



Similar rates of return to sports and BMI reduction regardless of age, gender and preoperative BMI as seen in matched cohort of hypoallergenic and standard Cobalt Chromium medial unicompartmental knee arthroplasty

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Abstract

Purpose To compare the rate of return to sports and body mass index (BMI) reduction in patients who underwent surgery for unicompartmental knee arthroplasty (UKA) with either Cobalt-Chromium (CoCr) alloy UKA or with hypoallergenic UKA, stratified by age, gender and BMI.

Methods Two consecutive cohorts of patients with a total of 172 UKA and a minimum 2-year follow-up period were prospectively included in this comparative study. The first cohort consisted of 136 consecutive series of standard Cobalt-Chromium (CoCr Group). The second cohort consisted of 36 consecutive mobile-bearing hypoallergenic Titanium Niobium Nitride UKA, (TiNbN Group). The clinical evaluation was based on the University of California, Los Angeles (UCLA) activity scores and the High-Activity Arthroplasty Score (HAAS) evaluated on the day before surgery (T_0) and after a minimum follow-up of 12 months (T_1) and 24 months (T_2). Radiographic evaluation performed at T_2 included the femoral component position in varus/valgus, the tibial component in varus/valgus and the anteroposterior slope.

Results No statistical differences were found between the groups at each follow-up, as shown by the UCLA and HAAS score (n.s.). Both groups showed a statistically significant improvement ($p < 0.05$) at each follow-up. Both groups showed a statistically significant BMI reduction between T_0 and T_2 ($p < 0.05$). Radiographic analysis revealed no statistical differences between the two groups in terms of the three measures after the final follow-up (n.s.). All the subgroups showed a significant ($p < 0.05$) rate of return to sport if compared with the preoperative value (T_2 versus T_0), except for male in TiNbN group.

Conclusions Both TiNbN and CoCr medial mobile-bearing UKA enabled patients to return to sports after the final follow-up, regardless of age, BMI, gender and metal sensitivity. These findings inform shared decision making and can help to manage patient expectations after surgery, in particular, in active patients with an overt metal allergy, a specific hypoallergenic implant should be considered the gold standard implant in partial knee replacement surgery.

Level of evidence Cohort Study, Level III.

Registration: researchregistry6250—www.researchregistry.com.

Keywords Unicompartmental knee arthroplasty · Return to sport · Metal hypersensitivity · Body mass index

Introduction

Over the last several years, unicompartmental knee arthroplasty (UKA) has become increasingly popular due to its shorter rehabilitation time, restoration of a wider range of

motion and physiological proprioception of the joint due to cruciate ligaments retention, especially active, younger patients, who show a more active lifestyle and typically want to participate in sports activities [23].

In modern knee arthroplasty, metal hypersensitivity appears to be a controversial issue [4]. Moreover, there is an ongoing debate about its clinical relevance owing to the possibility of premature implant failure [12]. Although skin hypersensitivity to metals has been reported in 25%

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of patients with well-functioning arthroplasties and up to 60% with poorly functioning arthroplasties, no causality has been reported due to cutaneous reactions and implant failure. Potentially, all metal components implanted in the human body can interact with the biological system after undergoing implant corrosion, thereby resulting in ion release [18]. These ions can form complexes with native proteins and evoke immunologic responses that may affect the implant–bone interface, causing periprosthetic osteolysis [6, 18].

Nickel is considered to be the metal most commonly responsible for causing adverse reaction in humans, followed by Cobalt and Chromium [11]. The latter two are generally used in orthopaedic implants such as standard knee prosthesis in the form of Cobalt-Chromium alloy (CoCr).

Cutaneous hypersensitivity to metals ranges from 10 to 48% in general osteoarthritis (OA) population, and this high incidence is likely to be shared with patients eligible for knee arthroplasty [4, 18].

Over the last few years, a considerable number of hypoallergenic prosthetic components with materials providing excellent alternatives to standard Cobalt-Chromium (CoCr) have been introduced. For instance, ceramic coatings have been proposed for their chemical inertness, high hardness and bioactive features [4, 25]. Titanium niobium nitride (TiNbN), in particular, is a thin ceramic coating applied using physical vapour deposition onto a metal substrate that shows high surface resistance to abrasion and corrosion. These features help in rendering the implants more susceptible to long-term biocompatibility and osteointegration.

