Journal of Orthopaedic Surgery and Research

RESEARCH

Open Access

The efficacy of oxidised regenerated cellulose powder in reducing blood loss during primary total hip arthroplasty: a retrospective cohort study

Pil Whan Yoon[1†], Hong Jin Kim[2,3†], Jae Youn Yoon[1], Jun-Ki Moon[4,7*†] and Sunhyung Lee[5,6†]

Abstract

Background Oxidised regenerative cellulose (ORC) is an absorbable haemostatic agent that acts independently on the blood coagulation mechanisms. Although ORC products have been used as adjuncts in various surgical procedures, their haemostatic effect, particularly the powder type (Surgicel®-P), during primary total hip arthroplasty (THA) remains uncertain. This study aimed to evaluate the effectiveness and safety of ORC powder in patients undergoing primary THA.

Methods This study included 279 patients who underwent primary THA between January 2022 and July 2024, and they were divided into two groups based on the use of ORC powder: the control ($n=138$) and SC (SurgiCel group, $n=141$) groups. Data on perioperative outcomes, including operative time, total blood loss (TBL), intraoperative blood loss (IBL), hidden blood loss (HBL), haemoglobin (Hb) drops, and complication rates over 3 months, were collected and compared between the two groups.

Results The mean IBL was significantly lower in the SC group (197.1 mL) than in the control group (243.5 mL) ($P<0.001$). The total operative time ($P=0.465$), procedure time ($P=0.117$), TBL ($P=0.167$), and HBL ($P=0.771$) showed no significant differences. The mean postoperative Hb drop was significantly different between the control and SC groups (1.5 vs. 1.0 g/dL, $P<0.001$). Similarly, the mean postoperative day 1 Hb drop was significantly lower in the SC group than in the control group (1.7 vs. 2.0 g/dL, $P=0.013$). Complication rates showed no significant differences during the 3-month postoperative follow-up.

Conclusions ORC powder significantly reduced IBL and postoperative Hb drops without any comparable complications in patients undergoing primary THA. These findings suggest that ORC powder is a safe and effective

†Pil Whan Yoon and Hong Jin Kim contributed equally, as co-first authors.

†Jun-Ki Moon and Sunhyung Lee contributed equally, as co-corresponding authors.

*Correspondence:
Jun-Ki Moon
junkimoon85@gmail.com

Full list of author information is available at the end of the article

haemostatic agent during primary THA procedures, which may be a valuable adjuvant for reducing blood loss and potential to reduce blood transfusion requirements.

Keywords Oxidised regenerative cellulose, Total hip arthroplasty, Blood loss, Haemoglobin drop, Haemostatic effect

Introduction

Total hip arthroplasty (THA) is one of the most successful orthopaedic procedures for treating end-stage hip arthritis, significantly improving patient mobility and quality of life [1–3]. However, despite its benefits, the postoperative complications such as blood loss, wound dehiscence, and dislocation, remain challenges that need to be addressed [4, 5]. Notably, significant blood loss during the THA procedures is almost unavoidable, with reports indicating approximately 1.0–1.5 L of total blood loss (TBL) [4, 6]. This substantial blood loss during THA causes postoperative anaemia and often necessitates allogeneic blood transfusion, which increases morbidity and carries potential risks for transfusion-related complications [7]. Therefore, reducing blood loss during THA is crucial for minimizing postoperative complications, and various haemostatic methods have been employed to achieve this goal [2, 6].

Haemostatic materials, including bone wax, haemostasis-osteogenesis integrated materials, and biodegradable materials, have been widely used in orthopaedic surgeries, demonstrating effectiveness in controlling perioperative blood loss [8]. Among these, oxidised regenerative cellulose (ORC) is a biodegradable haemostatic agent that acts independently on the blood coagulation mechanisms of the body [9–11]. ORC has proven to be effective and safe as an absorbable haemostat in various surgeries, including neurosurgery, thoracic surgery, general surgery, and total knee arthroplasty [12–15].

Unlike traditional fabric forms, the absorbable ORC powder, prefilled in an applicator, can be directly dispensed onto a target bleeding site during surgical procedures [10]. The unique properties of the powder allow it to effectively cover large surgical fields, including deep bleeding sites when ligation or other conventional methods of control are impractical or ineffective [10, 15]. Reducing continuous oozing can minimise intraoperative bleeding and facilitate better surgical field visualization. It may also reduce postoperative bleeding, hemoglobin (Hb) drop, and blood transfusion requirements. Therefore, we hypothesised that these properties make ORC powder an ideal adjunct for reducing intraoperative blood loss (IBL) during THA. However, there is limited data on the efficacy of ORC powder in hip surgeries, and its haemostatic effect during primary THA procedures remains unclear. Therefore, this retrospective cohort study aimed to evaluate the effectiveness and safety of ORC powder in patients undergoing primary THA.

Materials and methods

This retrospective analysis was conducted at a single institution where THA is routinely performed following the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology study [16]. Our institutional review board (No. 30-2025-2) approved the concepts and procedures of the study.

Study design and patients groups

We retrospectively reviewed the medical records of patients who underwent THA between January 27, 2022, and July 31, 2024. The ORC powder (Surgicel®-P, ETHICON Inc., Somerville, New Jersey, USA) has been routinely used for THA procedures since 8 June 2023, under the practice of a single experienced senior surgeon at our institution. Thus, the study population (time-based grouping based on 8 June 2023) was divided according to the use of ORC powder between 27 January 2022, and 31 July 2024 (Fig. 1a). The inclusion criteria comprised cases of THA performed at our institution between 27 January 2022, and 31 July 2024, with follow-up for > 3 months ($n = 572$). The exclusion criteria for patients were as follows: (1) bilateral THA in single admission ($n = 227$); (2) THA due to trauma ($n = 15$); (3) history of prior surgery in the affected hip ($n = 8$); (4) revisional THA ($n = 2$); (5) medical history of coagulation disorders ($n = 6$); and (6) current usage of antiplatelet and/or anticoagulation agents ($n = 35$). After excluding 293 cases, a total of 279 hips from 269 patients were included in the final analysis. These were divided into two groups based on ORC powder usage: the control ($n = 138$, no ORC powder during THA) and SC ($n = 141$, SurgiCel group, ORC powder usage during THA) groups (Fig. 1b).

