



저작자표시-비영리-변경금지 2.0 대한민국

이용자는 아래의 조건을 따르는 경우에 한하여 자유롭게

- 이 저작물을 복제, 배포, 전송, 전시, 공연 및 방송할 수 있습니다.

다음과 같은 조건을 따라야 합니다:



저작자표시. 귀하는 원저작자를 표시하여야 합니다.



비영리. 귀하는 이 저작물을 영리 목적으로 이용할 수 없습니다.



변경금지. 귀하는 이 저작물을 개작, 변형 또는 가공할 수 없습니다.

- 귀하는, 이 저작물의 재이용이나 배포의 경우, 이 저작물에 적용된 이용허락조건을 명확하게 나타내어야 합니다.
- 저작권자로부터 별도의 허가를 받으면 이러한 조건들은 적용되지 않습니다.

저작권법에 따른 이용자의 권리는 위의 내용에 의하여 영향을 받지 않습니다.

이것은 [이용허락규약\(Legal Code\)](#)을 이해하기 쉽게 요약한 것입니다.

[Disclaimer](#)

의학석사 학위논문

한국 사람 중 Kienböck 질병으로  
진단된 손목에 대한 방사선학적 위험  
요소의 정량적 분석

2016년 2월

서울대학교 대학원

의학과 정형외과학 전공

곽 상 호

**Radiological characteristics of  
Kienböck's disease in the Korean  
population**

February, 2016

**Seoul National University**

**College of Medicine**

**Orthopedic Surgery**

**Sang Ho Kwak**

한국 사람 중 Kienböck 질병으로  
진단된 손목에 대한 방사선학적 위험  
요소의 정량적 분석

지도교수 강 승 백

이 논문을 의학석사 학위논문으로 제출함.

2016년 1월

서울대학교 대학원  
의학과 정형외과학 전공  
곽 상 호

곽상호의 의학석사 학위논문을 인준함.

2016년 1월

위 원 장                백구현           (인)

부위원장                강승백           (인)

위      원                최자영           (인)

# **Radiological characteristics of Kienböck's disease in the Korean population**

by

**Sang Ho Kwak, M.D.**

A thesis submitted to the Department of Medicine in partial fulfillment of the requirements for the Degree of Master of Science in Medicine (Orthopedic Surgery) at the Seoul National University College of Medicine

January, 2014

**Approved by Thesis Committee**

**Professor Goo Hyun Baek Chairman**

**Professor Seung-Baik Kang Vice chairman**

**Professor Ja-Young Choi**

## **Abstract**

**Introduction:** In Kienböck's disease, the wrist displays certain characteristic radiological parameters, which have been reported to differ among countries. In the present study, we aimed to determine whether patients with Kienböck's disease have specific radiological features and to determine the extent of the association of each parameter with the disease in the Korean population.

**Methods:** This retrospective comparative study assessed the radiological parameters of patients with Kienböck's disease ( $n = 53$ ) and controls ( $n = 53$ ) who visited our institution between January 2000 and May 2013. As the affected wrists could not be appropriately evaluated, the radiological parameters were measured in the contralateral wrist of each patient.

**Results:** We observed that wrists with a high lunate tilting angle (LTA) and lunate covering index (LCI), and low ulnar variance (UV) and Ståhl's index (SI) had a tendency to develop Kienböck's disease. The radiological tendency of Kienböck's disease ( $Kt$ ) was expressed using these parameters.

**Conclusion:** A high LTA and LCI, and low UV and SI on plain radiography might be associated with Kienböck's disease in the Korean population. The radiological probability of Kienböck's disease could be assessed from the radiological parameters quantitatively. These radiological characteristics might help in the

detection of Kienböck's disease by physicians at an early stage in the Korean population.

-----  
**Key Words:** Kienböck's disease; radiological parameter; Korean; ulnar variance; lunate tilting angle

*Student number:* 2009-23498

## **Contents**

<b>Introduction</b> .....	1
<b>Methods</b> .....	3
<b>Results</b> .....	11
<b>Discussion</b> .....	14
<b>References</b> .....	23
국문 초록 .....	27

## List of Table

<b>Table 1.</b> Demographic information of the study subjects .....	12
<b>Table 2.</b> Results of the radiological parameters and reliability of the measurements.....	12, 13
<b>Table 3.</b> Results of binary logistic regression analysis assessing the influence of each parameter on Kienböck's disease.....	13
<b>Table 4.</b> Variable results according to different measurement methods, country, race, age, and gender in studies of ulnar variance in Kienböck's disease.....	15-18

## List of Figures

<b>Figure 1.</b> Measurement of the ulnar variance (UV) .....	5
<b>Figure 2.</b> Measurement of the radial inclination (RI) and lunate fossa inclination (LFI).....	6
<b>Figure 3.</b> Measurement of the lunate diameter (LD) and lunate height (LH).....	6
<b>Figure 4.</b> Measurement of the lunate tilting angle (LTA).....	7
<b>Figure 5.</b> Measurement of the lunate covering index (LCI).....	7
<b>Figure 6.</b> Measurement of the Ståhl's index (SI) .....	8
<b>Figure 7.</b> Distribution of each parameters .....	10