The present study aims to compare the rate of return to sports and body mass index (BMI) reduction in patients who underwent surgery for mobile-bearing UKA with either Cobalt-Chromium (CoCr) alloy implants or with hypoallergenic TiNbN alloy. It was hypothesised that TiNbN mobile bearing implants can be used in active patients with metal allergy with isolated end-stage anteromedial knee osteoarthritis patients, without inferior results as regards sports activity than standard CoCr implants regardless age, gender and BMI.

Material and methods

All the procedures involving human participants in this study were performed in accordance with the ethical standards of the institutional and/or national research committee, as well as the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was conducted following the STROBE checklist for cohort studies and has been registered in the Research Registry

(researchregistry6250; www.researchregistry.com) [33]. Informed consent was obtained from all the participants included in the study. Appropriate ethical approval was obtained from the local ethics committee.

Two consecutive cohorts of patients undergoing cemented medial mobile-bearing UKA were included. The first cohort consisted of 136 consecutive series of medial mobile-bearing standard Cobalt-Chromium UKA with the Oxford Microplasty instrumentation (CoCr Group). The second cohort consisted of 36 consecutive medial mobile-bearing anallergic Titanium Niobium Nitride medial UKA, with a single femoral peg, using the Microplasty instrumentation (TiNbN Group).

In all the patients, the surgery was performed by the same surgeon (NU), who is an expert in performing UKA arthroplasty [35].

In both the groups, the surgery was performed for treating isolated anteromedial OA or avascular necrosis (AVN) of the medial femoral condyle with bone on bone OA. Pre-operative magnetic resonance imaging (MRI) confirmed that both cruciates and collateral ligaments were intact in all the patients. Radiographic inclusion criteria followed those defined by the Oxford group [8]. Exclusion criteria for participation in this study were as follows: (1) missing data or radiographs unsuitable for getting an exact measurement, (2) revision surgery, and (3) previous surgery of the affected knee (except arthroscopy for meniscectomy).

The clinical follow-up was performed by two independent clinicians who were not involved in the index surgery. The clinical evaluation involved evaluating each patient's University of California, Los Angeles (UCLA) activity scores and the High-Activity Arthroplasty Score (HAAS). The UCLA score measures the level of physical activity on a scale from 1 ("no physical activity, depend on other") to 10 ("regular participation in impact sports") and is a validated for use in arthroplasty surgery. The HAAS score (scored from 0 to 18, worst to best) was designed to detect subtle variations in physical function of highly functioning patients. Each patient was clinically evaluated on the day before surgery (T_0), then after a minimum follow-up period of 12 months (T_1), and finally after 24 months (T_2) [2, 19]. Finally, the BMI of each patient was measured before surgery (T_0) and at the final follow-up (T_2) [26].

Positioning of the UKA was evaluated at a minimum 2-year follow-up period (T_2), as specified by radiological analysis in the Oxford Partial Knee Surgical Technique operating manual, using standing anteroposterior (AP) and lateral plain radiographs of the knee.

The following parameters were measured according to the manufacturer's manuals [27]:

- *Femoral component varus/valgus* Angle between the femoral component and the femoral axis in the coronal

plane; an angle of 7.0° was seen as neutral, with a range of tolerance of $\pm 10.0^\circ$.

- **Tibial component varus/valgus** Angle between the tibial axis and a line drawn along the tibial tray in the coronal plane; range of tolerance was $0.0^\circ \pm 5.0^\circ$.
- **Anteroposterior slope** Angle between a line drawn along the tibial tray and perpendicular to the tibial axis in the lateral view; a slope of 7° was seen as optimal, with a range of tolerance of $\pm 5.0^\circ$ (2.0° – 12.0°).

After extracting the Digital Imaging and Communications (DICOM) in Medicine data from Picture Archiving and Communications System (PACS), it was inserted into OsiriX® imaging software (version 4.1.2 32-bit) and evaluated by two independent observers, who were unaware of the instrumentation used for implantation [20].

