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Mix and Match Use of Revision Universal Head-Neck Adapters in Hip Arthroplasty: A Complications and Survival Analysis of 306 Cases

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ABSTRACT

Background: Outcomes and safety of "mix and match" in total hip arthroplasty (THA) using universal head-neck adapters (UHNA) are a matter of ongoing discussion and concern due to legal affairs. This study aimed at analyzing the "mix and match" use of UHNA and evaluating complication and reoperation rates, possible risk factors, and the implant's survival.

Methods: A total of 306 patients treated with THA (94.1% revisions) using a UHNA at our institution between 2006 and 2022 were identified and included. Diagnoses, comorbidities, implants, and UHNA specifications were retrospectively recorded. Outcomes, complications, and survival analyses were evaluated, taking into account various possible risk factors.

Results: There were 19.9% of the 306 included cases (58.5% women; median age 74 years; median follow-up 57 months) that had at least 1 complication. There were 43 patients (14.1%) who had to receive ≥1 rerevision surgery. The most common complication was postoperative recurrent dislocation (n = 27, 8.8%). There was one case of a prosthetic stem-neck fracture that was registered. Statistically significant risk factors for postoperative recurrent dislocations and postoperative aseptic loosening were, respectively, dislocation as an indication for UHNA implantation ($P < .001$) and oversized neck lengths (≥2XL; $P = .004$). The overall revision-free survival was 92% after 1 year and 82% at ten years. Statistically significant better survival rates were registered in patients ≥60 years old, who had fewer comorbidities (<2), and normal neck lengths (S to XL).

Conclusions: The results of this study underline the overall safety of UHNA use in THA through "mix and match." Only one case of a stem-neck fracture was identified. The highlighted risk factors for failure must be kept in mind during the decision-making process with patients.

In the field of revision total hip arthroplasty (THA), modular systems are currently state-of-the-art, with modular head-neck adapters being widely used [1–4]. Serving as a link between prosthesis' head and stem (Figure 1), the use of adapters allows for variable reconstruction of the hip's biomechanics without the need to replace a well osteo-integrated stem. By eliminating the risk of taper "mismatch" due to various stem models' designs and sizes, its universal adaptability enables the safer combination of components from various manufacturers, known as "mix and match" [5,6]. The expanded intraoperative flexibility through different versions of a universal head-neck adapter (UHNA) allows increased intraoperative biomechanical correction in revision THA and can offer particular advantages in primary THA with unconventional hip anatomy [7,8].

The rising incidence of both primary and revision THA [9,10] dictates the necessity to further evaluate the safety and possible risks of these universal adapter systems, especially in "mix and

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Fig. 1. Explanted example of the universal head-neck adapter with a lateralized configuration, a ceramic head, and an uncemented stem, with signs of mechanic wear and tear due to revision surgery.

match" solutions. The European Federation of National Associations of Orthopaedics and Traumatology published guidelines on "mix and match" in 2021 [5]. These recommendations allow "mix and match" in terms of a favorable outcome for the patient, although they highlight the need for further research on the topic and call for standardization in terms of tapers to minimize the problem of incompatibility [5]. On the other hand, the U.S. Food and Drug Administration considers "mix and match" joint arthroplasty an off-label use of medical devices and does not recommend it, primarily due to the risks and effects of taper mismatch [6,11,12]. However, UHNA systems offer to overcome this very issue: the metal's mechanical properties and adaptability of the adapters nullify this major "mix and match"-related concern.

Possible risks include implant fractures within the UHNA and "mix and match"-associated failures, such as breakage of the adapter, head fracture, femoral stem-neck failure, and metallosis, which have been outlined as rare events [4,13–17]. The current literature on modular head-neck adapters reveals an implant survival rate ranging from 87.9 to 98.0% [13,14,18,19], with 92.8% adapter survival in the longest published series (median follow-up of 52.5 months) [4]. A registry study analyzing 354 modular head-neck adapter systems in revision THA highlights a 5-year survival rate of 87.9%, indicating dislocations (2.8%) and cup aseptic loosening (4.2%) as the most frequent reasons for rerevision [13]. No breakage of the adapter system or the head occurred, while one femoral neck failed; no implant features impacted failures [13].

The long-term results of UHNA use in "mix and match" situations remain unclear and of great interest. Therefore, our goal was to contribute to research for quality purposes.

