Original article
https://doi.org/10.17816/2311-2905-17417

Which Factors Can Lead to Subsidence of a Non-Modular Tapered Stem after Revision Hip Arthroplasty?

Rashid M. Tikhilov [1], Alisagib A. Dzhavadov [1], Artur V. Koptsov [2], Pavel V. Filonov [1], Saida M. Kurbanova [3], Igor I. Shubnyakov [1]

[1] *Vreden National Medical Research Center of Traumatology and Orthopedics, St. Petersburg, Russia*

[2] *Tetyukhin Urals Clinical Treatment and Rehabilitation Center, Nizhny Tagil, Russia*

[3] *Pavlov First Saint Petersburg State Medical University, St. Petersburg, Russia*

Abstract

Aim of the study — to evaluate our own experience of the use of non-modular tapered stems in revision hip arthroplasty to determine the incidence and causes of repeated revisions, functional outcomes, and factors associated with the subsidence of non-modular tapered stems.

Methods. We retrospectively analyzed the results of using 78 non-modular tapered stems. The average follow-up period was 5.1 years.

Results. There were repeated revisions accompanied by the removal of non-modular tapered stems in 14 (17.9%) cases. Significant subsidence was observed in 5 (6.4%) cases. Bicortical contact less than 2.0 cm ($p = 0.017$) was a risk factor for the subsidence of non-modular tapered stems. The risk of having a bicortical contact of less than 2 cm was higher in patients with type IV femoral defect ($p = 0.048$). An improvement in functional parameters was found. Patients with significant subsidence of non-modular tapered stems had worse functional outcomes compared to the patients without significant subsidence.

Conclusions. The use of non-modular tapered stems in revision hip arthroplasty shows good results in terms of repeated revision rates and functional outcomes. Periprosthetic infection and aseptic loosening were the most frequent causes of repeated revisions with the removal of non-modular tapered stems. All patients with significant subsidence of non-modular tapered stems underwent repeated revision due to aseptic loosening. Bicortical contact less than 2.0 cm was a risk factor for significant subsidence of non-modular tapered stems. The risk of bicortical contact less than 2.0 cm was higher in patients with type IV femoral defects. Therefore, it is recommended to use non-modular tapered stems with caution or consider other hip reconstruction options in this type of defect.

Keywords: revision hip arthroplasty, non-modular tapered stem, bicortical contact, femoral defects.

Cite as: Tikhilov R.M., Dzhavadov A.A., Koptsov A.V., Filonov P.V., Kurbanova S.M., Shubnyakov I.I. Which Factors Can Lead to Subsidence of a Non-Modular Tapered Stem after Revision Hip Arthroplasty? *Traumatology and Orthopedics of Russia*. 2024;30(1):42-51. (In Russian). https://doi.org/10.17816/2311-2905-17417.

Alisagib A. Dzhavadov; e-mail: alisagib.dzhavadov@mail.ru

Submitted: 28.11.2023. Accepted: 08.02.2024. Published Online: 14.03.2024.

Научная статья
УДК 616.728.2-089.844-089.193.4-06
https://doi.org/10.17816/2311-2905-17417

Какие факторы могут привести к проседанию немодульного конического бедренного компонента после ревизионного эндопротезирования тазобедренного сустава?

Р.М. Тихилов [1], А.А. Джавадов [1], А.В. Копцов [2], П.В. Филонов [1], С.М. Курбанова [3], И.И. Шубняков [1]

[1] ФГБУ «Национальный медицинский исследовательский центр травматологии и ортопедии им. Р.Р. Вредена» Минздрава России, г. Санкт-Петербург, Россия

[2] ООО «Уральский клинический лечебно-реабилитационный центр им. В.В. Тетюхина», г. Нижний Тагил, Россия

[3] ФГБОУ ВО «Первый Санкт-Петербургский государственный медицинский университет им. акад. И.П. Павлова» Минздрава России, г. Санкт-Петербург, Россия

Реферат

Цель исследования — оценка собственного опыта использования немодульных конических бедренных компонентов при ревизионном эндопротезировании тазобедренного сустава для определения частоты и причин повторных ревизий, функциональных результатов, а также факторов, ассоциированных с проседанием немодульных конических бедренных компонентов.

Материал и методы. Был проведен ретроспективный анализ результатов использования немодульных конических бедренных компонентов (НКБК) в 78 случаях. Средний срок наблюдения составил 5,1 лет.