THA procedures

All included patients underwent primary THA performed by a single senior surgeon who is a specialist in managing hip diseases. The procedure was performed under spinal anaesthesia using the posterolateral approach. Each patient received 500 mg of tranexamic acid (mixed with 50 mL normal saline) intravenously before the skin incision. Following the incision through the subcutaneous tissues, posterior soft tissue dissection was performed, and electrocautery was used for mechanical coagulation. In the SC group, ORC powder was applied broadly to areas with blood oozing in the soft tissues (Fig. 2). The femoral head was dislocated posteriorly, and the femoral neck was cut at the appropriate level and angle based on preoperative templating of the

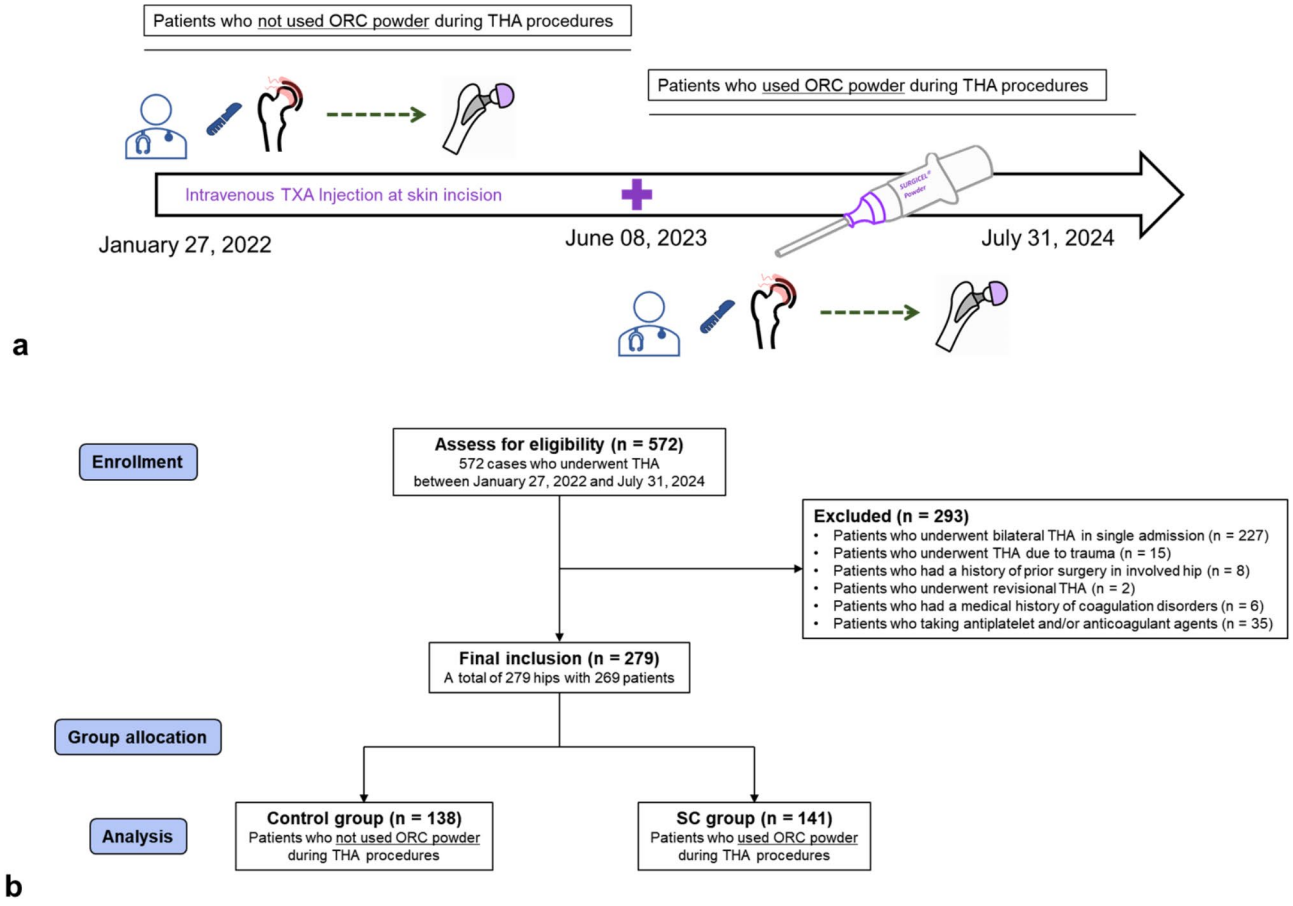

Fig. 1 The study protocols. (**a**) Study design for using oxidised regenerative cellulose powder. (**b**) Study flowchart