Statistical analysis

The data were presented as absolute numbers and percentage for categorical variables and as mean and standard deviation (SD) for continuous variables. Group comparison between TiNbN and CoCr implants were performed using a χ^2 test for categorical variables, a *t*-test for continuous normal data and Wilcoxon–Mann–Whitney test for continuous non-normal data. Moreover, a comparison between time points was made to assess a change in time of BMI, UCLA or HAAS scores in hypoallergenic and standard implants. A paired *t* test or the equivalent non-parametrical Wilcoxon signed rank-sum test, was performed for BMI. For UCLA and HAAS scores, a repeated measure ANOVA or a non-parametric analysis (Friedman test, Wilcoxon signed-rank test) was preferred with Bonferroni correction for multiple comparisons. Secondary analyses were conducted stratifying by gender, age and BMI to assess the difference in scores and angles among time points and between hypoallergenic and standard implants in groups with the same gender or similar age or BMI. Overall mean was used as threshold for age and BMI to identify patients for comparison. Correlations among the scores, BMI and angles were estimated and tested. A two-tailed *p* value of less than 0.05 was considered statistically significant. Statistical analyses were performed using SAS System Version 9.

To assess the possible differences between hypoallergenic and standard unicompartmental knee arthroplasty, a sample of 9 TiNbN and 135 CoCr implants was estimated to be necessary to detect a 3-point difference, both in UCLA and HAAS score, assuming a standard deviation (SD) of 3 for both the groups, a 5% two-tailed alpha and an 80% power [15, 30]. In addition, disproportion between the groups was taken into account during sample size calculation since the incidence of hypersensitivity to metals is estimated to be 15% [12]. Additional 27 and one subjects were included in

the two groups, respectively, to ensure statistical significance in case of unexpected events. This sample was also adequate to detect a 2-point increase in both UCLA and HAAS score in subsequent time points, with an SD of 3, a 5% two-tailed alpha and a 95% power. Sample size calculation was performed using non-parametric tests (Wilcoxon-Mann Whitney and Wilcoxon signed-rank).

Results

A total of 208 patients were able to complete the entire minimum 2-year follow-up, of which 172 satisfied all inclusion and exclusion criteria (136 in the CoCr group and 36 in TiNbN group). Of the 36 patients excluded 22 had a previous knee surgery (30 anterior cruciate ligament reconstruction, 3 anterior and posterior cruciate ligament reconstruction and 3 tibial osteotomy), while 14 had radiographs unsuitable for getting an exact measurement at final follow-up.

Pre-operative differences were found among groups with regard to gender and age ($p < 0.05$). However, the remaining parameters showed no significant differences. Detailed data are reported in Table 1.

Both the groups showed statistically significant improvement with regard to BMI between T_0 and T_2 ($p < 0.05$). No differences were found among groups at each time point (n.s.). Detailed results are reported in Table 2.

No statistical differences were found among the groups at each follow-up with regard to UCLA and HAAS score (n.s.). Both the groups showed statistically significant improvement ($p < 0.05$) at each follow-up and respective pre-operative value, except for UCLA for TiNbN group between T_2 and T_1 (n.s.). Detailed results are reported in Table 3.

Radiographic analysis revealed no statistical difference between the two groups in terms of the three measures at final follow-up (n.s.). Detailed results are reported in Table 4.

Subgroup Analysis

All the subgroups showed a significant ($p < 0.05$) return to sports when compared with the preoperative value (T_2 versus T_0), except for male in TiNbN group. An improvement in BMI value ($p < 0.05$) was found in male, female and young patients in the TiNbN group and in female and old patients in the CoCr group. Specific results are reported in Table 5.

Radiographic subgroup analysis showed no differences among the groups (n.s.).