Результаты. В 14 (17,9%) случаях были выполнены повторные ревизии, сопровождающиеся удалением НКБК. Значительное проседание наблюдалось в 5 (6,4%) случаях. Бикортикальный контакт менее 2,0 см (p = 0,017) был фактором риска проседания немодульных конических бедренных компонентов. Риск получения бикортикального контакта менее 2 см был выше у пациентов с дефектом бедренной кости IV типа (p = 0,048). Было выявлено улучшение функциональных показателей. Пациенты со значительным проседанием НКБК имели худшие функциональные результаты по сравнению с пациентами без значительного проседания.

Заключение. Использование НКБК при ревизионном эндопротезировании тазобедренного сустава показывает хорошие результаты в отношении частоты повторных ревизий и функциональных показателей. Наиболее частыми причинами повторных ревизий с удалением НКБК были перипротезная инфекция и асептическое расшатывание. У всех пациентов со значительным проседанием НКБК была выполнена повторная ревизия по причине асептического расшатывания. Бикортикальный контакт менее 2,0 см являлся фактором риска значительного проседания НКБК. Риск возникновения бикортикального контакта менее 2,0 см был выше у пациентов с дефектами бедренной кости IV типа, поэтому при данном типе дефекта рекомендуется использовать НКБК с осторожностью или рассматривать другие варианты реконструкции бедра.

Ключевые слова: ревизионное эндопротезирование тазобедренного сустава, немодульный конический бедренный компонент, бикортикальный контакт, дефект бедренной кости.

Для цитирования: Тихилов Р.М., Джавадов А.А., Копцов А.В., Филонов П.В., Курбанова С.М., Шубняков И.И. Какие факторы могут привести к проседанию немодульного конического бедренного компонента после ревизионного эндопротезирования тазобедренного сустава? *Травматология и ортопедия России*. 2024;30(1): 42-51. https://doi.org/10.17816/2311-2905-17417.

Джавадов Алисагиб Аббасович; e-mail: alisagib.dzhavadov@mail.ru

Рукопись получена: 28.11.2023. Рукопись одобрена: 08.02.2024. Статья опубликована онлайн: 14.03.2024.

BACKGROUND

National registries data indicate an increase in the number of revision hip arthroplasties (RHA) [1, 2, 3]. The choice of the femoral stem for achieving stable fixation is one of the most important stages of RHA. Nowadays, we have gained experience in the use of various types of stems in RHA [4, 5, 6, 7, 8].

In 1987, H. Wagner described the use of non-modular tapered stems (NMTS) in RHA. The stem is fixed in the diaphysis, the tapered geometry provides axial stability, and longitudinal ribs provide rotational stability [9]. These stems have shown good results in RHA. However, a significant subsidence (≥10 mm) remains one of the problems after implantation of these types of stems [10, 11]. Several authors have shown that subsidence of NMTS may be related to the extent of bone loss of the femur and poor filling of its canal with the stem [7, 10, 12]. Studies on the outcomes of using modular tapered stems indicate a greater risk of subsidence when bicortical stem contact is less than 2 cm [13, 14], while bicortical contact of less than 2 cm as a risk factor for NMTS subsidence has not been well studied.

Aim of the study is to evaluate our own experience of the use of non-modular tapered stems in revision hip arthroplasty to determine its incidence and causes, functional outcomes, and factors associated with subsidence of these types of stems.

METHODS

Study design

Inclusion criteria were the use of Wagner Self-Locking (SL) NMTS (Zimmer Biomet, USA) in RHA and a follow-up period of at least two years. An *exclusion criterion* was the use of Wagner SL NMTS in primary total hip arthroplasty. Seventy-eight RHAs performed between 2008 and 2020 by the same surgeon were included in the study. A retrospective analysis of medical histories and X-rays was performed. Patients were invited to the clinic for physical and radiological examination. Those who could not come to the clinic were contacted by phone and asked to send X-rays via e-mail. Mean follow-up was 5.1 years: standard deviation (SD) — 2.5; median (Me) — 4.9; interquartile range (IQR) (25-75) — 3.8-6.1; minimum and maximum values (min-max) — 2.1-14.3.

Assessment of results

We analyzed various types of complications in the postoperative period. Comparative assessment of functional outcomes in the pre- and postoperative periods was performed using the Oxford Hip Score questionnaire [15]. The Paprosky classification [16] was used to describe femoral bone defects. The type of periprosthetic fracture causing RHA was determined according to the unified classification system [17]. Intraoperative periprosthetic fractures were described according to the Vancouver classification [18].