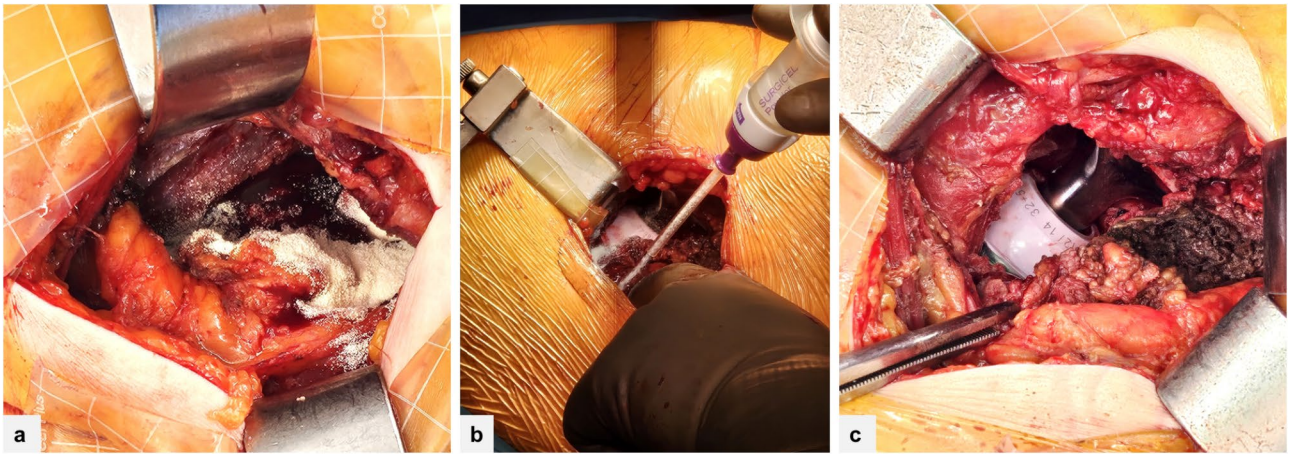

Fig. 2 Intraoperative view for the use of oxidised regenerative cellulose powder product. (**a**) During the total hip arthroplasty (THA) procedure, Surgicel® powder was applied to the visible oozing area around the quadratus femoris after dividing the proximal two-thirds of the quadratus femoris and cutting the piriformis muscle and the short external rotators. (**b**) The application of ORC powder provides a consistent dosage per use, regardless of orientation, minimizing product waste. In other words, with a single push when needed, a consistent amount is instantly dispensed, allowing for multiple effective applications without prolonging the surgical time (**c**) After the femoral and acetabular procedures with irrigation, no bleeding was detected in the dark-stained quadratus femoris area

trial components. A second application of ORC powder was applied around the capsule where further oozing was observed after the femoral neck was cut. Acetabular reaming was performed using an appropriately sized reamer, followed by the insertion of the actual acetabular component. Next, the femoral procedures were performed in sequence: serial rasping on the femoral side, verifying the correct size of the femoral component and acetabular cup position via intraoperative radiography, inserting the final femoral component, and manually testing joint stability. Before saline irrigation, electrocautery coagulation was performed on any observed active bleeding sites. In the SC group, a final application of ORC powder was made to blood-oozing areas. After irrigation with normal saline, posterior soft tissues, including capsules, muscles, and fascia, were sutured layer by layer. A suction drain was not used in any of the patients.

Outcome measures

Patient data from our hospital database were retrospectively collected and comparatively analysed between the two groups. The baseline characteristics collected included the demographic variables, patient status, and laboratory data. Demographic variables included sex, age, body mass index (BMI), diagnosis of hip conditions (primary osteoarthritis [OA], osteonecrosis of the femoral head [ONFH], dysplastic OA, others, or unspecified), and direction of the primary THA (right and left). Patient status was assessed using the American Society of Anaesthesiologists (ASA) grade, Charlson Comorbidity Index (CCI) score, comorbidities (hypertension, diabetes mellitus, and dyslipidaemia), smoking history, and preoperative blood volume (PBV). PBV was calculated using the method proposed by Nadler et al.: $k_1 \times \{height(m)\}^3 + k_2 \times \{weight(kg)\} + k_3$ (For men, $k_1 = 0.366$, $k_2 = 0.032$, and $k_3 = 0.604$; for women, $k_1 = 0.356$, $k_2 = 0.033$, and $k_3 = 0.183$) [17]. Baseline laboratory data comprised preoperative Hb, haematocrit (Hct), platelet, and coagulation index, including prothrombin time (PT), PT international normalised ratio (INR), and activated partial PT (aPTT).

The perioperative outcomes assessed in this study included total operative time (from the start to the end of anaesthesia), procedure time (from the time of surgical incision to the end of suturing), hospital stay, and blood loss-related variables. The blood loss-related variables included TBL, IBL, hidden blood loss (HBL), postoperative Hb drop, and postoperative day 1 Hb drop. TBL was calculated using the Gross method: PBV × ([preoperative Hct– minimum-allowable Hct]/[the average of the preoperative and minimum-allowable Hct]) [18]. IBL was calculated as follows: total volume collected in the suction bottle + blood volume absorbed by gauze (measured by postoperative gauze weight– net gauze weight)– intraoperative irrigation volume. Following THA, a complete blood count was routinely performed postoperatively, with an additional laboratory test conducted on postoperative day 1 and follow-up tests every 3 days during hospital stays. The postoperative Hb drop was defined as preoperative Hb level– postoperative Hb level, while the postoperative day 1 Hb drop was defined as preoperative Hb level– postoperative day 1 Hb level.

Complications monitored during the 3-month follow-up included allogeneic blood transfusion during the postoperative period, deep vein thrombosis (DVT), intramuscular venous thrombosis, pulmonary embolism (PE), wound-related challenges, early infection, and 90-day unplanned readmission.

Statistical analysis

Statistical analyses were conducted using Python (version 3.11.5., Python Software Foundation, Wilmington, DE, USA) with *matplotlib* (version 3.7.2.). Normal distribution was assessed using the Kolmogorov–Smirnov test. Based on the assessment of data homogeneity or heteroscedasticity, the Student's independent t-test was applied for continuous variables, and the chi-square test for categorical variables. A multivariate regression analysis was performed using the backward elimination method to identify the factors influencing postoperative Hb levels among the variables included in this study. Statistical significance was set at $P < 0.05$.