## **Introduction**

Kienböck was the first to describe the avascular necrosis of the lunate as lunatomalacia in 1910 [1]; however, the etiology of this disease remains unclear. A negative ulnar variance (UV), primary arterial ischemia, trauma, and hand-arm vibration are considered possible risk factors for Kienböck's disease, and among these risk factors, negative UV appears to be the most commonly reported risk factor [2]. In fact, since Hulth first reported the relationship between negative UV and Kienböck's disease [3], several studies have confirmed this relationship [4-7]. However, some studies have reported contrasting results [8-10]. In particular, Afshar et al. suggested that the presence of negative UV as a risk factor for Kienböck's disease may vary depending on the country of origin of the patient [7].

Other radiological parameters have been shown to be associated with Kienböck's disease. Mirabello et al. indicated that the carpal index, lunate deformation, and radial slope are clinically related parameters in patients with Kienböck's disease [5]. Two recent studies reported that the lunate diameter (LD), lunate height (LH), and lunate tilting angle (LTA) are significantly associated with Kienböck's disease, and Thienpont et al. indicated that wrists with certain characteristic radiological features may have a high risk of developing Kienböck's disease [11,12].

Although many radiological parameters have been studied, the influence of

each parameter in Kienböck's disease has not been estimated quantitatively. Therefore, in the present study, we aimed to determine whether patients with Kienböck's disease have specific radiological features and to determine the extent of the association of each parameter with the disease in the Korean population.

## Methods

This retrospective case control study enrolled 91 consecutive patients diagnosed with Kienböck's disease based on radiography and magnetic resonance imaging findings at our institution between January 2000 and May 2013. The study was approved by the institutional review board of our institution (IRB number: H-1404-009-569). The exclusion criteria were bilateral Kienböck's disease (n = 7), concomitant inflammatory arthritis (n = 6), wrist or hand tumor (n = 3), wrist infection (n = 3), previous trauma, such as carpal bone fracture (n = 4) and distal radius fracture (n = 8), history of forearm fracture (n = 2), and severe deformities of the unaffected wrist and forearm (n = 5). Therefore, 53 patients were finally included in the Kienböck's disease group. The control group included patients who visited our institution with distal radius fracture during the study period. We confirmed the absence of previous trauma on the contralateral wrist, inflammatory arthritis, infection, tumor, and severe deformities of the unaffected wrist and forearm. As UV has been reported to differ according to age and sex [13], we believed that other radiological parameters may also be influenced by age and sex. Therefore, we matched each patient from the Kienböck's disease group to a control subject from the control group according to age and sex, with a 1:1 ratio.

The parameters of the affected wrists were difficult to measure owing to the

presence of lunate deformity and secondary arthritis. Previous studies have shown that radiological parameters do not significantly differ between the right and left wrists [11,14]. Therefore, the unaffected wrists of the patients were assessed in the present study.

### **Projection technique of the wrist**

Standard posteroanterior wrist radiographs were obtained with the shoulder abducted to 90°, elbow flexed to 90°, forearm in the neutral position, and hand flat on a table-top. Moreover, lateral radiographs were obtained with the elbow flexed to 90° and hand rotated to 90° in the sitting position [15]. All the images were obtained in a digital format using a Picture Archiving and Communication System (PACS).

### **Radiological parameters**

For measuring the UV, the long axis of the radius was identified by bisecting its medullary width at 2 cm and 5 cm proximal to the distal radial cortex (Fig. 1) [16]. The UV was measured using the method of perpendiculars. A line was drawn perpendicular to the radial axis through the ulnar most point of the articular surface of the radius. The distance between this line and the distal cortex of the ulna was measured.

For measuring the radial inclination (RI), a line was drawn from the ulnar aspect of the carpal surface of the radius to the radial styloid process (Fig. 2).

The angle between this line and the line perpendicular to the radial axis was measured [16].

For measuring the lunate fossa inclination (LFI), a line was drawn from the ulnar aspect of the carpal surface of the radius to the radial prominence of the lunate fossa (Fig. 2). The angle between this line and the line perpendicular to the radial axis was measured [17].

For measuring the LD, a line was drawn from the ulnar tip of the distal facet to the radial tip (Fig. 3). Using this line as a base (the baseline of the lunate), the distance between the ulnar border of the lunate and the radial border was measured as the LD [11].



Figure 1. Measurement of the ulnar variance (UV)



Figure 2. Measurement of the radial inclination (RI) and lunate fossa inclination (LFI)



Figure 3. Measurement of the lunate diameter (LD) and lunate height (LH)



Figure 4. Measurement of the lunate tilting angle (LTA)



Figure 5. Measurement of the lunate covering index (LCI)



Figure 6. Measurement of the Ståhl's index (SI)

For determining the LH, from the baseline of the lunate, the distance between the distal border of the lunate and the radial border was measured (Fig. 3) [11].