Radiological assessment was used to compare the position of the components at two time points: immediately after surgery and at the time of the last radiological examination. Stem subsidence was determined by comparing landmarks on the femur and on the prosthesis, which were clearly visible in all X-rays. The medial point of the lesser trochanter, calcar, proximal or distal contour of the lesser trochanter, and cerclage wires were used as landmarks on the femur. The apex of the stem shoulder was used as a landmark on the prosthesis. We drew a line from the reference point on the femur to the reference point on the prosthesis. This vertical line allowed us to calculate the actual length of the stem subsidence over the cortical bone (Fig. 1).

A subsidence of 10 mm or more was considered clinically significant. Bicortical contact was determined as the total length of the direct contact between the cortical plate and the contour of the prosthesis without a radiolucent line on the femur X-ray in the AP view [13, 14] (Fig. 2). Stem varus-valgus alignment was determined by measuring the angle between the lateral periosteal surface of the femoral canal and the longitudinal axis of the stem [19]. The known diameter of the femoral head was used to assess the accuracy of all measurements.

For 5-6 weeks, patients were advised to use crutches and limit axial load on the operated leg. In the period from 6 weeks to 3 months, patients were recommended to start full weight bearing on the operated leg using crutches or cane.

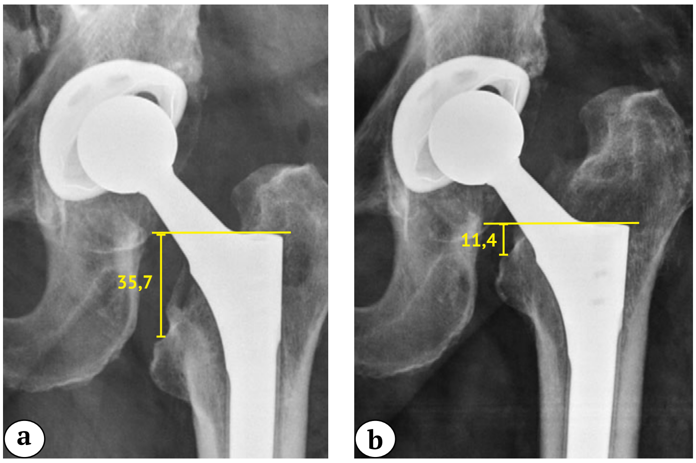

Fig. 1. X-ray images of the left hip of a 64-year-old patient after revision surgery:
a — on day 1;
b — in 9 months: 24.3 mm subsidence of the stem is observed

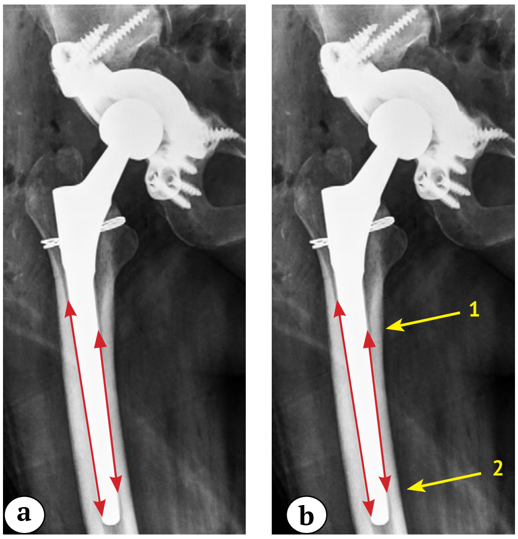

Fig. 2. X-ray images of the right hip of a 50-year-old patient on day 1 after revision surgery:
a — the lines indicate the contact between the femoral component and the cortical layer of the femur on the medial and lateral sides;
b — the length of the bicortical contact was defined as the total length of the direct contact between the cortical plate and the contour of the prosthesis without a radiolucent line (arrows 1 and 2)

Mean length of the implanted stems was 235.4 mm (SD — 40.2; Me — 225; IQR — 190-265, min-max — 190-305 mm); diameter — 16.9 mm (SD — 2.6; Me — 17; IQR — 15-18; min-max — 14-25). Mean surgery duration was 188.8 min (SD — 48.5; Me — 180; IQR — 160.0-271.5; min-max — 100-310), and mean blood loss was 605 ml (SD — 330.4; Me — 500; IQR — 400-825; min-max — 150-1600). Patients' characteristics and the features of surgical treatment are presented in Tables 1, 2, 3.