Results

Baseline characteristics between the two groups

The mean age in the control and SC groups was 56.1 and 55.1 years, respectively, with no statistical difference ($P = 0.522$). The mean BMI was 25.6 and 25.4 kg/m^2 in the control and the SC groups, respectively ($P = 0.665$). The primary diagnoses among patients who underwent primary THA were ONFH (42.7%) and dysplastic OA (42.7%). The two groups showed no significant difference regarding hip diagnosis ($P = 0.379$). The majority of patients in both groups were classified as ASA grade II, comprising 80.4% of the control group and 76.6% of the SC group with no significant difference ($P = 0.595$). Additionally, the mean CCI score ($P = 0.144$), comorbidities ($P > 0.05$ for all), and smoking history ($P = 0.395$) were not significantly different between both groups. The mean PBV values were 4,155.5 and 4,141.2 mL in the control and SC groups ($P = 0.879$), respectively, while the mean preoperative Hb levels were 13.9 g/dL and 13.7 g/dL in the control and SC groups ($P = 0.148$), respectively. Preoperative laboratory findings also showed no significant differences between the two groups ($P > 0.05$ for all). Table 1 details the baseline characteristics of the study participants.

Table 1 Baseline characteristics between two groups in this study

Variables	Control group (*n* = 138)	SC Group (*n* = 141)	*P*
Demographics			
Sex (male: female, n,%)	66:72 (47.8%:52.2%)	60:81 (42.6%:57.4%)	0.376
Age (years, mean ± SD)	56.1 ± 13.4	55.1 ± 13.2	0.522
BMI (kg/m^2, mean ± SD)	25.6 ± 3.8	25.4 ± 3.4	0.665
Diagnosis (n, %)			0.379
Primary OA	11 (8.0%)	18 (12.8%)	
ONFH	64 (46.4%)	55 (39.0%)	
Dysplastic OA	56 (40.6%)	63 (44.7%)	
Others or unspecified	7 (5.0%)	5 (3.5%)	
Direction of primary THA (n, %)			0.494
Right	80 (58.0%)	76 (53.9%)	
Left	58 (42.0%)	65 (46.1%)	
Patients' status			
ASA grade (I: II: III, n, %)	21:111:6 (18.9%:80.4%:0.7%)	23:108:10 (16.3%:76.6%:7.1%)	0.595
CCI score (mean ± SD)	1.3 ± 1.1	1.1 ± 1.1	0.144
Comorbidities (yes: no, n, %)	49:89 (35.5%)	40:101 (28.4%)	0.201
Hypertension			
Diabetes mellitus	9:129 (6.5%)	11:130 (7.8%)	0.679
Dyslipidemia	39:99 (28.3%)	36:105 (25.5%)	0.607
Smoking (yes: no, n, %)	29:109 (26.6%)	24:117 (17.0%)	0.395
PBV (mL, mean ± SD)	4155.5 ± 774.0	4141.2 ± 793.5	0.879
Baseline laboratory findings			
Preoperative Hb (g/L, mean ± SD)	13.9 ± 1.5	13.7 ± 1.2	0.148
Preoperative Hct (%, mean ± SD)	41.2 ± 4.0	41.4 ± 3.6	0.585
Preoperative platelet (×10^9 /L, mean ± SD)	254.5 ± 56.1	262.8 ± 58.2	0.227
Preoperative coagulation index (mean ± SD)			
PT (sec)	10.7 ± 0.7	11.3 ± 8.5	0.354
PT INR (n)	1.5 ± 4.5	1.8 ± 5.6	0.666
aPTT (sec, n)	27.3 ± 19.2	30.2 ± 35.7	0.397

BMI, Body mass index; OA, Osteoarthritis; ONFH, Osteonecrosis of the femoral head; ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; PBV, Preoperative blood volume; Hb, Hemoglobin; Hct, Hematocrit; PT, Prothrombin time; INR, International normalized ratio; aPTT, Activated partial prothrombin time

Perioperative outcomes between the two groups

The total operative time ($P = 0.465$) and procedure time ($P = 0.117$) were 112.7 min and 66.7 min in the control group and 111.1 min and 63.7 min in the SC group, respectively. The proportion of patients with hospital stays > 2 weeks was not significantly different between the two groups ($P = 0.508$). The mean TBL were 876.8 mL and 817.5 mL in the control and SC groups ($P = 0.167$), respectively. However, the mean IBL was significantly lower in the SC group than in the control group (197.1 vs. 243.5 mL, $P < 0.001$). The mean HBL was not significantly different between the two groups ($P = 0.771$) (Table 2). The mean postoperative Hb drop (1.0 vs. 1.5 g/dL, $P < 0.001$, Fig. 3a) and mean postoperative day 1 Hb drop (1.7 vs. 2.0 g/dL, $P = 0.013$; Fig. 3b) were significantly lower in the SC group than in the control group.

Meanwhile, when we extracted patients with a moderate grade of CCI (3 or 4), the results were consistent with the main findings observed in the total included patient population. The SC group ($n = 16$) was significantly lower in the mean IBL (191.2mL vs. 218.8mL, $P = 0.029$) and the mean postoperative Hb drop (0.9 g/dL vs. 1.4 g/dL, $P = 0.036$) compared to the control group ($n = 24$) in patients with a moderate grade of CCI.

Complications during the 3-month follow-up between the two groups

None of the patients in our retrospective cohort received intraoperative allogeneic blood transfusion. Complications were not significantly different between the two groups ($P > 0.05$ for all). During the postoperative period, only two patients (one patient in each group) required allogeneic blood transfusion ($P = 0.987$). DVT and PE were observed in the control group, with one patient affected by each condition. The 90-day unplanned readmission was reported in three patients in the control group due to the outbreak of Behcet's enteritis in one patient and pneumonia in two patients (Table 3).