This retrospective study's hypothesis was the overall safety of the "mix and match" use of a UHNA of a single design with few or no specific complications. The authors aimed at evaluating complication and reoperation rates as well as providing an implant survival analysis that included a large variety of possible risk factors.

Table 1
Baseline Characteristics of Included Cohort.

Total No. of Patients, n (%)	306 (100)
Sex category, n (%)	
Women	179 (58.5)
Men	127 (41.5)
Age at UHNA implantation (years), median (IQR)	74 (62 to 81)
Age groups, n (%)	
<60 y	58 (19)
≥60 y	248 (81)
Follow-up (months), median (IQR)	56 (23 to 85)
Patients with revision prior to UHNA implantation, n (%)	100 (32.7)
Burden of comorbidity	
No. of comorbidities, median (IQR)	3 (1 to 4)
<2 comorbidities, n (%)	137 (44.8)
≥3 comorbidities, n (%)	169 (55.2)

UHNA, universal head-neck adapter; IQR, inter quartile range.

Table 2
Indications/Diagnoses Leading to Universal Head-Neck Adapter Implantation in Revision Total Hip Arthroplasty.

Indications/Diagnoses	n (%)[a]
Aseptic loosening	119 (27.7)
Cup aseptic loosening	100 (23.2)
Stem aseptic loosening	16 (3.7)
Cup and stem aseptic loosening	3 (0.7)
Liner wear	114 (26.5)
Polyethylene liner wear	106 (24.7)
Metal liner wear	8 (1.9)
Recurrent dislocation	65 (15.1)
Periprosthetic fracture	42 (9.8)
Periprosthetic femoral fracture	30 (7)
Periprosthetic acetabular fracture	12 (2.8)
Prosthesis infection	19 (4.4)
Early prosthesis infection (<3 mo)	4 (0.9)
Delayed prosthesis infection (3 to 24 mo)	3 (0.7)
Late prosthesis infection (>24 mo)	6 (1.4)
Chronical prosthesis infection	6 (1.4)
Septic loosening	11 (2.6)
Cup septic loosening	8 (1.9)
Stem septic loosening	2 (0.5)
Cup & stem septic loosening	1 (0.2)
Osteolysis	18 (4.2)
Other	18 (4.2)
Psoatic impingement	9 (2.1)
Conversion hemi to total hip arthroplasty	5 (1.2)
Heterotopic ossification	3 (0.7)
Offset dysfunction	1 (0.2)
Material fracture	14 (3.3)
Rescue procedures	10 (2.3)
St.p. spacer implantation	9 (2.1)
St.p. Girdlestone situation	1 (0.2)

[a] Multiple diagnoses for each patient were possible; the percentages of each indication should be interpreted as a percentage share of the total no. of indications (n = 430, 100%).

Table 3
Complications and Rerevisions.

Complication	No. of Cases with complications after UHNA Implantation, n(%)[a]	No. of Complications after UHNA Implantation (%)[b]	No. of Complications Leading to (re-) revision after UHNA Implantation (%)[c]	No. of (re-) Revisions due to Primary Surgery Indication (%)[d]
Total No.	61 (19.9)	71 (100)	52 (100)	19 (100)
Recurrent dislocation	27 (8.8)	27 (38)	19 (36.5)	14 (73.7)
Prosthesis infection	13 (4.2)	13 (18.3)	10 (19.2)	–
Early infection (<6 we)	4 (1.3)	4 (5.6)	3 (5.8)	–
Late infection (>6 we)	3 (1.0)	3 (4.2)	3 (5.8)	–
Chronic infection	6 (2.0)	6 (8.5)	4 (7.7)	–
Periprosthetic fracture	11 (3.6)	11 (15.5)	7 (13.5)	1 (5.3)
Femoral fracture	9 (2.9)	9 (12.7)	6 (11.5)	1 (5.3)
Acetabular fracture	2 (0.6)	2 (2.8)	1 (1.9)	–
Aseptic loosening	10 (3.3)	10 (14.1)	8 (15.4)	3 (15.8)
Cup aseptic loosening	7 (2.3)	7 (9.9)	5 (9.6)	3 (15.8)
Stem aseptic loosening	3 (1.0)	3 (4.2)	3 (5.8)	–
Septic loosening	5 (1.6)	5 (7)	5 (9.6)	–
Cup septic loosening	3 (1.0)	3 (4.2)	3 (5.8)	–
Stem septic loosening	2 (0.6)	2 (2.8)	2 (3.8)	–
Minor complications	3 (1.0)	3 (4.2)	1 (1.9)	–
Wound healing defect	3 (1.0)	3 (4.2)	1 (1.9)	–
Liner wear	1 (0.3)	1 (1.4)	1 (1.9)	1 (5.3)
Stem fracture	1 (0.3)	1 (1.4)	1 (1.9)	–
Patients with rerevisions after UHNA implantation, n (%)[a]				43 (14.1)
One rerevision				37 (12.1)
Multiple rerevisions				6 (2.0)

