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Survivorship and Modes of Failure of Varus-Valgus Constrained Implants in Revision Knee Arthroplasty: A Study with a Median Follow-Up of 2.9 Years in an Asian Population

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Purpose: This study aims to evaluate the survival rate, primary causes of failure, and complications associated with varus-valgus-constrained (VVC) implants in revision total knee arthroplasty (TKA) at a large Asian medical institution.
Methods: We retrospectively reviewed 161 patients who underwent revision TKA with VVC implants at our institution between January 2013 and December 2021. Data on patient demographics, initial diagnosis, revision dates, causes of failure, and subsequent re-revisions were collected and analyzed. The Kaplan-Meier method was used to estimate implant survival rates.
Results: This study included 161 patients who received VVC implant revisions, with a mean age of 73 years at the time of surgery. The mean follow-up period was 2.9 years, extending up to 10.0 years. The primary reasons for revision were infection (47.8%), aseptic loosening (36%), and instability (8.1%). The overall survival rate of VVC implants was 86.3%, with aseptic revisions at 84.5% and septic revisions at 88.3%, based on a median follow-up of 2.9 years. The 2-year survival rates were 92.5% overall, 88.1% for aseptic revisions, and 97.4% for septic revisions. The re-revision rate was 13.7% (22 VVC implants), primarily due to infections (86.4%).
Conclusions: VVC implants demonstrated a high 2-year survival rate of 92.5% in revision TKA at a large Asian medical institution. The most common indications for VVC implant use in revisions were infection and aseptic loosening, with infection being the leading cause of subsequent re-revisions.

Keywords: Varus-valgus constrained, Revision knee arthroplasty, Survival rate

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A varus-valgus constrained (VVC) insert is an unlinked constrained device that utilizes a cam-and-post mechanism featuring a taller and thicker post. This design improves stability by resisting posterior translation and varus-valgus stress[1] and is indicated in both complex primary[2] and revision total knee arthroplasty (TKA). It is particularly indicated in cases involving medial collateral ligament insufficiency[3], flexion-extension gap mismatch[4], severe flexion contracture[5], and inade-

quate bone stock following prosthesis removal[6]. Notably, implant loosening is the most common reason for revision to a VVC implant[7]. Several studies[8 - 10] have reported that second-generation nonlinked semi-constraint implants, such as the CCK [Zimmer], TC-3 [Johnson & Johnson], and Endolink [Link], offer favorable survival rates with fewer complications.

Literature has identified instability, loosening, dislocation, arthrofibrosis, and fracture as potential failure modes for VVC implants. Additionally, aseptic revisions have been found to carry a 2.1 times higher risk of failure compared to primary VVC implants, while septic revisions have a 4.3 times higher risk of failure[7].

Notably, the majority of TKA prostheses have been designed primarily for the Caucasian population. Consequently, reports[11] suggest that anatomical and functional differences in Asian populations, such as a higher degree of tibial torsion and a mismatched femoral aspect ratio, may influence the suitability and performance of VVC implants originally designed for Caucasian populations[12].

This study aims to evaluate the survivorship of these implants, identify factors contributing to failures that necessitate revision TKA using a VVC insert, and assess the incidence of complications within a large Asian medical institution.

METHODS

We retrospectively reviewed our institution's database from January 1, 2013, to December 5, 2023, following approval from our institutional review board (COA No. Si 363/2023). The study included all patients who underwent revision knee replacement with VVC implants, performed by fellowship-trained orthopedic surgeons between January 2013 and December 2021. Patients who received VVC implants as their primary procedure or had incomplete data were excluded from the study. Data collection encompassed patient demographics, diagnosis at the time of revision, the revision date, and the cause of VVC implant failure. Failure causes were categorized into infection, aseptic loosening, periprosthetic fracture, polyethylene wear, instability, recurrent dislocation, and malalignment. The majority of VVC implants used at our institution were CCK [Zimmer] and TC-3 [Johnson & Johnson]. Implant survival was calculated from the date of surgery, with re-revision surgery serving as the endpoint. Re-revision included the exchange of modular components or partial or complete removal of implants. In the implant survivorship analysis, death was considered a competing risk to provide a comprehensive outcome evaluation. The reasons for re-revision were recorded and categorized similarly to the initial causes of failure. Prosthetic joint infection (PJI) was analyzed separately under 'Septic Revision' to account for revisions caused by infection-related complications. Additionally, re-revisions due to infection were classified as PJI-related, ensuring that the impact of infection on implant survival was independently assessed.