Table 2 Perioperative outcomes between two groups in this study

Variables	Control group (*n* = 138)	SC Group (*n* = 141)	*P*
Operative time and hospital stay			
Total operative time (min, mean ± SD)	112.7 ± 18.3	111.1 ± 19.4	0.465
Procedure time (min, mean ± SD)	66.7 ± 14.7	63.7 ± 16.8	0.117
Hospital stay more than two weeks (n, %)	19 (13.8%)	24 (17.0%)	0.508
Blood loss-related variables			
Total blood loss (mL, mean ± SD)	876.8 ± 369.2	817.5 ± 342.4	0.167
Intraoperative blood loss (mL, mean ± SD)	243.5 ± 86.9	197.1 ± 77.9	< 0.001
Hidden blood loss (mL, mean ± SD)	632.7 ± 357.1	620.4 ± 342.0	0.771

Total operative time was determined from the start of anesthesia to the end of anesthesia

Procedure time was determined from the start time of the surgical incision to the end of the suture

Postoperative Hb drop was calculated as preoperative Hb level– postoperative Hb level

Postoperative day 1 Hb drop was calculated as preoperative Hb level– postoperative day 1 Hb level

Hb, hemoglobin

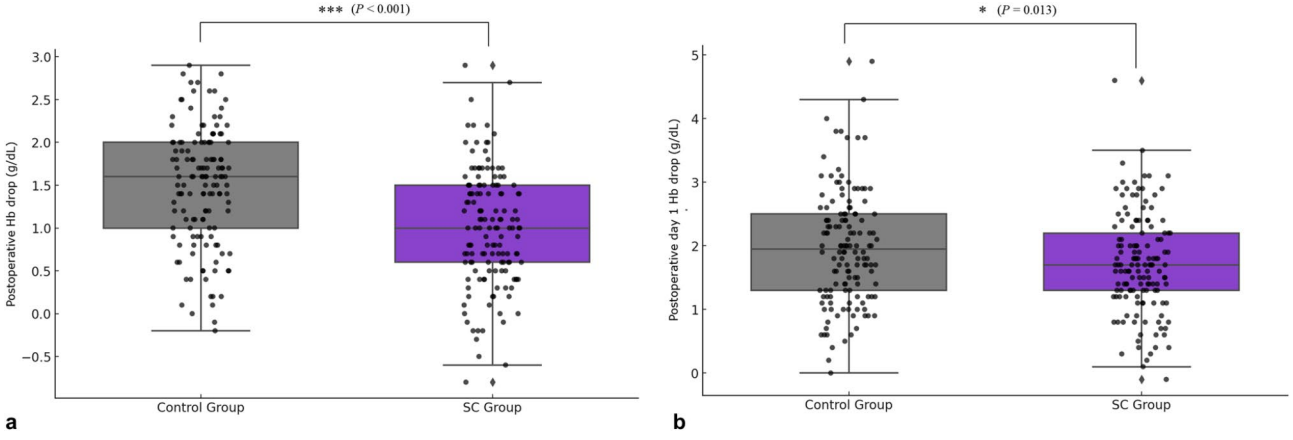

Fig. 3 Haemoglobin (Hb) drop between the control and SC groups. (**A**) A jitter scatter plot with box plot of postoperative Hb drop (Preoperative Hb– Postoperative Hb). (**B**) A jitter scatter plot with box plot of postoperative day 1 Hb drop (Preoperative Hb– Postoperative day 1 Hb)

Table 3 Complication rates for three months follow-up between two groups in this study

Variables	Control group (*n* = 138)	SC Group (*n* = 141)	*P*
Transfusion (n, %)	1 (0.7%)	1 (0.7%)	0.987
DVT (n, %)	1 (0.7%)	0	0.311
IVT (n, %)	0	0	N/A
PE (n, %)	1 (0.7%)	0	0.311
Wound-related problems (n, %)	3 (2.2%)	1 (0.7%)	0.303
Early infection (n)	1 (0.7%)	0	0.311
90-day unplanned readmission (n)	3 (2.2%)	0	0.078

DVT, deep vein thrombosis; IVT, intramuscular venous thrombosis; PE, pulmonary embolism; 90-day unplanned re-admission: Behcet enteritis (1), pneumonia (2)

Multivariate regression analysis for the postoperative hb drop

Using the backward elimination method in multivariate regression analysis, two factors were identified as potentially influencing the postoperative Hb drop. ORC powder application significantly affected the postoperative Hb drop in the primary THA patients (B = – 0.49, β=–0.338, $P < 0.001$). Additionally, the type of hip disease significantly affected the postoperative Hb drop (B = 0.15, β = 0.150, $P = 0.008$) (Table 4).

Table 4 Multivariate regression analysis for the postoperative hemoglobin drop

Postoperative Hb drop	Unstandardized coefficient			Standardized coefficient	t	*P*
	B	SE	95% CI	β		
Use of ORC powder	-0.49	0.08	-0.65 – -0.33	-0.338	-6.06	< 0.001
Diagnosis	0.15	0.06	0.04 – 0.26	0.150	2.69	0.008

Multivariate regression analysis for the postoperative Hb drop was calculated with the backward elimination method for included variables in this study. Hb, hemoglobin; ORC, Oxidized regenerated cellulose

Subgroup analysis for perioperative outcomes between ONFH and dysplastic OA

Based on the result from the multivariate regression analysis, a subgroup analysis was conducted to compare perioperative outcomes between patients with dysplastic OA and ONFH. The analysis revealed a significant difference in the mean postoperative Hb drop with ORC use (1.1 in dysplastic OA vs. 0.9 in ONFH, $P = 0.048$) and the mean postoperative day 1 Hb drop with ORC use (1.9 in dysplastic OA vs. 1.5 in ONFH, $P = 0.002$). The use of ORC significantly reduced IBL ($P = 0.003$ in dysplastic OA, $P = 0.014$ in ONFH) and postoperative Hb drop ($P < 0.001$ in dysplastic OA and ONFH), irrespective of the disease type. Moreover, postoperative day 1 Hb drop was significantly reduced in ONFH (1.8 without ORC, 1.5 with ORC, $P = 0.040$) but not in dysplastic OA (2.0 without ORC, 1.9 with ORC, $P = 0.440$). Meanwhile, the procedure time, TBL, IBL, and HBL were not significantly different between ONFH and dysplastic OA ($P > 0.05$ for all).