Table 1 Characteristics of patient study population

Variables	TiNbN <i>N</i> = 36	CoCr <i>N</i> = 136	<i>p</i> value
Gender			
Female	29 (80.6)	79 (58.1)	0.013*
Male	7 (19.4)	57 (41.9)	
Side			
Right	70 (51.5)	20 (55.6)	n.s
Left	66 (48.5)	16 (44.4)	
Age (pre operative)	66.11 ± 6.14	69.51 ± 7.47	0.007*
Follow up T ₁ (months)	12.39 ± 0.73	12.39 ± 0.73	n.s
Follow up T ₂ (months)	66.65 ± 19.03	63.37 ± 21.18	n.s
Preoperative weight (kg)	72.58 ± 10.12	75.95 ± 14.04	n.s
Preoperative height (m)	1.61 ± 0.04	1.65 ± 0.08	0.007*

Note: values are presented as *n* (%) or mean ± SD

*Statistical significant difference

TiNbN titanium niobium nitride, CoCr cobalt-chromium, *n.s.* not significant

Table 2 BMI at different time points

Variables	TiNbN <i>N</i> = 36 mean ± SD	CoCr <i>N</i> = 136 mean ± SD	Group comparison <i>p</i> value
BMI			
T ₀	27.90 ± 3.55	27.89 ± 4.33	n.s
T ₂	26.87 ± 3.11	27.61 ± 4.26	
Comparison between time points (<i>p</i> value)	< 0.0001*	< 0.0001*	

Note: values are presented as mean ± SD

BMI body mass index, TiNbN titanium niobium nitride, CoCr Cobalt-Chromium, *n.s.* not significant

*Statistical significant difference

Correlations

Pre-operative and final BMI showed a positive correlation in the TiNbN group with HAAS at T₀ ($p < 0.05$), while in the CoCr group, BMI at T₂ was found to be negatively correlated with UCLA at T₂ ($p < 0.05$).

A radiographic positive correlation has been found between the femoral angle and HAAS at T₂ in the TiNbN group and between the tibial slope and HAAS at T₁ in the CoCr group. Specific results are reported in Table 6.

Discussion

The main findings of the current study demonstrate that no differences were found between the TiNbN and CoCr mobile-bearing UKAs at any follow-up level in terms of return to sport and radiographic outcomes regardless age, gender and BMI. This study entailed head-to-head comparisons of patients with metal hypersensitivity and medial knee osteoarthritis and have undergone TiNbN UKA and patients with isolated medial osteoarthritis and have undergone CoCr UKA, along with an assessment to determine the rate of return to sports and activity scores while controlling for age, sex and body mass index. Preoperatively, both groups participated in similar sports activities. These results carry over to postoperative outcomes; analysis of subgroups indicated a lack of improvement only in the male TiNbN group. This can be due to the relatively low number of patients in the subgroup (7) or the high preoperative value of sports activity in this cohort. To date, no study has directly compared the sports-related outcomes of these two types of implants in a matched population. Several studies have focused their attention only on standard CoCr medial knee replacement,

Table 3 Mean score at different time points

Score	Time period	Groups		Group comparison <i>p</i> value	Comparison between time points (Bonferroni adjusted <i>p</i> value)	
		TiNbN <i>N</i> = 36 mean ± SD	CoCr <i>N</i> = 136 mean ± SD		TiNbN <i>N</i> = 36	CoCr <i>N</i> = 136
UCLA	T ₀	3.61 ± 1.20	3.77 ± 1.19	n.s	T ₁ - T ₀ :	< 0.0001*
	T ₁	6.11 ± 0.75	6.04 ± 0.79	n.s	T ₂ - T ₁ :	n.s
	T ₂	6.31 ± 0.62	6.31 ± 0.67	0.9284	T ₂ - T ₀ :	< 0.0001*
HAAS	T ₀	4.50 ± 1.52	4.50 ± 1.51	n.s	T ₁ - T ₀ :	< 0.0001*
	T ₁	10.25 ± 1.32	10.32 ± 1.37	n.s	T ₂ - T ₁ :	0.003*
	T ₂	11.00 ± 0.89	10.99 ± 0.88	n.s	T ₂ - T ₀ :	< 0.0001*

Note: values are presented as mean ± SD

BMI body mass index, TiNbN titanium niobium nitride, CoCr cobalt-chromium, *n.s.* not significant, UCLA University of California, Los Angeles activity scores, HAAS high-activity arthroplasty score