Table 1

Baseline characteristics of patients

Parameter	Number (%)	M±SD	Me	IQR (25–75)	min-max
Age, years old	–	57.1±12.2	58.0	49–65	24–84
Gender male female	26 (33.3) 52 (66.7)	–	–	–	–
BMI, kg/m^2	–	26.9±4.2	27.1	23.7–28.7	17.8–38.2
Previous surgeries	–	2.6±19.0	2	1–3	1–11

Table 2

Revisions causes, types of defects and periprosthetic fractures

Parameter	Number (%)
Revision cause	
aseptic loosening	31 (39.7)
periprosthetic infection (second stage)	33 (42.3)
periprosthetic fracture	5 (6.4)
pain after arthroplasty	2 (2.6)
dislocation	1 (1.3)
mechanical destruction	6 (7.7)
Defect type (Paprosky classification)	
II	16 (20.5)
IIIA	33 (42.3)
IIIB	24 (30.8)
IV	5 (6.4)
Periprosthetic fracture type (unified classification system)	
B2	2 (40)
B3	3 (60)

Table 3

Specific characteristics of surgeries

Parameter	Number (%)
Side	
left	41 (52.6)
right	37 (47.4)
Extent of revision	
femoral stem replacement	19 (24.4)
femoral and acetabular component replacement	59 (75.6)
Femoral bone grafting	
morselized bone graft	5 (50)
structural bone graft	5 (50)

Statistical analysis

Clinical (age, weight, gender, number of hip surgeries, previous infection, allograft use, femoral stem length, femoral stem diameter, preoperative periprosthetic fractures, intraoperative periprosthetic fractures, extended femoral osteotomy, type of femoral defect) and radiological (medial-lateral bicortical contact of the stem and stem varus-valgus alignment) factors were analyzed. Normality of the distribution was tested using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. In case of normal distribution of quantitative indicators, we used Student's t-test to analyze the independent samples. If the distribution of quantitative indicators differed from normal, the Mann-Whitney U test was used to analyze the independent samples. Wilcoxon's test was used for analysis of dependent samples. The chi-square test and Fisher's exact test were used to assess the differences between nominal variables. In some cases, the odds ratio (OR) was identified. A value of $p<0.05$ was used as a criterion for statistical significance of observed differences. However, a Bonferroni correction for p-value was applied when comparing individual categories in categorical variables. Thus, for intraoperative periprosthetic fractures, periprosthetic fractures as causes of RHA, and types of femoral defects according to the Paprosky classification, $p<0.01$, $p<0.025$, and $p<0.0125$ values were determined as criteria for statistical significance, respectively.

Statistical analysis was performed using Past software version 4.03 (Norway) [20].

RESULTS

In 14 (17.9%) out of 78 cases, repeated revisions with stem removal were performed for the following reasons: periprosthetic joint infection (PJI) in 7 cases, aseptic loosening of the femoral stem in 5 cases, pain syndrome in 1 case, and mechanical failure in 1 case. The mean time for complications was 31 months (SD — 42.5; Me — 15; IQR — 5.0-46.5; min-max — 3-166). The mean stem subsidence in all patients was 1.9 mm (SD — 7.0; Me — 0; IQR — 0-0-0; min-max — 0.0-37.8). Significant subsidence was observed in 5 (6.4%) cases. The mean subsidence in this group of patients was 26.5 mm (SD — 8.4; Me — 24.7; IQR — 18.8-35.1; min-max — 18.4-37.8). All 5 patients underwent repeated revision due to aseptic loosening of the femoral stem. In 73 (93.6%) cases, the subsidence was less than 10 mm with the mean subsidence of 0.07 (SD — 0.4; Me — 0; IQR — 0-0; min-max — 0.0-3.3).

In 9 (12.3%) out of 73 cases with subsidence less than 10 mm, complications that required repeated revisions with stem removal were observed: in 7 cases due to PJI, in one — due to pain, and in one more — due to mechanical stem destruction. Patients with significant stem subsidence were significantly more likely to have a bicortical contact less than 2 cm compared to the group of patients with stem subsidence less than 10 mm (Table 4). The odds ratio for the bicortical contact factor less than 2.0 cm when comparing two groups of patients was 15.5 (95% CI 1.6-148.9; p = 0.017). The lowest value of bicortical contact was found in patients with type IV femoral defect — 2.8 cm (SD — 2.2; Me — 1.3; IQR — 1.2-4.8; min-max — 1.2-6.3). In patients with less femoral bone loss, we obtained the following bicortical contact values: type II femoral defects — 5.3 cm (SD — 3.1; Me — 6.1; IQR — 2.6-8.2; min-max — 0.0-9.5), type IIIA femoral defects — 4.6 cm (SD — 3.7; Me — 4.5; IQR — 0.8-7.5; min-max — 0.0-10.8), and type IIIB femoral defects — 5.5 cm (SD — 4.0; Me — 4.3; IQR — 2.2-8.6; min-max — 0.0-14.3). The risk of bicortical contact less than 2.0 cm was higher in patients with type IV hip defects (OR = 6.3; 95% CI — 0.9-41.5; p = 0.048 for type IV compared to types II, IIIA, IIIB).

