	86	12%	2%	none
	cases without PC	36	17%	none	none

Table 6. Overview of fracture rates distal to the osteotomy level from similar studies with fracture location information

Study groups	Subgroups	Number of hips	Fracture rate at the distal region
Rectangular implants	Total	190	2%
	cases with prophylactic cabling (PC)	119	none
	cases without PC	71	20%
Other femoral implants	total	757	3%
	cases with prophylactic cabling (pc)	225	1%
	cases without PC	532	2%
Current study	total	122	5%
	cases with prophylactic cabling (PC)	86	2%
	cases without PC	36	11%

ing factors on these results. The results from this study revealed that cabling successfully decreased the fracture rate at the diaphyseal region and it prevented displacement, when a fracture occurred.

Prophylactic cabling or wiring have been reported to be preventive of intraoperative fractures in high riding dysplastic hips operated on with THA and a shortening osteotomy (7, 15). Supportive biomechanical results to these suggestions are also available in the literature. Chrome-cobalt cable was shown to theoretically reduce the risk of femoral fracture by reducing strain and increasing hoop stress resistance (23). A double wrapped CoCr cable is able to stop all cracks from progressing distally in a revision THA setting using a conical femoral component (17). Frisch et al. investigated the effect of different cerclage constructs in fixation of intraoperative periprosthetic fractures during cementless THA in both axial load and torsional load testing. CoCr cable and hose clamb provided the highest construct stiffness and least reduction in stiffness (24). In an other study, the authors concluded that prophylactic wiring should be addressed on a case-to-case basis, because of possible complications. Decision should depend on poor bone quality findings on preoperative images or surgeon based subjective evaluation during the surgery (16). The current study is the first in the literature to selectively investigate the effect of cerclage cabling on intraoperative fractures in a consecutive patient group, which is the largest reported series on high riding hips operated on using the same femoral component and surgical technique. Homogenous features of the study group further support the results obtained in this study.

Cable or wire constructs were both used in the literature with inconclusive results in favor of the neither option (25). Cerclage cabling or wiring related complications were mostly seen in cases of displaced diaphyseal fractures or trochanteric fractures (26). Besides, both cabling and wiring were found related to osteolysis around the material (27). However, many studies published excellent results with cerclage treatment of periprosthetic fractures (28). Prophylactic diaphyseal cabling as performed in the current study revealed no complications related to the cabling process. This might be related to the facts that in most of the cases (1) cable was prophylactically placed prior to a potential fracture, and (2) cabling was performed under direct visualization of the diaphyseal segment with no additional soft tissue dissection necessary, because the proximal femur was displaced markedly superiorly as a result of the severe hip dysplasia.

The clinical outcome of patients with a periprosthetic fracture in the current study were non-significantly different from those without a fracture. This might have several causes. First, many of the patients (70%) were cabled prophylactically, which prevented fracture or fracture related displacements. Second, there were only Vancouver type B1 fractures at the level of diaphysis in the current study. Studies with longer follow-up periods with intraoperative fractures stated successful results in these patients. Perka et al. stated that survival rate wasn't influenced by intraoperative fractures in a cohort consisting of patients with dysplastic hips, although the authors reported mainly on milder hip dysplasia (29). Berend et al. also concluded that intraoperative nondisplaced or minimally displaced fractures does not affect the long-term survival of the femoral implant (30).

The study is not without limitations. First, patients were not randomized into the respected treatment groups. They were retrospectively grouped. Second, no economic impact was evaluated. However, relatively younger age of this patient group and high morbidity associated with periprosthetic fractures increases the importance of preventive measures. The obtained results showed that this prevention method was effective. Lastly, cerclage cable related complications may arise in later years, although no complications were detected in the current study, a longer follow time is necessary to draw conclusions.

CONCLUSIONS

Femoral diaphyseal fracture rates are low when cementless, rectangular stems are used in severely dysplastic high riding hips. Prophylactic cerclage cabling further decreases the fracture risk and eases treatment in case of a fracture without causing additional complications and therefore is recommended.