UHNA, universal head-neck adapter.
[a] Percentages of the total number of included patients (306).
[b] Percentages of the total no. of complications (71). Multiple complications for each patient were possible: 61 patients developed 71 complications.
[c] Percentages of the total no. of indications for rerevisions (52). Multiple diagnoses leading to rerevision after universal head-neck adapter implantation for each patient were possible: 43 patients required rerevisions due to 52 diagnoses.
[d] Percentage of the total no. of rerevisions due to the primary diagnosis and surgery indication (19).

Materials and Methods

Study Population and Data Collection

A total of 336 cases treated using the Merete BioBall UHNA (Merete Medical, Berlin, Germany) in THA between October 1, 2006, and May 31, 2022, were recorded through our hospital database, of which 306 cases (91.1%) could be included and retrospectively analyzed in this study. The exclusion criteria included duplicates and hip hemiarthroplasties. Most of the included patients received UHNA implantation during revision THA (n = 288, 94.1%); the remaining cases were primary THA (n = 18, 5.9%). In all revision THA cases where the UHNA was used in combination with an *in situ* stem, the compatibility and fit of the adapter on the stem taper were checked intra-operatively through the Bioball AdapterSelector device. The demographic characteristics (age, sex, and comorbidities registered according to the functional comorbidity index), case history (indication for UHNA implantation, prior surgeries, and revisions), and surgical data (procedures performed in combination with UHNA implantation, UHNA specifications, and arthroplasty components) were retrieved. Complete follow-up data (until July 31, 2023 or date of death), postoperative complications, and rerevisions were recorded. Complications and implant survival analyses were performed, taking into account various possible risk factors. Failure was defined as rerevision surgery after UHNA implantation. Case history and clinical follow-up were retrieved from the hospital intern data systems using keyword identification for all reports. Mortality was obtained from insurance data. Medical follow-up data (eg, outpatients' department visits) was retrieved from our hospital database systems, also including data from other regional public hospitals (minimizing the chance of undetected revision surgeries).

Data Analyses

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, IBM, Version 29 for Windows, Chicago). The normal distribution was tested using the Shapiro–Wilk and Kolmogorov–Smirnov tests. For non-normally distributed data, the median and interquartile ranges (IQRs) were reported. To identify risk factors for failure, we examined various variables with *Chi*-square tests (χ^2) or Fisher's exact tests, testing the strength of the associations through phi coefficients (ϕ) and odds ratios (ORs), respectively. These evaluated variables included sex category, age cohorts (<60 or ≥60 years), indications, THA or revision THA, prior revisions, UHNA specifications, and comorbidities. Revision-free survival analyses were conducted using Kaplan-Meier and log-rank tests, considering various influencing factors. Censoring criteria included instances of no rerevision after UHNA implantation and deaths unrelated to UHNA implantation. A P value <.05 was considered to be statistically significant.

Ethics Statement

The current study was approved by the local institutional ethical review board (Reference number: 35-033 ex 22/23).

Cohort Specifications

In total, 306 patients (58.5% women; median age of 74 years; IQR: 62 to 81) who had a median follow-up of 57 months (IQR, 23 to 85) were analyzed. Some patients had a history of prior revision THA before UHNA implantation (n = 100, 32.7%) (Table 1). The median number of comorbidities was 3. Overweight or obesity (body mass index [BMI] ≥30) was the most documented comorbidity (n = 150 cases, 49%), followed by degenerative disc disease