When comparing the Oxford Hip Score, there was a statistically significant difference (p<0.001): preoperatively (M±SD — 14.5±7.2; Me — 15; IQR — 10-20; min-max — 0 to 27) and postoperatively (M±SD — 34.2±7.2; Me — 34; IQR — 28-41; min-max — 22 to 48). Patients with significant stem subsidence had lower Oxford Hip Score values compared to patients without significant subsidence — (M±SD — 22.8±1.3; Me — 22; IQR — 22-24; min-max — 22 to 25) vs (M±SD — 36.5±7.1; Me — 36; IQR — 31-43; min-max — 22 to 48) (p<0.001) (Fig. 3).

Table 4

Analysis of the influence of various factors on the femoral stem subsidence

Factor	Patients with significant stem subsidence, n = 5	Patients without significant stem subsidence, n = 73	p
Age, years old	Mean — 62.4 (SD — 2.6; Me — 62; IQR — 60–65; min-max — 60-66)	Mean — 56.7 (SD — 11.9; Me — 57; IQR — 52–64; min-max — 24-84)	0.136
BMI, kg/m2	Mean — 29.9 (SD — 2.7; Me — 39; IQR — 27.5–31.8; min-max — 27.2-32.5)	Mean — 26.5 (SD — 4.6; Me — 26.5; IQR — 23.9–28.5; min-max —17.8-38.2)	0.102
Male	3 (60%)	23 (31%)	0.326
Number of surgeries on the hip joint	Mean — 2.4 (SD — 1.9; Me — 1; IQR — 1–4.5; min-max — 1-5)	Mean — 2.5 (SD — 1.9; Me — 2; IQR — 1–3; min-max — 1-11)	0.835
Infection in the medical history	2 (40%)	31 (42.5%)	1.0
Use of the structural allograft	0 (0%)	5 (6.8%)	1.0

End of Table 4

Factor	Patients with significant stem subsidence, n = 5	Patients without significant stem subsidence, n = 73	p
Length of the stem, mm	Mean — 249 (SD — 35.8; Me — 225; IQR — 225–285; min-max — 225-305)	Mean — 232.3 (SD — 41.3; Me — 225; IQR — 190–265; min-max — 190-305)	0.412
Diameter of the stem, mm	Mean — 16.2 (SD — 1.9; Me — 16; IQR — 14.5–18; min-max — 14-19)	Mean — 17.1 (SD — 2.7; Me — 17; IQR — 15–18; min-max — 14-25)	0.566
Factor	Patients with significant stem subsidence, n = 5	Patients without significant stem subsidence, n = 73	p
Intraoperative periprosthetic fractures			
A2	0 (0%)	2 (2.7%)	1.0*
A3	0 (0%)	1 (1.4%)	1.0*
B2	0 (0%)	1 (1.4%)	1.0*
B3	1 (20%)	0 (0%)	0.064*
C2	0 (0%)	1 (1.4%)	1.0*
Periprosthetic fractures as a cause of RHA			
B2	0 (0%)	2 (2.7%)	1.0**
B3	0 (0%)	3 (4.1%)	1.0**
Extended osteotomy of the femur	1 (20%)	14 (19.2%)	1.0
Defect type (Paprosky classification)			
II	1 (20%)	15 (20.5%)	1.0***
IIIA	2 (40%)	31 (42.5%)	1.0***
IIIB	0 (0%)	24 (32.9%)	0.316***
IV	2 (40%)	3 (4.1%)	0.031***
Medial-lateral bicortical contact <2,0 cm	4 (80%)	15 (20.5%)	**0.011**
Stem varus-valgus alignment, deg.	Mean — 0.32 (SD — 0.3; Me — 0.3; IQR — 0–0.65; min-max — 0-0.8)	Mean — 0.63 (SD — 0.9; Me — 0.2; IQR — 0–0.9; min-max — 0.3-3.6)	0.874

Statistically significant *p* is in bold.
After application of the Bonferroni correction: * — $p<0{,}01$; ** — $p<0{,}025$; *** — $p<0{,}0125$.