Statistical Analysis

Continuous data were presented as mean ± standard deviation or median (interquartile range), depending on data distribution. A comprehensive data collection process was conducted, including patient demographics, clinical characteristics, and follow-up information. To ensure accuracy and reliability, data validation processes were implemented, including double-checking entries by our author team. Categorical data were expressed as numbers and percentages. Comparisons of continuous variables across various failure causes were performed using a one-way analysis of variance or the Kruskal-Wallis test, depending on data distribution. Implant survivorship was assessed utilizing the Kaplan-Meier analysis, with hazard ratios calculated to estimate survival rates. Additionally, Cox regression analysis was used to adjust multiple variables. Statistical significance was defined as a p-value less than 0.05.

RESULTS

Our study included 161 patients who underwent revision surgery using a VVC insert. The patient group consisted of 28 (17.4%) males and 133 (82.6%) females. The mean age of participants at the time of surgery was 73 years, with a 95% confidence interval (CI) of 67–81 years. The mean

body mass index of participants was 25 kg/m² (95% CI: 23.7–27.4). Based on the World Health Organization classification[15], 7.5% of the participants were categorized as obese, 43.75% as pre-obese (overweight), and 48.75% as having a normal weight. The most prevalent underlying medical conditions were diabetes mellitus (72.7%), hypertension (54%), and dyslipidemia (26.7%). The average follow-up period was 2.9 years. A detailed summary of patient characteristics is presented in Table 1. The primary indications for revisions were PJI in 77 (47.8%) cases, aseptic loosening in 58 (36%) cases, and instability in 13 (8.1%) patients, as shown in Figure 1.

Table 1 Demographic data.

Variables	Data
Age	73 years (67–81)
Height	152.7 cm (149.1–157.7)
Weight	60.7 kg (54.2–64.8)
Body mass index	25 kg/m² (23.7–27.35)
Sex	
Female	133 (82.6%)
Male	28 (17.4%)
Side	
Right	96 (59.6%)
Left	65 (40.4%)
Underlying disease	
Diabetes mellitus	117 (72.7%)
Hypertension	87 (54%)
Dyslipidemia	43 (26.7%)
None	32 (19.9%)
Cause of Failure	
Aseptic loosening	58 (36%)
Dislocation	2 (1.2%)
Instability	13 (8.1%)
Loosening	2 (1.2%)
Malalignment	0 (0%)
Periprosthetic fracture	9 (5.6%)
Prosthetic joint infection	77 (47.8%)
Re-revision	22 (13.7%)
Cause of failure	
Dislocation	1 (4.55%)
Infection	19 (86.36%)
Instability	2 (9.09%)
Implant	
Exchange modular part	14 (63.63%)
Rotating Hinge Knee	4 (18.18%)
Debridement with prosthesis removal	2 (9.09%)
Revision Stem	1 (4.55%)

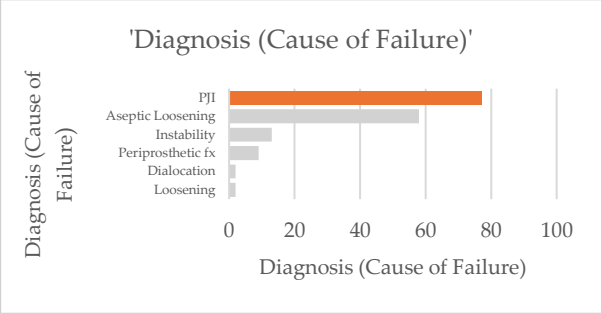

Fig. 1 Causes of failure.

This figure illustrates the distribution of various causes of failure in revision knee arthroplasty with varus-valgus-constrained inserts. The bar lengths represent the number of cases for each cause, highlighting PJI as the predominant cause of failure in the study cohort.

Survival Rate

The Kaplan-Meier analysis revealed that the average implant survival time in our study was 8.88 ± 0.21 years. The overall survival rate was 86.3%, with 84.5% for aseptic revisions and 88.3% for septic revisions, as depicted in Figure 2. Furthermore, the 2-year survival rate was 92.5% across all revisions, 88.1% for aseptic revisions, and 97.4% for septic revisions.

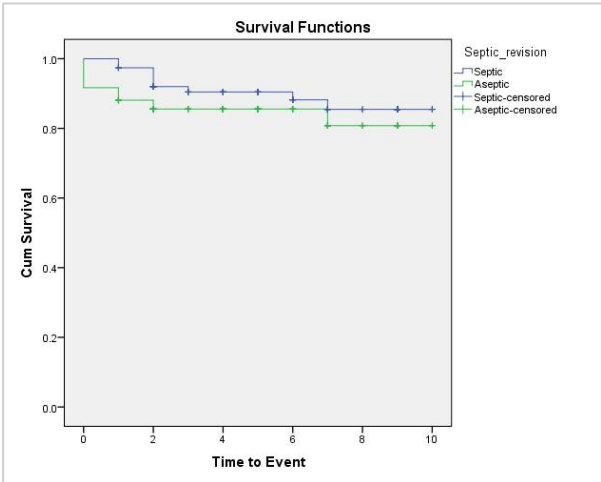

Fig. 2 Survival analysis.