*Statistical significant difference

Table 4 Radiographic analysis at final follow-up

Variables	TiNbN <i>N</i> = 36 mean $\pm$ SD	CoCr <i>N</i> = 136 mean $\pm$ SD	Group comparison <i>p</i> value
Tibial angle (°)	2.94 $\pm$ 2.04	3.04 $\pm$ 2.41	n.s
Femoral angle (°)	6.81 $\pm$ 4.46	7.49 $\pm$ 5.09	n.s
Slope (°)	5.08 $\pm$ 3.23	6.04 $\pm$ 2.95	n.s

Note: values are presented as mean $\pm$ SD

TiNbN titanium niobium nitride, CoCr cobalt-chromium, n.s. not significant

*Statistical significant difference

reporting good to excellent outcomes in terms of returning to perform sports activity. However, nowadays metal sensitivity is a growing problem, with a high number of revision reported in the literature, and in view of the fact that between 10 to 48% of the population is sensitive to metal [18].

There has been a degree of acceptance in some countries that metal-related pathology might exist, as demonstrated by the Australian Arthroplasty register, wherein metal hypersensitivity was reported as one of the main cause for knee revision arthroplasty, making up 1.3% of the revisions in 2012 and 1.8% in 2014 [18]. This has led to the development of a new shift in notion—from ‘metal sensitivity’ to ‘metal-related pathology’ [18].

Furthermore, it is believed that after wound healing and tissue regeneration, most arthroplasty patients adapt to the implant and regain their quality of life. However, tissue homeostasis around the “foreign body” may be disturbed by inflammatory mediator response to wear and metal ions, particularly in standard CoCr arthroplasties; these aspects have been analysed in detail by Thomas et al. [13, 32]. In fact, in 2018, the authors assessed immunological and clinical parameters at a 5-year follow-up using either a standard total knee replacement or the identical implant with multilayer surface zirconium nitride-based coating. The survival and clinical data were comparable among the two groups, but the mean interleukin-8 and interleukin-10 levels were higher in the group with an uncoated implant [32]. The degree of elevated serum IL-8 is related to the extent of potential inflammation and fibrosis in chronic liver disease; notably, elevated serum IL-8 levels are found in several types of cancer and are considered to be prognostic markers for malignancies [22]. Moreover, Tanaka et al. had reported two observations: serum and synovial fluid IL-8 levels were significantly correlated in hip arthroplasty patients, and elevated IL-8 levels correlated with aseptic loosening of hip arthroplasty [31].

Contrary to these results, Walker et al. evaluated the clinical outcome and survival rates of UKA using a standard CoCr alloy in patients reporting signs of a hypersensitivity to metal [34]. At a mean follow-up of 3 years, no local

or systemic symptoms of hypersensitivity to metal were observed [34].

In recent years, significant improvements have been reported in UKA bioengineering, leading to excellent results in terms of return to sports, particularly in active [15, 21].

Most patients who undergo UKA surgery have high expectations concerning the post-operative level of physical activity. Return to activity following UKA is of concern to every patient’s increasing standards of living in terms of higher physical and social mobility and better cardiovascular performance [5]. Furthermore, the literature confirms that being active increases their general health status, thereby reducing costs related to treatments especially after knee arthroplasty [5, 15, 21]. However, returning to sports activity after hypoallergenic or standard unicompartmental knee arthroplasty has not as thoroughly been studied as other aspects of functional recovery; in fact, most of the literature has analysed only standard implants.

In a recent systematic review, Waldstein et al. found in 10 studies a statistically significant improvement of physical activity following UKA, as per the UCLA activity score, the Tegner activity score, and the HAAS [34]. Hiking, cycling, and swimming are the most common activities following UKA. Participation in sports before the onset of restricting symptoms ranged from 64 to 93% and slightly decreased by 2% to 9% following UKA. The rate of return to activity ranged from 87 to 98% [34].

Similar results were found by Lo Presti et al., who analysed 53 athletic patients who underwent medial UKA [17]. At the final follow-up of 48 months, 48 out of 53 patients were engaged in sports and recreational disciplines, resulting in a return-to-activity rate of 90% [17]. No early failure and no cases of revision were reported. The frequency of activities (sessions per week) and the periods remained constant at the time of the survey. The most common activities after surgery were hiking, cycling and swimming. Several high-impact activities, including skiing and football, significantly decreased among the participating patients [17]. Higher rates of sport-specific return were observed for low-impact sports, whereas a full return to activities was prevented in high-impact sports. With regard to the return to sports after UKA, Harbourne et al. evaluated predictive factors of return to desired activities 12 months after surgery; worse Oxford Knee Score, higher BMI, and worse expectations were identified as negative predictive factors [9].