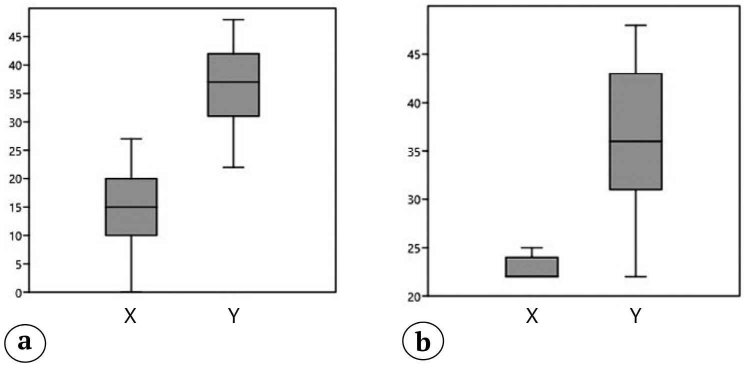

Fig. 3. The functional status according to the Oxford Hip Score:
a — preoperative (x), postoperative (y);
b — patients with significant stem subsidence (x), patients without significant stem subsidence (y)

DISCUSSION

In our study, we evaluated the results of NMTS use in 78 cases of RHA. A statistically significant improvement in functional outcomes was noted, which is consistent with the results of the studies by other authors [21]. The subsidence in all patients was 1.9 mm. A significant subsidence was observed in 5 (6.4%) cases. These results are comparable to those reported in other studies [10, 11, 22]. The risk factor for significant subsidence was a bicortical contact of less than 2 cm. S. Tangsataporn et al. also identified bicortical contact of less than 2 cm as a risk factor for significant subsidence, but only for modular tapered stems [13]. P. Moriarty et al. also reported that modular tapered stems with bicortical contact less than 2 cm were characterized by a higher incidence of significant subsidence [14]. Regarding NMTS, J. Gutiérrez Del Alamo et al. and A. Baktır et al. reported that significant subsidence was associated with poor filling of the femoral canal. In our opinion, poor femoral canal filling may indirectly indicate insufficient bicortical contact. However, this is only our assumption, since bicortical contact was not evaluated in these studies [10, 12].

We found that the risk of having a bicortical contact of less than 2 cm was higher in patients with Paprosky type IV femoral defect (p = 0.048). Thus, in this case it is much more difficult to achieve a bicortical contact threshold of 2 cm, which may result in significant subsidence. The option of using NMTS in this type of defect was considered in a study by D. Regis et al. Wagner SL revision stem was implanted in 12 (29.3%) out of 41 cases in type IV femoral defect according to the Paprosky classification, and no significant subsidence of the stem was observed in any case [11]. On the other hand, P. Böhm and O. Bischel noted a positive association between femoral defects graded as 1B or higher according to the Böhm and Bischel classification system and subsidence of the Wagner SL revision stem; however, it should be noted that the characteristics of the femoral defects according to this classification differ from those of the femoral defects according to the Paprosky classification [7]. We believe that NMTS should be used with caution in type IV femoral defects. We would like to emphasize that the use of NMTS in other types of femoral defects may be a good solution because, for example, in types IIIA, IIIB, and II femoral defects we obtained bicortical contact values well above the 2 cm threshold, which ultimately reduces the risk of significant subsidence.

We recommend aggressive reaming, especially in the pedestal region, to ensure adequate contact of the stem with the cortical bone. We also consider it reasonable to perform intraoperative X-rays in the AP view to assess the achievement of the 2 cm bicortical contact threshold, although in our cohort of patients there were only a few cases with intraoperative radiological control.

The most common cause of NMTS removal in the study by A.J. Clair et al., similar to our report, was PJI — 4.5% of the total number of cases [23]. The authors noted that the higher PJI incidence in patients with NMTS compared to patients with modular stems may be related to the longer mean surgery duration in case of NMTS use — 193±66 minutes versus 163±78 minutes. Mean surgery duration when implanting NMTS in our study was shorter compared to the data of A.J. Clair et al. and amounted to 188.8 min. At the same time, in 5 out of 7 cases where the Wagner SL revision stem was removed due to PJI, the patients had previously undergone hip interventions associated with PJI. In our opinion, PJI development in these patients may be related not only to the duration of revision surgery, but also to the presence of infectious complications in the medical history.