References

1. Abdel MP, Houdek MT, Watts CD, Lewallen DG, Berry DJ. Epidemiology of periprosthetic femoral fractures in 5417 revision total hip arthroplasties: a 40-year experience. Bone Joint J. 2016;98-B:468–474.
2. Alp NB, Akdag G, Erdogan F. Long-term results of total hip arthroplasty in developmental dysplasia of hip patients. Jt Dis Relat Surg. 2020;31:298–305.
3. Berend KR, Lombardi AV Jr., Mallory TH, Chonko DJ, Dodds KL, Adams JB. Cerclage wires or cables for the management of intraoperative fracture associated with a cementless, tapered femoral prosthesis: results at 2 to 16 years. J Arthroplasty. 2004;19(7 Suppl 2):17–21.
4. Berend ME, Ritter MA, Meding JB, Faris PM, Keating EM, Redelman R, Faris GW, Davis KE. Tibial component failure mechanisms in total knee arthroplasty. Clin Orthop Relat Res. 2004;428:26–34.
5. Berton C, Puskas GJ, Christofilopoulos P, Stern R, Hoffmeyer P, Lübbeke A. Comparison of the outcome following the fixation of osteotomies or fractures associated with total hip replacement using cables or wires: the results at five years. J Bone Joint Surg Br. 2012;94:1475–1481.
6. Caglar O, Ozdemir E, Tokgozoglu AM, Atilla B. Use of proximal humerus plates for the fixation of the subtrochanteric femoral shortening osteotomy during total hip arthroplasty for Crowe type IV developmental dysplasia of the hip patients. Jt Dis Relat Surg. 2020;31:306–311.
7. Carli AV, Negus JJ, Haddad FS. Periprosthetic femoral fractures and trying to avoid them: what is the contribution of femoral component design to the increased risk of periprosthetic femoral fracture? Bone Joint J. 2017;99-B(1 Suppl A):50–59.
8. Cruz-Pardos A, Garcia-Rey E, Garcia-Cimbrelo E. Total hip arthroplasty with use of the cementless Zweymüller Alloclassic system: a concise follow-up, at a minimum of 25 years, of a previous report. J Bone Joint Surg Am. 2017;99:1927–1931.
9. Decking J, Decking R, Schoellner C, Fuerderer S, Rompe JD, Eckardt A. Cementless total hip replacement with subtrochanteric femoral shortening for severe developmental dysplasia of the hip. Arch Orthop Trauma Surg. 2003;123:357–362.
10. Frisch NB, Charters MA, Sikora-Klak J, Banglmaier RF, Oravec DJ, Silverton CD. Intraoperative periprosthetic femur fracture: a biomechanical analysis of cerclage fixation. J Arthroplasty. 2015;30:1449–1457.
11. Grappiolo G, La Camera F, Della Rocca A, Mazziotta G, Santoro G, Loppini M. Total hip arthroplasty with a monoblock conical stem and subtrochanteric transverse shortening osteotomy in Crowe type IV dysplastic hips. Int Orthop. 2019;43:77–83.
12. Herzwurm PJ, Walsh J, Pettine KA, Ebert FR. Prophylactic cerclage: a method of preventing femur fracture in uncemented total hip arthroplasty. Orthopedics. 1992;15:143–146.
13. Kayaalp ME, Can A, Erdogan F, Ozsahin MK, Aydingoz O, Kaynak G. Clinical and radiological results of Crowe type 3 or 4 dysplasia patients operated on with total hip arthroplasty using a cementless rectangular femoral component without fixating or grafting the transverse osteotomy site. J Arthroplasty. 2020;35:2537–2542.
14. Kayaalp ME, Can A, Erdogan F, Ozsahin MK, Aydingoz O, Kaynak G. Level of osteotomy is relevant to obtain better union and clinical results in patients with severe hip dysplasia operated on with total hip arthroplasty and shortening osteotomy using a cementless, rectangular femoral component. Arch Orthop Trauma Surg. Epub 2020. 2021;141:155–163.
15. Krych AJ, Howard JL, Trousdale RT, Cabanela ME, Berry DJ. Total hip arthroplasty with shortening subtrochanteric osteotomy in Crowe type-IV developmental dysplasia: surgical technique. J Bone Joint Surg Am. 2010;92(Suppl 1 Pt 2):176–187.
16. Kuster LS, Marshall D, Fassler C, Duff SJ, Hayes A, Kuster MS. Can prophylactic cables stop crack propagation in revision arthroplasty: a biomechanical study. J Arthroplasty. 2019;34:987–990.
17. Li C, Zhang C, Zhang M, Ding Y. Comparison of transverse and modified subtrochanteric femoral shortening osteotomy in total hip arthroplasty for developmental dysplasia of hip: a meta-analysis. BMC Musculoskelet Disord. 2014;15:331.
18. Liu S, Zuo J, Li Z, Yang Y, Liu T, Xiao J, Gao Z. Study of three-dimensional morphology of the proximal femur in developmental adult dysplasia of the hip suggests that the on-shelf modular prosthesis may not be an ideal choice for patients with Crowe type IV hips. Int Orthop. 2017;41:707–713.
19. McCarthy JC, Bono JV, Turner RH, Kremchek T, Lee J. The outcome of trochanteric reattachment in revision total hip arthroplasty with a Cable Grip System: mean 6-year follow-up. J Arthroplasty. 1999;14:810–814.
20. Mehta V, Finn HA. Femoral artery and vein injury after cerclage wiring of the femur: a case report. J Arthroplasty. 2005;20:811–814.
21. Mu W, Yang D, Xu B, Mamtimin A, Guo W, Cao L. Midterm outcome of cementless total hip arthroplasty in Crowe IV–Hartofilakidis Type III developmental dysplasia of the hip. J Arthroplasty. 2016;31:668–675.
22. Noble PC, Kamaric E, Sugano N, Matsubara M, Harada Y, Ohzono K, Paravic V. Three-dimensional shape of the dysplastic femur: implications for THR. Clin Orthop Relat Res. 2003;417:27–40.
23. Ollivier M, Abdel MP, Krych AJ, Trousdale RT, Berry DJ. Long-term results of total hip arthroplasty with shortening subtrochanteric osteotomy in Crowe IV developmental dysplasia. J Arthroplasty. 2016;31:1756–1760.
24. Park M-S, Kim K-H, Jeong W-C. Transverse subtrochanteric shortening osteotomy in primary total hip arthroplasty for patients with severe hip developmental dysplasia. J Arthroplasty. 2007;22:1031–1036.