The second objective of the current study was to analyse if patients who underwent UKA could improve their BMI; a statistically significant improvement was found in both the groups; furthermore, patients with a higher BMI (> 28) showed improvement in sports and physical activities.

Obesity is currently one of the major underlying causes of mortality, and BMI is the most commonly used measure

Table 5 Subgroup analysis

Score	Time period	Groups		Group comparison	Comparison between time points (Bonfer- roni adjusted <i>p</i> value)		
Male					Male		
		TiNbN <i>N</i> = 7 mean ± SD	CoCr <i>N</i> = 57 mean ± SD	<i>p</i> value		TiNbN <i>N</i> = 7	CoCr <i>N</i> = 57
UCLA	T ₀	3.57 ± 1.72	3.93 ± 1.16	n.s	T ₁ - T ₀ :	0.063	< 0.0001*
	T ₁	6.14 ± 0.38	6.04 ± 0.87	n.s	T ₂ - T ₁ :	#	n.s
	T ₂	6.14 ± 0.38	6.30 ± 0.65	n.s	T ₂ - T ₀ :	0.063	< 0.0001*
HAAS	T ₀	4.14 ± 1.95	4.63 ± 1.55	n.s	T ₁ - T ₀ :	0.047*	< 0.0001*
	T ₁	10.57 ± 1.13	10.37 ± 1.37	n.s	T ₂ - T ₁ :	n.s	0.016*
	T ₂	11.29 ± 0.95	10.95 ± 0.87	n.s	T ₂ - T ₀ :	0.047*	< 0.0001*
BMI	T ₀	27.88 ± 2.35	29.78 ± 4.43	n.s	T ₂ - T ₀ :	0.063*	n.s
	T ₂	26.49 ± 1.44	29.57 ± 4.40	0.029*			
Female					Female		
		TiNbN <i>N</i> = 29 mean ± SD	CoCr <i>N</i> = 79 mean ± SD	<i>p</i> value		TiNbN <i>N</i> = 29	CoCr <i>N</i> = 79
UCLA	T ₀	3.62 ± 1.08	3.66 ± 1.20	n.s	T ₁ - T ₀ :	< 0.0001*	< 0.0001*
	T ₁	6.10 ± 0.82	6.04 ± 0.74	n.s	T ₂ - T ₁ :	n.s	0.027*
	T ₂	6.34 ± 0.67	6.32 ± 0.69	n.s	T ₂ - T ₀ :	< 0.0001*	< 0.0001*
HAAS	T ₀	4.59 ± 1.43	4.41 ± 1.48	n.s	T ₁ - T ₀ :	< 0.0001*	< 0.0001*
	T ₁	10.17 ± 1.36	10.28 ± 1.38	n.s	T ₂ - T ₁ :	0.012*	0.0003*
	T ₂	10.93 ± 0.88	11.03 ± 0.89	n.s	T ₂ - T ₀ :	< 0.0001*	< 0.0001*
BMI	T ₀	27.91 ± 3.82	26.52 ± 3.71	n.s	T ₂ - T ₀ :	0.001*	0.008*
	T ₂	26.96 ± 3.41	26.20 ± 3.56	n.s			
< 70 years					< 70 years		
		TiNbN <i>N</i> = 26 mean ± SD	CoCr <i>N</i> = 59 mean ± SD	<i>p</i> value		TiNbN <i>N</i> = 26	CoCr <i>N</i> = 59
UCLA	T ₀	3.38 ± 1.06	3.85 ± 1.16	n.s	T ₁ - T ₀ :	< 0.0001*	< 0.0001*
	T ₁	6.12 ± 0.82	5.98 ± 0.78	n.s	T ₂ - T ₁ :	n.s	n.s
	T ₂	6.31 ± 0.68	6.20 ± 0.69	n.s	T ₂ - T ₀ :	< 0.0001*	< 0.0001*
HAAS	T ₀	4.58 ± 1.27	4.54 ± 1.44	n.s	T ₁ - T ₀ :	< 0.0001*	< 0.0001*
	T ₁	10.35 ± 1.44	10.29 ± 1.41	n.s	T ₂ - T ₁ :	0.023*	0.007*
	T ₂	11.12 ± 0.91	10.98 ± 0.90	n.s	T ₂ - T ₀ :	< 0.0001*	< 0.0001*
BMI	T ₀	27.96 ± 3.55	26.96 ± 3.71	n.s	T ₂ - T ₀ :	0.001*	n.s
	T ₂	27.00 ± 3.18	26.71 ± 3.58	n.s			
≥ 70 years					≥ 70 years		
		TiNbN <i>N</i> = 10 mean ± SD	CoCr <i>N</i> = 77 mean ± SD	<i>p</i> value		TiNbN <i>N</i> = 10	CoCr <i>N</i> = 77
UCLA	T ₀	4.20 ± 1.40	3.71 ± 1.21	n.s	T ₁ - T ₀ :	0.023*	< 0.0001*
	T ₁	6.10 ± 0.57	6.08 ± 0.81	n.s	T ₂ - T ₁ :	n.s	0.007*
	T ₂	6.30 ± 0.48	6.39 ± 0.65	n.s	T ₂ - T ₀ :	0.012*	< 0.0001*
HAAS	T ₀	4.30 ± 2.11	4.47 ± 1.57	n.s	T ₁ - T ₀ :	0.006*	< 0.0001*
	T ₁	10.00 ± 0.94	10.34 ± 1.34	n.s	T ₂ - T ₁ :	n.s	0.001*
	T ₂	10.70 ± 0.82	11.00 ± 0.87	n.s	T ₂ - T ₀ :	0.006*	< 0.0001*