Limitations of the study

Our study is retrospective. We do not have complete data on each patient at certain time points. All operations were performed by the same surgeon.

CONCLUSIONS

The use of non-modular tapered stems in revision hip arthroplasty shows good results in terms of revision rates and functional outcomes. Periprosthetic infection and aseptic loosening were the most frequent causes of repeated revisions with removal of non-modular tapered stems. All patients with significant subsidence of these stems underwent repeated revision due to aseptic loosening. Bicortical contact less than

2.0 cm was a risk factor for significant subsidence of non-modular tapered stems. The risk of bicortical contact of less than 2.0 cm was higher in patients with type IV femoral defects. Therefore, it is recommended to use non-modular tapered stems with caution or consider other hip replacement options in this type of defect.

DISCLAIMERS

Funding source. This study was not supported by any external sources of funding.

Disclosure competing interests. The authors declare that they have no competing interests.

Ethics approval. Not applicable.

Consent for publication. The authors obtained written consent from patients to participate in the study and publish the results.

REFERENCES

1. Furnes O.G.J., Hallan G., Visnes H., Gundersen T., Fenstad A.M., Dybvik E. et al. Annual Report Norwegian National Advisory Unit on Arthroplasty and Hip Fractures. Bergen: Health Bergen H.F.; 2021:2021.
2. Kärrholm J., Rogmark C., Naucler E., Nåtman J., Vinblad J., Mohaddes M. et al. Swedish Hip Arthroplasty Register Annual report 2019. Available from: https://registercentrum.blob.core.windows.net/shpr/r/VGR_Annual-report_SHAR_2019_EN_Digital-pages_FINAL-ryxaMBUWZ_.pdf.
3. Shubnyakov I.I., Riahi A., Denisov A.O., Korytkin A.A., Aliev A.G., Veber E.V. et al. The Main Trends in Hip Arthroplasty Based on the Data in the Vreden's Arthroplasty Register from 2007 to 2020. *Traumatology and Orthopedics of Russia*. 2021;27(3):119-142. (In Russian). doi: 10.21823/2311-2905-2021-27-3-119-142.
4. Hamilton W.G., Cashen D.V., Ho H., Hopper R.H. Jr., Engh C.A. Extensively porous-coated stems for femoral revision: a choice for all seasons. *J Arthroplasty.* 2007;22(4 Suppl 1):106-110. doi: 10.1016/j.arth.2007.01.002.
5. Cameron H.U. The long-term success of modular proximal fixation stems in revision total hip arthroplasty. *J Arthroplasty.* 2002;17(4 Suppl 1):138-141. doi: 10.1054/arth.2002.32462.
6. Ovesen O., Emmeluth C., Hofbauer C., Overgaard S. Revision total hip arthroplasty using a modular tapered stem with distal fixation: good short-term results in 125 revisions. *J Arthroplasty.* 2010;25(3):348-354. doi: 10.1016/j.arth.2008.11.106.
7. Böhm P., Bischel O. Femoral revision with the Wagner SL revision stem: evaluation of one hundred and twenty-nine revisions followed for a mean of 4.8 years. *J Bone Joint Surg Am.* 2001;83(7):1023-1031.
8. Ornstein E., Linder L., Ranstam J., Lewold S., Eisler T., Torper M. Femoral impaction bone grafting with the Exeter stem – the Swedish experience: survivorship analysis of 1305 revisions performed between 1989 and 2002. *J Bone Joint Surg Br.* 2009;91(4):441-446. doi: 10.1302/0301-620X.91B4.21319.
9. Wagner H. Revision prosthesis for the hip joint in severe bone loss. *Orthopade.* 1987;16(4):295-300. (In German).
10. Baktır A., Karaaslan F., Gencer K., Karaoğlu S. Femoral Revision Using the Wagner SL Revision Stem: A Single-Surgeon Experience Featuring 11-19 Years of Follow-Up. *J Arthroplasty.* 2015;30(5):827-834. doi: 10.1016/j.arth.2014.12.024.
11. Regis D., Sandri A., Bonetti I., Braggion M., Bartolozzi P. Femoral revision with the Wagner tapered stem: a ten- to 15-year follow-up study. *J Bone Joint Surg Br.* 2011;93(10):1320-1326. doi: 10.1302/0301-620X.93B10.25927.
12. Gutiérrez Del Alamo J., Garcia-Cimbrelo E., Castellanos V., Gil-Garay E. Radiographic bone regeneration and clinical outcome with the Wagner SL revision stem: a 5-year to 12-year follow-up study. *J Arthroplasty.* 2007;22(4):515-524. doi: 10.1016/j.arth.2006.04.029.
13. Tangsataporn S., Safir O.A., Vincent A.D., Abdelbary H., Gross A.E., Kuzyk P.R. Risk Factors for Subsidence of a Modular Tapered Femoral Stem Used for Revision Total Hip Arthroplasty. *J Arthroplasty.* 2015;30(6):1030-1034. doi: 10.1016/j.arth.2015.01.009.
14. Moriarty P., Sheridan G.A., Wong L., Guerin S., Gul R., Harty J.A. Bicortical Contact Predicts Subsidence of Modular Tapered Stems in Revision Total Hip Arthroplasty. *J Arthroplasty.* 2020;35(8):2195-2199. doi: 10.1016/j.arth.2020.03.047.
15. Dawson J., Fitzpatrick R., Carr A., Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg Br.* 1996;78-B:185-190. doi: 10.1302/0301-620X.78B2.0780185.
16. Weeden S.H., Paprosky W.G. Minimal 11-year follow-up of extensively porous-coated stems in femoral revision total hip arthroplasty. *J Arthroplasty.* 2002;17(4 Suppl 1):134-137. doi: 10.1054/arth.2002.32461.
17. Duncan C.P., Haddad F.S. The Unified Classification System (UCS): improving our understanding of periprosthetic fractures. *Bone Joint J.* 2014;96-B(6):713-716. doi: 10.1302/0301-620X.96B6.34040.
18. Masri B.A., Meek R.M., Duncan C.P. Periprosthetic fractures evaluation and treatment. *Clin Orthop Relat Res.* 2004;(420):80-95. doi: 10.1097/00003086-200403000-00012.
19. Callaghan J.J., Salvati E.A., Pellicci P.M., Wilson P.D. Jr., Ranawat C.S. Results of revision for mechanical failure after cemented total hip replacement, 1979 to 1982. A two to five-year follow-up. *J Bone Joint Surg Am.* 1985;67(7):1074-1085.
20. Hammer Ø., Harper D.A.T., Ryan P.D. PAST: Paleontological statistics software package for education and data analysis past: paleontological statistics software package for education and data analysis. *Palaeontol Electron.* 2001;4:1-9.