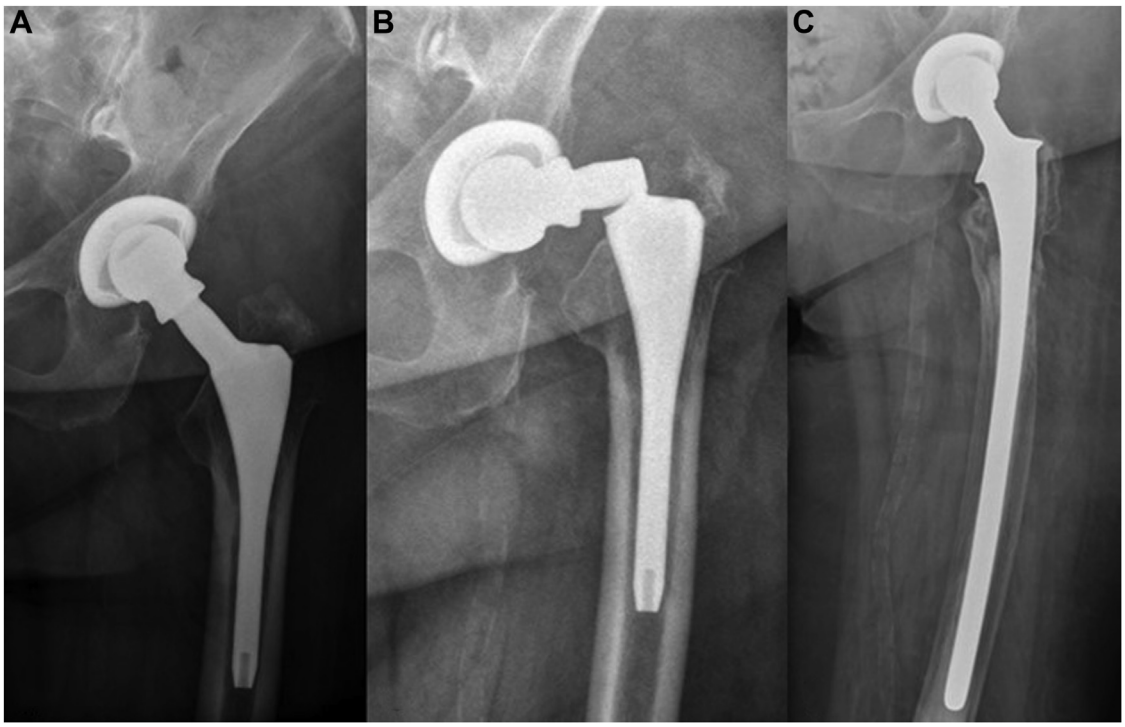

Fig. 2. Stem-neck fracture case. X-rays after revision total hip arthroplasty with the universal head-neck adapter in 2014 (A), of the stem-neck fracture at 16 months of follow-up (B), and after the rerevision surgery (C).

(n = 125, 40.8%). The main indications for UHNA implantation in revision THA were as follows: polyethylene (PE) inlay wear (n = 106, 24.7%), aseptic prosthesis cup loosening (n = 100, 23.3%), and recurrent dislocation (n = 65, 15.1%) (Table 2). In addition to UHNA implantation, several other procedures were performed, including revision of the prosthesis cup (n = 190, 59.6%), replacement of the hip prosthesis stem (n = 45, 14.1%), strut graft (n = 41, 12.9%), and support cup implantation (n = 26, 8.2%). Most patients did not need an exchange of the prosthesis stem (n = 255, 83.3%). In terms of UHNA specifications, mainly standard adapters (n = 253, 82.7%) were combined with a 12/14 mm taper size (n = 166, 54.2%) and 36 mm heads (n = 194, 64.4%). The heads were mostly made of Delta ceramic (n = 273, 89.2%), while the inlays were mainly made of PE (n = 175, 57.2%). Therefore, ceramic on polyethylene bearings were the foremost tribological bearings in our study (n = 158, 51.6%). There were 46.7% of patients who had an oversize adapter neck length (2XL to 5XL, n = 143). No dual- mobility bearings were used in our study group in connection with UHNA.

Results

The overall rerevision rate after UHNA implantation was 14.1% (n = 43). Of the patients, 19.9% (n = 61) developed at least 1 postoperative complication. The most common complication was postoperative recurrent dislocation (n = 27, 8.8%), followed by periprosthetic infection (n = 13, 4.2%) and aseptic component loosening (n = 10, 3.3%). These were also the prominent complications leading to rerevision. Furthermore, recurrent dislocation was the leading indication for rerevision due to the same diagnosis as the primary UHNA implantation (n = 14, 4.6%; 73.7% of the total

Table 4
Statistically Significant Results of the Multivariate Outcome and Complication Analysis.