Table 5 (continued)

≥ 70 years					≥ 70 years		
		TiNbN N=10 mean ± SD	CoCr N=77 mean ± SD	p value		TiNbN N=10	CoCr N=77
BMI	T ₀	27.75 ± 3.74	28.60 ± 4.64	n.s	T ₂ - T ₀ :	n.s	0.016*
	T ₂	26.53 ± 3.06	28.30 ± 4.62	n.s			
BMI < 28					BMI < 28		
		TiNbN N=19 mean ± SD	CoCr N=75 mean ± SD	p value		TiNbN N=19	CoCr N=75
UCLA	T ₀	3.79 ± 0.98	3.88 ± 1.16	n.s	T ₁ - T ₀ :	<0.0001*	<0.0001*
	T ₁	6.16 ± 0.69	6.03 ± 0.77	n.s	T ₂ - T ₁ :	n.s	0.002*
	T ₂	6.26 ± 0.65	6.40 ± 0.66	n.s	T ₂ - T ₀ :	<0.0001*	<0.0001*
HAAS	T ₀	3.84 ± 1.42	4.53 ± 1.49	n.s	T ₁ - T ₀ :	<0.0001*	<0.0001*
	T ₁	9.84 ± 1.12	10.23 ± 1.37	n.s	T ₂ - T ₁ :	0.047*	0.001*
	T ₂	10.74 ± 0.81	10.93 ± 0.95	n.s	T ₂ - T ₀ :	<0.0001*	<0.0001*
BMI ≥ 28					BMI ≥ 28		
		TiNbN N=17 mean ± SD	CoCr N=61 mean ± SD	p value		TiNbN N=17	CoCr N=61
UCLA	T ₀	3.41 ± 1.42	3.64 ± 1.21	n.s	T ₁ - T ₀ :	0.0004*	<0.0001*
	T ₁	6.06 ± 0.83	6.05 ± 0.83	n.s	T ₂ - T ₁ :	n.s	n.s
	T ₂	6.35 ± 0.61	6.20 ± 0.68	n.s	T ₂ - T ₀ :	<0.0001*	<0.0001*
HAAS	T ₀	5.24 ± 1.30	4.46 ± 1.54	n.s	T ₁ - T ₀ :	<0.0001*	<0.0001*
	T ₁	10.71 ± 1.40	10.43 ± 1.37	n.s	T ₂ - T ₁ :	n.s	0.007*
	T ₂	11.29 ± 0.92	11.07 ± 0.79	n.s	T ₂ - T ₀ :	<0.0001*	<0.0001*