25. Perka C, Fischer U, Taylor WR, Matziolis G. Developmental hip dysplasia treated with total hip arthroplasty with a straight stem and a threaded cup. J Bone Joint Surg Am. 2004;86:312–319.
26. Unnanuntana A, Saiyudthong N. Outcomes of cerclage wiring to manage intra-operative femoral fracture occurring during cementless hemiarthroplasty in older patients with femoral neck fractures. Int Orthop. 2019;43:2637–2647.
27. Waligora AC 4th, Owen JR, Wayne JS, Hess SR, Golladay GJ, Jiranek WA. The effect of prophylactic cerclage wires in primary total hip arthroplasty: a biomechanical study. J Arthroplasty. 2017;32:2023–2027.
28. Wang D, Li DH, Li Q, Wang H-Y, Luo Z-Y, Yang Y, Pei F-X, Zhou Z-K. Subtrochanteric shortening osteotomy during cementless total hip arthroplasty in young patients with severe developmental dysplasia of the hip. BMC Musculoskelet Disord. 2017;18:491.
29. Wang D, Li LL, Wang HY, Pei FX, Zhou ZK. Long-term results of cementless total hip arthroplasty with subtrochanteric shortening osteotomy in Crowe type IV developmental dysplasia. J Arthroplasty. 2017;32:1211–1219.
30. Young PS, Patil S, Meek RMD. Intraoperative femoral fractures: prevention is better than cure. Bone Joint Res. 2018;7:103–104.

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