Independent Variables	*P*-value	Test Method	Effect Size	
			ϕ	Or (95% CI)
Postoperative complication (overall)				
Comorbidity: rheumatoid arthritis	.017	Fisher	–	3.287 (1.260 to 8.575)
Postoperative aseptic loosening				
Oversize UHNA neck length (2XL-5XL)	.004	Fisher	–	1.067 (1.023 to 1.113)
Postoperative recurrent dislocation				
Indication: recurrent dislocation	<.001	$\chi 2$	0.350	–
Postoperative periprosthetic fracture				
Comorbidity: osteoporosis	.049	Fisher	–	3.480 (1.026 to 11.804)
Postoperative prosthesis infection				
Age cohort (≥60 versus <60 y)	.021	Fisher	–	0.252 (0.081 to 0.780)
Revisions before UHNA implantation	.033	Fisher	–	3.496 (1.113 to 10.977)
Postoperative septic loosening				
Age cohort (≥60 versus <60 y)	.049	Fisher	–	0.149 (0.024 to 0.913)

The association of each variable with complications (overall and for each specific complication) was tested as possible risk factor.
UHNA, universal head-neck adapter.

Table 5
(Re-)Revision-free Implant Survival. Percentage and Confidence Interval (95% CI).

Survival in Years	1 y	3 y	5 y	7 y	10 y
UHNA	92% (88.1 to 95.9)	88% (84.1 to 91.9)	86% (82.1 to 89.9)	85% (81.1 to 88.9)	82% (76.1 to 87.9)
Remaining implants	282	269	263	260	251

UHNA, universal head-neck adapter.

revisions due to the same recurrent diagnosis) (Table 3). Material fractures in connection with the UHNA bearing couple (adapter and head) did not occur. Only 1 patient had a prosthesis stem-neck fracture with a following revision. This patient had received a UHNA (2XL adapter neck length) in revision THA due to PE wear. At the 16-month follow-up, a rerevision was performed due to a fracture of the prosthesis stem-neck (Future stem, DePuy Synthes, Johnson & Johnson, NJ) after a fall (inadequate trauma) (Figure 2). Moreover, 1 bearing-associated complication was identified (recurrent PE liner wear after UHNA implantation; this patient's revision-free survival time was 94 months).

The association between postoperative complications after UHNA implantation and statistically significant surveyed variables is summarized in Table 4. In general, the odds of postoperative complications were higher in patients who had rheumatoid arthritis. A statistically significant higher risk for postoperative recurrent dislocations was found in patients who had recurrent dislocations as a diagnosis leading to UHNA implantation. Furthermore, patients who had oversized neck lengths (2XL to 5XL) had higher odds of postoperative aseptic loosening than those who had normal neck lengths. The likelihood of both postoperative prosthesis infection and septic loosening was increased in younger patients (<60 years) compared to older patients. Additional risk factors for postoperative prosthesis infection also included the number of revision THA procedures prior to UHNA implantation. Also, higher odds of postoperative periprosthetic fractures were found in osteoporotic patients.

The overall revision-free survival after UHNA implantation was reported after one (n = 282, 92%), 3, 5, 7, and 10 (n = 251, 82%) years (Table 5). There were 2 patients who died within the postoperative period of 4 weeks, one of whom died during intraoperative resuscitation. When comparing the different revision-free survival rates, the statistics displayed better implant survival in patients ≥60 years old ($P = .018$), who had fewer comorbidities (<2 comorbidities; $P = .039$), and normal neck lengths (S to XL; $P = .028$) (Figures 3 through 5).

Discussion

The use of UHNA through "mix and match" solutions has become a widespread treatment option in revision THA, but no sufficient evidence has yet been gathered to support this clinical practice. Recent European Federation of Orthopaedics and Traumatology (EFORT) recommendations highlight the necessity for further follow-up studies and research, although allowing "mix and match" in terms of a favorable outcome for the patient [5]. Therefore, this study's aim was to provide an extensive UHNA (all Merete BioBall) follow-up for quality purposes (according to recent EFORT recommendations), including the identification of risk factors correlated with implant failure.