21. Sandiford N.A., Garbuz D.S., Masri B.A., Duncan C.P. Nonmodular tapered fluted titanium stems osseointegrate reliably at short term in revision THAs. *Clin Orthop Relat Res.* 2017;475(1):186-192. doi: 10.1007/s11999-016-5091-x.
22. Huang Y., Zhou Y., Shao H., Gu J., Tang H., Tang Q. What is the difference between modular and nonmodular tapered fluted titanium stems in revision total hip arthroplasty. *J Arthroplasty.* 2017;32(10):3108-3113. doi: 10.1016/j.arth.2017.05.021.
23. Clair A.J., Cizmic Z., Vigdorchik J.M., Poultsides L.A., Schwarzkopf R., Rathod P.A. et al. Nonmodular Stems Are a Viable Alternative to Modular Stems in Revision Total Hip Arthroplasty. *J Arthroplasty.* 2019;34(7S): S292-S296. doi: 10.1016/j.arth.2019.03.007.

Authors' information

✉ *Alisagib A. Dzhavadov* — Cand. Sci. (Med.)
Address: 8, Akademika Baykova st., St. Petersburg, 195427, Russia
https://orcid.org/0000-0002-6745-4707
e-mail: alisagib.dzhavadov@mail.ru

Rashid M. Tikhilov — Dr. Sci. (Med.), Professor
https://orcid.org/0000-0003-0733-2414
e-mail: rtikhilov@gmail.com

Artur V. Koptsov
https://orcid.org/0000-0002-4353-4710
e-mail: avkoptsov@gmail.com

Pavel V. Filonov
https://orcid.org/0000-0001-7758-0128
e-mail: drpavelfilonov@gmail.com

Saida M. Kurbanova
https://orcid.org/0009-0004-5825-5548
e-mail: angelina6791@list.ru

Igor I. Shubnyakov — Dr. Sci. (Med.)
https://orcid.org/0000-0003-0218-3106
e-mail: shubnyakov@mail.ru