Small bone defects around the femoral component are detected more easily in a nitrided Ti-6Al-4V alloy component than in a cobalt-chromium alloy component after total knee arthroplasty

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INTRODUCTION:

The number of primary total knee arthroplasty (TKA) procedures is increasing worldwide. With the rise in TKA volume, there is also an increase in TKA among younger and more active individuals. However, TKA in younger patients is associated with a higher rate of revision, with loosening reported as the leading cause of revision 10 years postoperatively.

Early detection of radiolucent lines (RLLs) caused by component loosening is important, because delayed detection results in larger bone defects and more complicated revision surgeries. Detecting RLLs around the femoral component is challenging because the thick metal of the femoral component hinders the visualization of bone defects.

It has been reported that the appropriate imaging modality for detecting RLLs in the femoral component varies depending on the implant material; however, no studies have yet identified the best imaging modality for detecting the RLLs around the titanium alloy femoral components.

This study aimed to investigate the sensitivity and specificity of various imaging modalities for detecting RLLs around titanium alloy and cobalt-chromium (Co-Cr) alloy femoral components.

METHODS:

Cemented posterior-stabilized TKA was performed on eight pig knees, purchased from a butcher shop, and TKA was performed only on the femur. Four TKAs were performed using titanium alloy femoral components, and the remaining, using Co-Cr alloy femoral components. Both metals were identical in shape, size, and all other aspects, except material composition. Two types of TKA models were fabricated for each metal component: two normal and two RLL TKA models (Figure 1, 2). RLL TKA models were created by implanting femoral components with 4-mm-thick defects between the bone cement and the bone.

All knees underwent imaging examinations, including fluoroscopically guided plain radiography, tomosynthesis, computed tomography (CT), and magnetic resonance imaging (MRI). Seven experienced orthopedic surgeons, who were blinded to the study, assessed the images as having no RLLs or RLLs. The sensitivity and specificity for detecting RLLs in each imaging modality were analyzed. The chi-square test was used to compare the differences in sensitivity and specificity between the different metal types. Statistical analyses were conducted using R software (version 4.1.2; R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was set at $p < 0.05$.

RESULTS:

Table 1 displays the sensitivity and specificity for detecting RLLs around the titanium alloy and Co-Cr alloy femoral components using various imaging modalities. The sensitivity for detecting the RLLs was significantly higher for titanium alloy TKA than for Co-Cr alloy TKA on fluoroscopically guided plain radiographs and CT (Figure 3, 4).

DISCUSSION AND CONCLUSION:

This study demonstrated that titanium alloy femoral components exhibited superior sensitivity for detecting RLLs, especially when using CT, the sensitivity was 100%.

Previous studies have shown that the sensitivity of detecting RLLs around the Co-Cr femoral components was highest when using tomosynthesis, and the sensitivity of detecting RLLs around zirconium femoral components was highest when using MRI. Thus, the effectiveness of different imaging modalities varies depending on the material of the femoral component. Using titanium alloy components resulted in higher sensitivity for detecting RLLs on fluoroscopically guided plain radiographs and CT compared to Co-Cr alloy components. Thus, titanium TKA not only offers benefits for patients with metal allergies, but also for the early detection of component loosening.

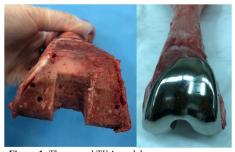

Figure 1: The normal TKA model
The bone is cut as usual, and TKA is implanted.
TKA, total knee arthroplasty.

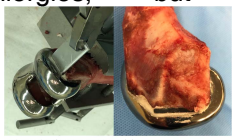

Figure 2: The RLL TKA model
After the usual bone cut, an additional bone cut is made in the distal femur, and the TKA is implanted with a 4 mm defect maintained using an aluminum plate.
RLL, radiolucent line; TKA, total knee arthroplasty.

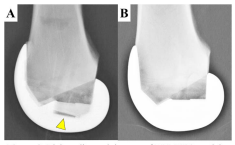

Figure 3: Plain radiograph images of RLL TKA model
(A) Titanium alloy TKA and (B) Co-Cr alloy TKA.
The RLL is detected in titanium alloy TKA but not in Co-Cr alloy TKA (yellow arrows).
RLL, radiolucent line; Co-Cr, cobalt-chromium;
TKA, total knee arthroplasty.

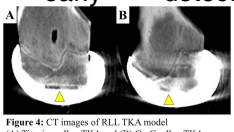

Figure 4: CT images of RLL TKA model
(A) Titanium alloy TKA and (B) Co-Cr alloy TKA.
The RLL is more clearly detected in titanium alloy TKA than in Co-Cr alloy TKA (yellow arrows).
RLL, radiolucent line; Co-Cr, cobalt-chromium;
TKA total knee arthroplasty.

Table 1. The sensitivity and specificity for detecting RLLs around femoral components

Methods	Titanium alloy	Co-Cr alloy	P Value
Fluoroscopic radiography			
Sensitivity (%)	71.4	0	< 0.01*
Specificity (%)	100	92.8	1.00
Tomosynthesis			
Sensitivity (%)	92.9	71.4	0.32
Specificity (%)	71.4	50.0	0.44
CT			
Sensitivity (%)	100	57.1	0.02*
Specificity (%)	85.7	78.6	1.00
MRI			
Sensitivity (%)	64.3	21.4	0.06
Specificity (%)	78.6	92.9	0.59

The values are given as the percentage.
RLLs, radiolucent line; Co-Cr, cobalt-chromium; CT, computed tomography; MRI, magnetic resonance imaging.