Discussion

Although THA has shown favourable long-term outcomes in managing patients with end-stage hip diseases, substantial perioperative blood loss remains a significant concern, leading to increased morbidity, mortality, and socioeconomic burdens [2, 5, 19]. Perioperative blood loss in patients who underwent arthroplasty is commonly managed and prevented with adjuvant methods using haemostatic materials such as tranexamic acid injection [2]. Given the limited use of ORC powder in elective hip surgeries, we retrospectively assessed its haemostatic effect during THA procedures. Our study demonstrated that the application of ORC powder effectively reduced IBL and postoperative Hb drops without significantly increasing complications. Furthermore, subgroup analysis revealed that the reduction in postoperative Hb drop was significantly greater in patients with ONFH compared with those with dysplastic OA. Therefore, our findings suggest that ORC is a safe and effective adjuvant for reducing IBL and postoperative Hb drop in patients undergoing THA.

Notable findings of this study focused on perioperative blood loss and Hb drop in THA procedures. First, the use of ORC powder significantly reduced IBL without increasing HBL or TBL during THA procedure. Second, ORC powder contributed significant reduction in postoperative Hb drop, particularly up to postoperative day 1. Interestingly, the application of ORC powder provides a consistent dosage per use, regardless of orientation, minimizing product waste [20]. In other words, with a single push when needed, a constant amount of ORC powder is instantly dispensed, allowing for multiple effective applications without prolonging the procedure time. This ease of application ensures that its use does not lead to an increase in procedure time, as presented in our result. Therefore, the use of ORC powder during THA effectively reduced intraoperative bleeding and postoperative Hb drop, thereby contributing to a potential reduction in blood transfusion requirements.

ORC is a plant-based polymer consisting of continuous fibres that provide mechanical haemostatic properties, making it effective as a topical haemostatic agent, including a matrix for clot formation, platelet activation, and platelet adhesion [9, 15]. Furthermore, the powder form of ORC products was developed to help control mild-to-moderate bleeding over a broad or uneven range of tissue surfaces [10]. Conventional methods such as suturing, ligation, or electrocautery often fall short in controlling soft tissue bleeding from capillaries, veins, and small arteries or diffuse bleeding in broad or deep areas, particularly near critical nerves or blood vessels, which is often experienced in THA procedures [7, 10]. However, studies assessing the efficacy and safety of Surgicel®-P in THA procedures are lacking. Previous research has only explored the haemostatic effects of structured, nonwoven ORC products in THA performed via an anterolateral approach [21]. In a study by Wang et al., ORC was applied just before incision closure, resulting in reduced HBL and Hb loss [21]. However, our study is the first to utilise powder formulations in THA, and unlike other materials, Surgicel®-P offers the distinct advantage of being used frequently during THA via a posterolateral approach.

AI-Attar et al. conducted a postmarket clinical trial to assess the safety and effectiveness of Surgicel®-P in managing mild-to-moderate intraoperative bleeding [10]. This multicentre study, which included cardiothoracic, abdominal, gynaecological, and urological surgeries, confirmed the safety and efficacy of Surgicel®-P in controlling parenchymal surgical bleeding [10]. Furthermore, a notable advantage of Surgicel®-P is its intuitive and easy-to-use nature, regardless of the device orientation during surgical procedures [10]. However, limited information is available on the use of ORC products in orthopaedic surgery. Li et al. demonstrated that ORC could effectively reduce postoperative blood loss in patients undergoing total knee arthroplasty, as shown in a prospective randomised controlled trial [15]. These results, together with our findings, suggest that ORC products are safe and effective haemostatic agents in arthroplasty [15].

Our analysis of blood loss-related perioperative outcomes showed that the use of Surgicel®-P significantly reduced IBL during THA. However, HBL showed no significant difference with the Surgicel®-P application. This contrasts with findings from previous studies on arthroplasty, which reported a significant reduction in HBL but no significant differences in IBL [15, 21]. However, these

studies used fillable ORC materials, not the powder form. Fillable materials applied to the bony surface can reduce the soft tissue gap and create a tamponade effect, which may help control 'invisible bleeding' and thus reduce HBL [10, 15, 21]. However, their frequency of use is limited during surgical procedures. In contrast, Surgicel®-P offers the advantage of being readily available for repeated use, which is reflected in reduced IBL [10]. Furthermore, the use of ORC products may reduce the need for additional electrocoagulation during surgical procedures, thereby preventing unnecessary soft tissue injury, bleeding, and nerve damage [10]. These findings suggest that surgeons should carefully select the appropriate type of topical haemostatic agent during preoperative planning.

ORC functions independently of the blood coagulation mechanisms and has a natural affinity for Hb in erythrocytes, which aids in the clotting process and reduces further blood loss [11]. Multiple mechanisms may contribute to the reduction of postoperative Hb loss in the joint cavity and bone: the transformation into a dark brown gelatinous material due to red blood cell degradation and acid haematin production, vasoconstriction, platelet aggregation, and adhesion facilitated by the local low-PH environment [15, 21]. Moreover, the powder form of ORC may lower the risks of infection, foreign body reactions, and compressive-related complications compared to other types of ORC [10]. Complications, including local swelling, spinal cord compression, and haematoma formation, have been reported in previous studies as case reports [22–24]. Most of these cases resulted from the compression of the narrow spinal canal after aortic surgery and/or neurosurgery [21, 24]. However, our study found no significant differences in complication rates with ORC use. Considering the larger joint cavity of the hip compared to the spinal canal, we believe that the compressive effects are less likely to occur, thereby minimising the risk of compression-related complications, reflected in our results.