This figure presents the Kaplan-Meier survival curves comparing the cumulative survival rates of septic and aseptic revisions in knee arthroplasty with varus-valgus-constrained inserts.

Complications

The overall re-revision rate was 13.7%, affecting 22 VVC implants. The predominant cause of these re-revisions was infections, which accounted for 86.4% (19 out of 22 cases). Instability was responsible for two (9.1%) cases, while dislocation occurred in one (4.6%) case. The most commonly performed procedure for re-revision was debridement, antibiotics, and implant retention, conducted in 14 (63.6%) knees, followed by a revision with a rotating hinge knee performed on four (18.2%) knees.

DISCUSSION

The consensus among surgeons is to use the least-constrained prosthesis possible in revision surgeries to minimize the risk of mechanical loosening and failure[4, 13, 14]. The VVC insert is widely used in both primary and revision procedures. Comparative studies have highlighted differences in the age at which revisions are performed. Hernandez et al.[15] reported a mean age of 63.9 years, while Siqueira et al.[7] found an average of 66.0 years. In contrast, our study demonstrated a higher average age of 73.0 years, reflecting differences in healthcare systems and the timing of specialist consultations between Asian and other regions. Furthermore, this study supports existing evidence that primary TKA is performed at an older age in Asian populations[16, 17].

The primary indications for revision TKA with VVC, as reported in previous studies[7, 15, 18], include aseptic loosening (29.9–48.8%), infections (28.1–32.1%), and instability (7.7–23.5%). These findings are consistent with our study, which identified PJI, aseptic loosening, and instability as the primary causes for revision procedures.

To the best of our knowledge, this study reports the largest VVC revisions in Asia currently available, demonstrating a strong survival rate of 86.3% overall, 88.3% for septic revisions, and 84.5% for aseptic revisions. As shown in Table 2, the survival rate in this study is slightly lower than that reported in other Asian studies[3, 19-21]. This difference may be attributed to the significantly higher proportion of septic revision cases in our study, which stands at 11.8%, a figure greater than those reported in any other Asian study. Notably, Mancino et al.[2] reported an overall reoperation rate of 11.1%. This finding aligns with those reported by Hernandez et al.[15], who additionally

Table 2 Revision total knee arthroplasty with varus-valgus-constrained implants in Asia.

Author (year of publication)	No. of Knees	Duration of follow-up (years)	Overall Reoperations	Overall Re-revisions	Re-revisions for Aseptic Loosening	Re-revisions for Infection	Reoperations for Other Reasons	Complications	All-Cause Survivorship
Nakano (2016)	41	4.1	7.30%	7.30%	0.00%	7.30%	0.00%	7.30%	92.68%
Lee JK (2012)	79	5.3	7.59%	7.59%	1.27%	5.06%	3.80% (1 Periprosthetic fracture and 2 stem tip pain)	10.10%	93% at 8 years
Kim YH (2009)	114	7.2	8.75%	7.00%	3.51%	1.75%	3.51% (Quadricep tendon rupture and fracture)	8.75%	96 % at 10 years
Hwang SC (2010)	15	2.4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Current study	161	2.9	13.66%	13.66%	0.00%	11.80%	1.86% (Instability and dislocation)	13.66%	86.3%

reported survival rates of 81% at 3 years and 74% at 6 years. Moreover, Siqueira et al.[7] conducted a comprehensive analysis of 685 consecutive VVC cases, with an average follow-up period of 8.2 years, revealing a 10-year survival rate of 75.8% for aseptic revision and 54.6% for septic revisions.

Several studies[22-24] have highlighted the primary causes of failure in revision TKA to include infection (43%), stiffness (13%), and aseptic loosening (11%). Infection is often the leading cause of re-revision, likely due to the complexity of the procedure, prolonged operative times, and compromised soft tissue conditions[17, 25]. Specifically, in the context of revision TKA with VVC, a review by Siqueira et al.[7] supports our finding, showing that infection was the most frequent cause of re-revision, accounting for 42% of cases.

However, this study has some limitations, including the relatively short follow-up period and the limited sample size. We recommend that future research include longer-term follow-up periods and the implementation of prospective randomized controlled trials to provide more robust evidence.

CONCLUSIONS

At our large Asian medical institution, we recorded an impressive 2-year survival rate of 92.5% for revision TKA using a VVC insert. The primary reasons for VVC implant revisions were infection and aseptic loosening. Additionally, infection emerged as the most prevalent complication, which necessitated further revisions.

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