Previous literature reported the 2 main indications for UHNA in revision THA being cup aseptic loosening and primary instability (recurrent dislocation), with a well-fixed and appropriately aligned femoral stem allowing partial revision [4,13–15,19,20]. Similarly, the main indications for UHNA implantation in revision THA in our study were PE inlay wear (24.7%), aseptic prosthesis cup loosening (23.3%), and recurrent dislocation (15.1%). Recurrent dislocations and cup aseptic loosening have been reported as the 2 most frequent reasons for rerevision after UHNA implantation [13–15]. In accordance with available literature, our study registered recurrent dislocation (8.8%), prosthesis infection (4.2%), and aseptic loosening (3.3%) as the main complications leading to rerevision after UHNA implantation.

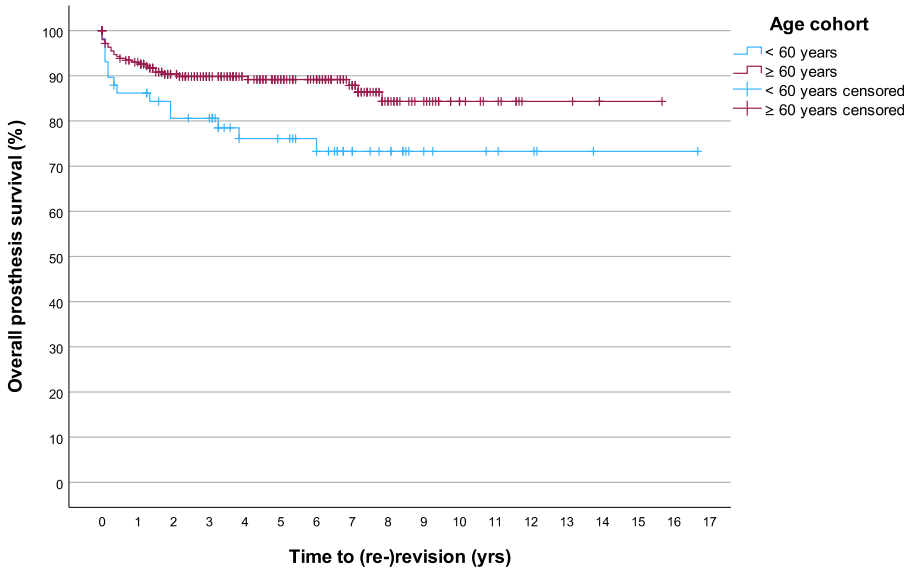

Fig. 3. Curve depicting the rerevision-free survival after the universal head-neck adapter implantation depending on age cohorts.

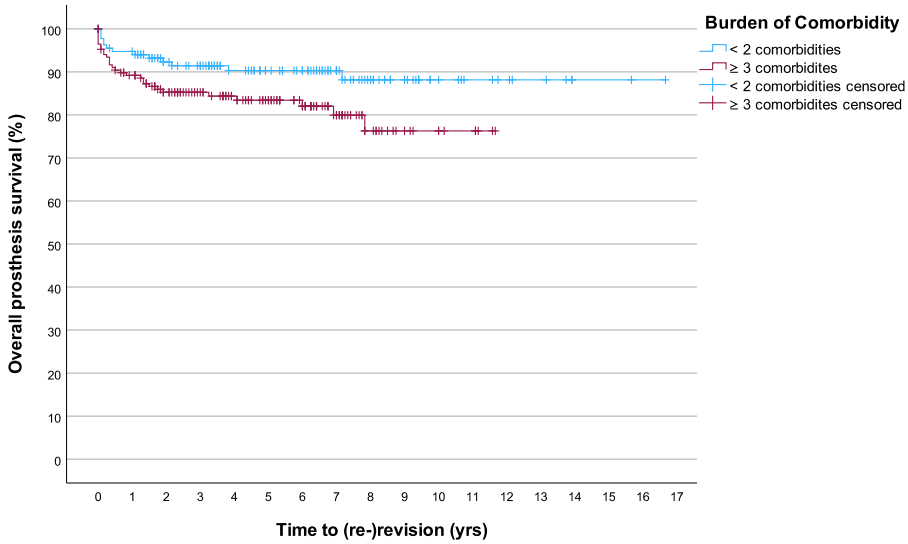

Fig. 4. Curve depicting the rerevision-free survival after the universal head-neck adapter implantation depending on the burden of comorbidity.

In our cohort, we identified acceptable cumulative complication and rerevision rates of 19.9 and 14.1%, respectively (median follow-up of 57 months). Similarly, a rerevision rate of 12.1% was reported in previous literature (mean follow-up of 60 months) [13].