Our regression analysis indicated that the postoperative Hb drop was influenced by the use of ORC and hip disease diagnosis. Our study suggests that the hip disease type also influences Hb loss during THA procedures, likely due to these variations in surgical techniques, which may impact the overall intraoperative outcome [1, 4, 19]. Interestingly, our subgroup analysis demonstrated that the use of powder ORC during primary THA was more beneficial in patients with ONFH compared to those with dysplastic hips. For the comparison according to the hip disease type, Reddy et al. showed that the patients with ONFH had worse outcomes after THA with respect to intraoperative blood loss, postoperative transfusion, and myocardial infarction, rather than OA [25]. This different pattern of intraoperative blood loss between ONFH and OA originated from several pathological factors such as marrow oedema, synovitis, and altered vascularity [26, 27]. Therefore, considering the increased intraoperative bleeding associated with the pathogenic mechanism of ONFH, the powder form of ORC offers the advantage of effectively reducing the intraoperative bleeding risks.

This study has several strengths and offers insights for future research. We analysed relatively large-sized sample ($n = 279$) to evaluate the haemostatic effect of Surgicel®-P during THA procedures. Our findings demonstrated that Surgicel®-P is an effective and safe adjuvant material for controlling intraoperative bleeding in patients undergoing THA, thereby improving the surgical field. The cost per application of ORC was approximately 117 USD in South Korea. During the THA procedure, ORC powder is primarily applied to areas with oozing around the soft tissue or capsule after posterior soft tissue dissection, following femoral neck osteotomy, and before final closure. A single unit is sufficient to address visible bleeding sites during THA. Considering the cost of each unit in South Korea, this approach may offer potential cost-effectiveness for intraoperative management. In future, the cost-effectiveness study will be required to strengthen our findings. Ultimately, use of ORC powder may contribute to lowering postoperative Hb drop and reducing potential transfusion requirements. Furthermore, these benefits may help decrease contamination risk and surgical site hematoma, potentially alleviating postoperative pain. However, further studies are needed to confirm these effects, which would further strengthen the clinical impact of our findings. Since we excluded several population who had a medical history of coagulation disorders and taking antiplatelet and/or anticoagulant agents, our study did not include patients with severe comorbidities (such as CCI 5 or higher). Instead, our sub-group analysis in patients who had a moderate grade of CCI showed a consistent trend for our main results of this study. Therefore, although our study did not include populations with higher Hb goals such as patients with coronary artery diseases, ischemic disease, end-stage renal diseases, our findings suggested that specific high-risk subgroups potentially also benefit most from ORC use in THA. However, future studies for high-risk subgroups may be essential to strengthen the use of ORC in THA.

This study has some limitations. First, the retrospective design may introduce biases, such as randomisation and selection bias. Although this study is retrospective, the balanced distribution between the two groups and the consistency in baseline characteristics among our study participants help to minimise potential confounding effects. Furthermore, the THA procedures and perioperative protocols were conducted by a single senior surgeon at our institution, and all patients in this study followed the same perioperative management protocols after THA via posterolateral approaches, which helped

minimise potential bias. Second, our study did not assess the clinical and functional outcomes of the patients who underwent primary THA. Third, the follow-up period was relatively short. Therefore, future research should include a randomised controlled trial with a longer follow-up period to validate our findings further.

Conclusions

ORC powder significantly reduced IBL and postoperative Hb drops without significant differences in complications in patients who underwent primary THA. These findings suggest that ORC powder is a safe and effective haemostatic agent and may be a valuable adjuvant for reducing blood loss during primary THA procedures.

Abbreviations

ORC	Oxidised regenerative cellulose
THA	Total hip arthroplasty
TBL	Total blood loss
IBL	Intraoperative blood loss
HBL	Hidden blood loss
Hb	Haemoglobin
BMI	Body mass index
OA	Osteoarthritis
ONFH	Osteonecrosis of the femoral head
ASA	American Society of Anaesthesiologists
CCI	Charlson Comorbidity Index
PBV	Preoperative blood volume
Hct	Haematocrit
PT	Prothrombin time
INR	International normalised ratio
aPTT	Activated partial PT
DVT	Deep vein thrombosis
PE	Pulmonary embolism

Author contributions

PWY: Conceptualization, Data curation, Resources, Methodology, Writing– review & editing. HJK: Writing– original draft, Data curation, Formal analysis, Methodology, Validation. JYY: Validation, Software; J-KM: Project administration, Investigation, Resources, Writing– review & editing; SL: Project administration, Resources, Writing– review & editing. PWY and HJK contributed equally, as co-first authors. J-KM and SL contributed equally, as co-corresponding authors. All authors reviewed the manuscript.

Funding

This study was supported by grants from Johnson & Johnson MedTech Korea (0000000037).

Data availability

The datasets generated and/or analysed during the current study are not publicly available due to ethical issues but are available from the corresponding author on reasonable request.

Declarations

Ethical approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Review Board of the university hospital prior to conducting this study (IRB number: 30-2025-2). A waiver to obtain written informed consent from the patients was obtained from the Institutional Review Board of the university hospital.

Consent to publish

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Orthopaedic Surgery, Seoul Now Hospital, Anyang, Gyeonggi, South Korea
[2]Department of Orthopaedic Surgery, Kyung-in Regional Military Manpower Administration, Suwon, South Korea
[3]Department of Orthopaedic Surgery, Inje University Sanggye Paik Hospital, Seoul, South Korea
[4]Department of Orthopaedic Surgery, Chung-Ang Top Orthopaedic Clinic, Seoul, South Korea
[5]Department of Orthopaedic Surgery, Seoul Metropolitan Government-Seoul National University Boramae Medical Center, Seoul, South Korea
[6]Department of Orthopaedic Surgery, Seoul National University College of Medicine, Seoul, South Korea
[7]Department of Orthopaedic Surgery, Chung-Ang Top Orthopaedic Clinic, 92 Sangdo-ro, Dongjak-gu, Seoul 07041, South Korea

Received: 19 February 2025 / Accepted: 3 April 2025
Published online: 11 April 2025