Note: values are presented as mean ± SD

BMI body mass index, *UCLA* University of California, Los Angeles activity scores, *HAAS* high-activity arthroplasty score, *TiNbN* titanium niobium nitride, *CoCr* cobalt-chromium, *n.s.* not significant

*Statistical significant difference; # = Lack of variability

Table 6 Statistical significant correlations

Variables		Rho	p value
TiNbN (N=36)			
BMI T ₀	HAAS T ₀	0.51	0.002*
BMI T ₂	HAAS T ₀	0.51	0.002*
Femoral angle	HAAS T ₂	0.33	0.048*
CoCr (N=136)			
BMI T ₂	UCLA T ₂	- 0.19	0.027*
Slope	HAAS T ₁	0.18	0.038*

Note: values are presented as mean ± SD

BMI body mass index, *UCLA* University of California, Los Angeles activity scores, *HAAS* high-activity arthroplasty score, *TiNbN* titanium niobium nitride, *CoCr* cobalt-chromium

*Statistical significant difference

of obesity in clinical practice and population-based studies because of its low cost and relative ease of measurement [14]. Overweight status and obesity in adults increase the risk for arthrosis in the hips and legs and subsequent pain, along with the risk of cardiovascular diseases and diabetes, which may lead to an earlier death. Previous studies have reported that obesity is directly correlated to impaired overall health-related quality of life [7, 28].

Holmgren et al. in 2014, investigated the association of mobility disability with overweight status and obesity and concluded that mobility disability had a higher mean BMI than those without mobility disability and that the risk of pain and low general health (parts of health-related quality of life) increased for every 5 units of higher BMI [10].

Chen et al. evaluated the relationship between BMI and mortality varies according to age, race, and ethnicity in older women founding a consistent relationship between central obesity and mortality [3].

Similar results were found also by Lidstone et al., confirming that obesity is independently associated with a range of disabling conditions in adults [16].

Considering the importance of BMI in the general state of health, and by virtue of the results of our study, in the presence of localized overweight patients with osteoarthritis of the knee, the possibility to intervene with a unicompartmental prosthesis should always be taken into consideration; in fact, literature shows that BMI is not a risk factor for the failure of knee arthroplasty.

Affatato et al. analysed retrospectively the data of patients who received unicompartmental knee prostheses to examine if obesity has an effect on the clinical outcomes. They reported no statistically significant differences in terms of the type of insert, type of tibial component, prosthetic condyle, prosthesis fixation and clinical outcomes [1]. The difference between survival curves was also found, with no significant statistical difference at 10 years for non-obese vs. obese [1].

Similarly, Sundaram et al. noted no increased risk of 30-day postoperative complications as compared to normal-weight individuals [29].

Finally, Polat et al. recently demonstrated that is possible to obtain excellent results after UKA in obese and overweight patients with good planning and correct surgical technique [24].

The present study has some limitations to be considered. The study setting is a high-volume tertiary referral hospital, so our findings may not be generalizable to institutions where UKAs are not performed as frequently. Moreover, this study followed patients for only 1–2 years post-surgically; however, patient activity levels may change beyond this period. Additionally, the TiNbN group was relatively small, even though a power analysis was performed to ensure sample size, which again reduces the generalizability of the study.

These findings inform shared decision-making and can help to manage patient expectations after surgery, in particular, in active patients with an overt metal allergy, a specific hypoallergenic implant should be considered the gold standard implant in partial knee replacement surgery.

Conclusions

Both TiNbN and CoCr UKA procedures enabled patients to return to sports after the final follow-up. Moreover, UKA can also be considered in overweight patients as a modality of relieving pain and helping them resume sports activities by reducing BMI and improving general health status.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interest.

Ethical approval Ethical approval was achieved from the local ethics committee.

Informed consent Informed consent was obtained from all individual participants included in the study.

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