No material fractures in connection with the UHNA-bearing couple (adapter and head) occurred in the present study, though one case of stem-neck fracture was detected. In accordance with our findings, Pardo et al. reported no breakage of the adapter system or the ceramic head, while one femoral neck failed (0.3%) [13]. Similarly, Novoa et al. detected a total of 2 ceramic head fractures and one stem-neck fracture in their systematic review [4]. No incidence of mechanical dissociation, breakage of the adapter, or ceramic head fractures was identified by Garabadi et al. [19].

It is important to highlight, that the one stem-neck fracture was the only "mix and match"-specific complication reported in our cohort (0.3%). Previous literature identified prior revision surgery and mixing components from different manufacturers as potential risk factors for stem-neck fractures in THA [21]. Cook et al. recently analyzed stem fractures, pointing out the following contributing factors: heat-treatment reduction of mechanical properties, iatrogenic implant damage, and "mix and match" of arthroplasty components [22]. The stem-neck failure in our series can be attributed to the secondarily higher offset (2XL adapter neck) and consequently unphysiological load on the stem. Also, the THA was revised 11 years after primary implantation, suggesting that the necessary manipulation and applied force on the stem-neck during revision (including heating) could have led to relevant iatrogenic damage, weakening the prothesis neck.

A very important result of this study was the identification of possible risks or influencing factors for UHNA failure.

A higher risk for postoperative recurrent dislocation was found in patients who had a recurrent dislocation as a diagnosis leading to UHNA implantation. This was already hypothesized by Novoa et al., as higher reoperation rates were found in cases where dislocation was the indication for revision THA with UHNA [4]. Other recent studies highlighted the importance of postoperative dislocation or

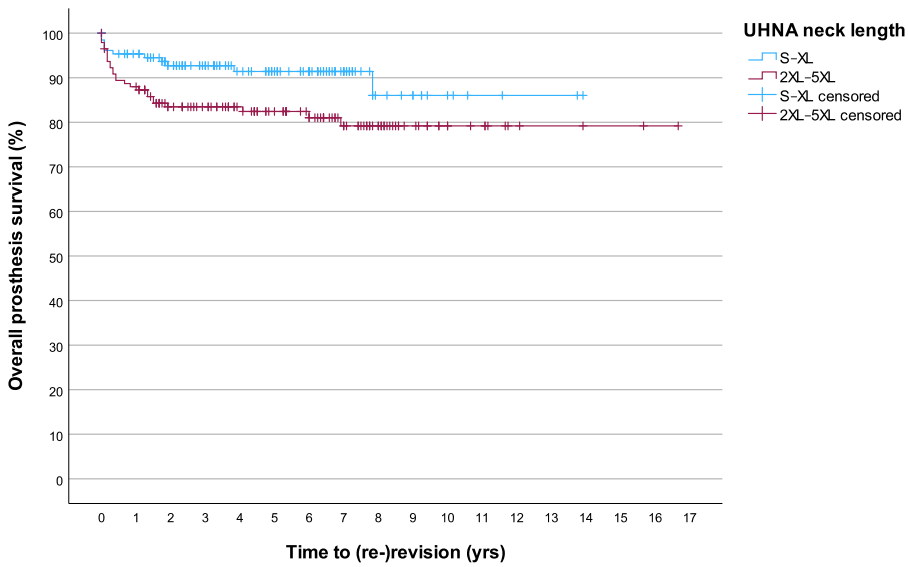

Fig. 5. Curve depicting the rerevision-free survival after the universal head-neck adapter implantation depending on the adaptor's neck length.

instability as complications after modular head-neck adapter implantation [4,13,14,18–20], although none had performed a risk analysis for this specific complication. As no dual-mobility bearings were used in this study cohort in connection with UHNA, further studies would be necessary to investigate the possible influence of dual mobility on instability or complications generally.

Interestingly, the odds of postoperative complications (overall) were found to be higher in patients who had rheumatoid diseases. The negative influence of rheumatoid diseases on outcomes following THA is well-described [23] and confirmed by our findings.

Furthermore, patients who had oversized neck lengths (2XL to 5XL) had higher odds of postoperative aseptic loosening than those who had normal neck lengths. The association between oversized necks and higher failure rates (specifically, loosening) could be due to the increased mechanical forces transmitted to the remaining fixed components through the resulting, unphysiologically high offset. Consequently, it should be highlighted that the main issue with the oversized adapter neck length does not seem to be material breakage. Also, no significant association was found between oversized adapter necks and instability. Our findings suggest that oversized length is rather associated with aseptic prosthetic loosening. This finding is strengthened by previous findings in the literature, as Jud et al. highlighted an association between lateralized stems (high offset in THA) and aseptic femoral loosening (3.7-fold increased probability) [24].