References

1. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet. 2007;370(9597):1508–19.
2. Sodhi N, Mont MA. Survival of total hip replacements. Lancet. 2019;393(10172):613.
3. Yoon PW, Lee YK, Ahn J, Jang EJ, Kim Y, Kwak HS, et al. Epidemiology of hip replacements in Korea from 2007 to 2011. J Korean Med Sci. 2014;29(6):852–8.
4. Magill P, Cunningham EL, Hill JC, Beverland DE. Identifying the period of greatest blood loss after lower limb arthroplasty. Arthroplast Today. 2018;4(4):499–504.
5. Patel I, Nham F, Zalikha AK, El-Othmani MM. Epidemiology of total hip arthroplasty: demographics, comorbidities and outcomes. Arthroplasty. 2023;5(1):2.
6. Song JH, Park JW, Lee YK, Kim IS, Nho JH, Lee KJ, et al. Management of blood loss in hip arthroplasty: Korean hip society current consensus. Hip Pelvis. 2017;29(2):81–90.
7. Kopanidis P, Hardidge A, McNicol L, Tay S, McCall P, Weinberg L. Perioperative blood management programme reduces the use of allogenic blood transfusion in patients undergoing total hip and knee arthroplasty. J Orthop Surg Res. 2016;11(1):28.
8. Tanghe KK, Chalmers BP, Blevins JL, Figgie MP, Carli AV, Agrusa CJ, et al. Hemostatic agents in orthopedic surgery. Hss J. 2023;19(2):247–53.
9. Zhang S, Li J, Chen S, Zhang X, Ma J, He J. Oxidized cellulose-based hemostatic materials. Carbohydr Polym. 2020;230:115585.
10. Al-Attar N, de Jonge E, Kocharian R, Ilie B, Barnett E, Berrevoet F. Safety and hemostatic effectiveness of SURGICEL(R) powder in mild and moderate intraoperative bleeding. Clin Appl Thromb Hemost. 2023;29:10760296231190376.
11. Cheng W, Li H, Zheng X, Chen L, Cheng F, He J, et al. Processing, characterization and hemostatic mechanism of a ultraporous collagen/orc biodegradable composite with excellent biological effectiveness. Phys Chem Chem Phys. 2016;18(42):29183–91.
12. Franceschini G. Use of oxidized regenerated cellulose as a hemostatic agent in neurosurgery: appraisals and recommendations to prevent postoperative complications and facilitate Follow-Up. Surg Technol Int. 2021;38:481–5.
13. Shimizu N, Tanaka Y, Kuroda S, Nakamura H, Matsumoto G, Mitsui S, et al. Oxidized regenerated cellulose for a clear thoracoscopic view: a single-centre randomized trial. Interact Cardiovasc Thorac Surg. 2020;30(3):346–52.
14. Ng CWQ, Asgeirsson K, Khout H, Gilani SN, Macmillan RD. Off-the-shelf volume replacement in breast-conserving surgery: oxidized regenerated cellulose for upper inner quadrant defects. Br J Surg. 2022;109(5):466–7.
15. Li B, Pan W, Sun X, Qin K, Bai G, Bao H, et al. Hemostatic effect and safety evaluation of oxidized regenerated cellulose in total knee arthroplasty- a randomized controlledtrial. BMC Musculoskelet Disord. 2023;24(1):797.
16. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008;61(4):344–9.

17. Nadler SB, Hidalgo JH, Bloch T. Prediction of blood volume in normal human adults. Surgery. 1962;51(2):224–32.
18. Donovan RL, Lostis E, Jones I, Whitehouse MR. Estimation of blood volume and blood loss in primary total hip and knee replacement: an analysis of formulae for perioperative calculations and their ability to predict length of stay and blood transfusion requirements. J Orthop. 2021;24:227–32.
19. Vrontis K, Tsinaslanidis G, Drosos GI, Tzatzairis T. Perioperative blood management strategies for patients undergoing total hip arthroplasty: where do we currently stand on this matter?? Arch Bone Jt Surg. 2020;8(6):646–55.
20. MacDonald MH, Wang AY, Clymer JW, Hutchinson RW, Kocharian R. An in vivo comparison of the efficacy of hemostatic powders, using two Porcine bleeding models. Med Devices (Auckl). 2017;10:273–9.
21. Wang JQ, Chen LY, Jiang BJ, Zhao YM. Oxidized regenerated cellulose can reduce hidden blood loss after total hip arthroplasty: A retrospective study. J Invest Surg. 2019;32(8):716–22.
22. Dogan S, Kocaeli H, Doygun M. Oxidised regenerated cellulose as a cause of paraplegia after thoracotomy: case report and review of the literature. Spinal Cord. 2005;43(7):445–7.
23. Jaspan D, Dandolu V, Miller M, Dunton C. Oxidized regenerated cellulose presenting as a postoperative cyst: a case report. J Reprod Med. 2007;52(12):1109–10.
24. Brodbelt AR, Miles JB, Foy PM, Broome JC. Intraspinal oxidised cellulose (Surgicel) causing delayed paraplegia after thoracotomy–a report of three cases. Ann R Coll Surg Engl. 2002;84(2):97–9.
25. Reddy GB, Tremblay JO, Yakkanti RR, Hernandez VH, D'Apuzzo MR. Increased risk of In-Hospital complications and costs after total hip arthroplasty for primary and secondary osteonecrosis. J Arthroplasty. 2023;38(11):2398–403.
26. Lovecchio FC, Manalo JP, Demzik A, Sahota S, Beal M, Manning D. Avascular necrosis is associated with increased transfusions and readmission following primary total hip arthroplasty. Orthopedics. 2017;40(3):171–6.
27. Pachore JA, Shah VI, Upadhyay S, Shah K, Sheth A, Kshatriya A. The use of Tranexamic acid to reduce blood loss in uncemented total hip arthroplasty for avascular necrosis of femoral head: a prospective blinded randomized controlled study. Arthroplasty. 2019;1(1):12.

Publisher's note