Additionally, the likelihood of postoperative periprosthetic infection and septic loosening was increased in younger patients (<60 years) compared to older patients (≥60 years). This is supported by previous evidence in THA: Prentice et al. recorded a higher risk of septic revision (hazard ratio 1.3) in patients <55 years old in comparison with patients aged ≥65 years. In the younger age group, risk factors for septic revision included a higher BMI, drug abuse, and liver disease [25]. Additional risk factors for postoperative periprosthetic infection in our series also included multiple revision procedures before UHNA implantation; increasing fibrotic tissue formation and soft tissue damage would lead to higher odds of developing a periprosthetic infection.

In addition, higher odds of postoperative periprosthetic fractures were found in osteoporotic cases. This reflects and confirms the known association between osteoporosis and the incidence of periprosthetic femoral fractures [26].

Also, the survival analysis results of this study are in accordance with previous literature, describing revision-free survival rates of modular head-neck adapters ranging from 86.9 to 98% [13,14,18,19]. A registry study analyzing 354 implants (Pardo et al.) reported similar 5- and 7-year survival rates of 87.9 and 86.9%, respectively, without identifying any implant features impacting failure [13]. Similarly, Caternicchia et al. highlighted a survival rate of 87.9% at 5 years in 32 revision THAs using a modular head-neck adapter system [18]. A higher survival rate was found by Garabadi et al., analyzing the UHNA use in revision THAs in the elderly (American Society of Anesthesiologists grades II to IV); in the 47 patients included, the UHNA survival rate was 98% [19].

Our additional survival analyses, taking into account various possible risk factors, showed significantly better survival rates for patients ≥60 years old, who had fewer comorbidities (<2), and normal neck lengths (S to XL). The lower revision-free survival rates for implants in younger patients can be attributed to the higher activity and mobility level, as well as less frequent censoring (higher life expectancy). Previous literature highlighted that higher BMI and obesity are independently associated with early THA failure and early revision [27]. As obesity was the most frequently registered comorbidity in our cohort, it seems coherent that a higher comorbidity burden was consequently associated with shorter revision-free survival. As for the adapter neck length, Pardo et al. observed no difference between normal and oversized adapter necks in terms of survival rates [13], contrary to our findings (oversize neck lengths were associated with higher failure rates).

This study has several potential limitations. The data were gathered retrospectively, relying on electronic patient dossiers and documentation. However, since our survival data were received via centralized insurance data from health authorities, there is a very high probability of completeness. Furthermore, functional and patient-related outcome measures were not documented. Functional and subjective outcomes were not the aim of the present study, which focused on a safety analysis of the “mix and match” use of UHNA through outcome and survival analyses. Also, due to the wide range of implants used in association with the UHNA, possible prior surgeries and/or revisions, and high variability in terms of indications for the UHNA implantation, co-treatment bias could not be ruled out.

Nevertheless, to our knowledge, this is the first study to systematically analyze possible risk or influencing factors for UHNA failure in “mix and match” THA, including comorbidity burden, UHNA specifications, demographic data, and indications and diagnoses, achieving its goal through the study’s design.

Conclusions

We found the overall security and safety of UHNA use in THA through “mix and match” solutions. Only one “mix and match”-specific complication, a stem-neck fracture, and no UHNA-specific failures were identified in 306 cases. The underlined possible risk factors for complications (comorbidity burden, oversize adapter neck length, age, and recurrent dislocations) must be kept in mind in terms of the decision-making process with patients. In particular, caution should be taken in regards to oversize adapter neck lengths (significantly associated with postoperative aseptic loosening) and dislocations and instability (correlated with postoperative recurrent dislocations). However, more studies and compatibility testing for all prosthesis producers are required to draw more concise conclusions, according to EFORT recommendations.

CRediT authorship contribution statement

Marisa Valentini: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alexander Thaller:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Paul Ruckenstuhl:** Writing – review & editing, Visualization, Validation. **Patrick Sadoghi:** Writing – review & editing, Visualization, Validation. **Andreas Leithner:** Writing – review & editing, Visualization, Validation, Supervision. **Lukas Leitner:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Conceptualization.

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