To determine the LTA, the angle between the baseline of the lunate and the line perpendicular to the radial axis was measured (Fig. 4) [12].

To determine the lunate covering index (LCI), the lunate was divided with a longitudinal line from the radial side of the distal radioulnar joint, which was parallel to the radial axis (Fig. 5). The ratio of the lunate on the radius to the entire lunate was defined as the LCI [18], and the LCI was represented as a percentage value for convenience.

Ståhl's index (SI) was defined as the ratio of the longitudinal height to the

dorsopalmar width of the lunate in lateral radiographs (Fig. 6) [11], and the SI was represented as a percentage value for convenience.

### **Data measurements**

All the parameters were measured up to the first decimal place. The inter-observer reliability of the measurements was assessed by three orthopedic specialists. The intra-observer reliability was investigated by the first author, and was reassessed twice, at intervals of three weeks.

### **Statistical analysis**

We evaluated the intra- and inter-observer reliability for each parameter using the intra-class correlation coefficient (ICC) with 95% confidence intervals (CIs). An ICC of 1 indicates perfect reliability, and an ICC of 0 indicates no reliability. The multicollinearity between the parameters was determined using the variance inflation factor (VIF). A VIF of >10 indicates high multicollinearity, and a VIF of 1 indicates no multicollinearity. A radiological risk factor model was established using a binary logistic regression model with the backward elimination method. The level of significance was set at  $p < 0.05$ , and the CIs of odds containing 1.00 were excluded.

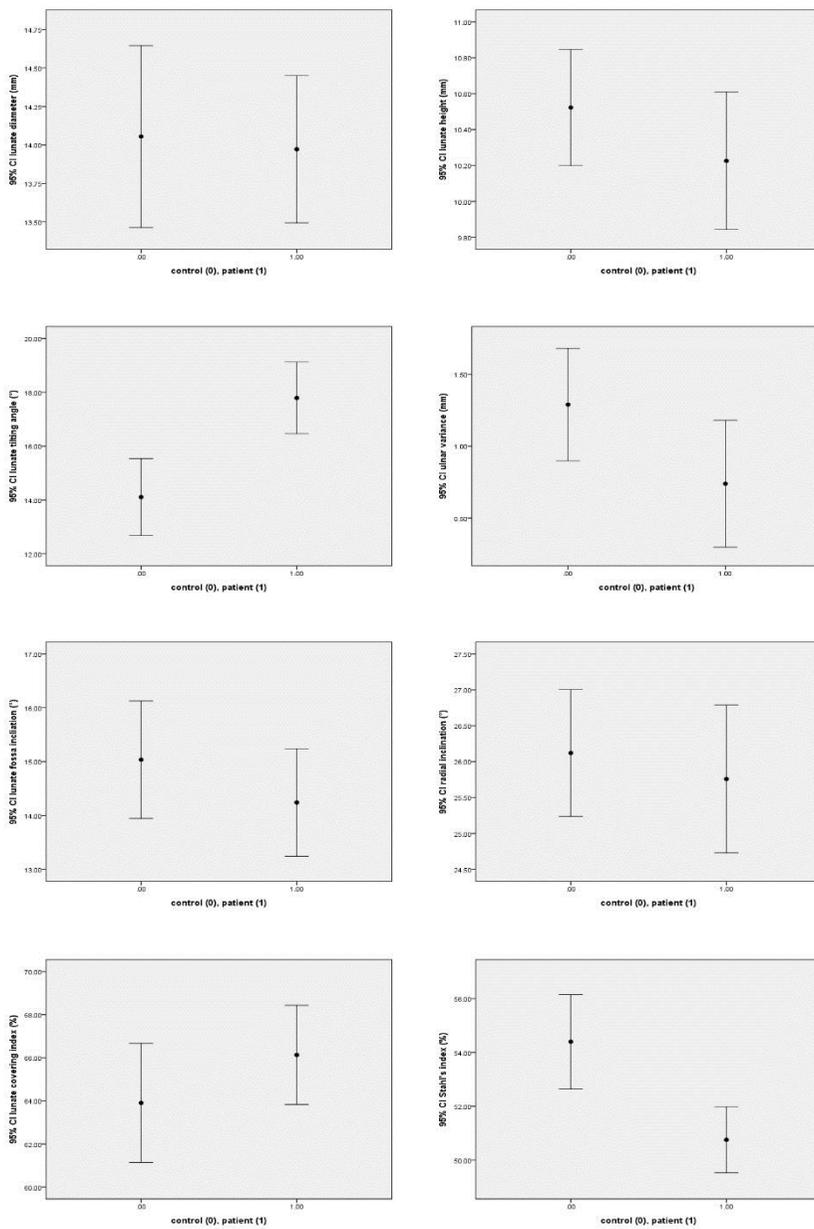


Figure 7. Distribution of each parameters. The mean values (black dots) and 95% of confidence intervals were displayed.

## Results

The demographic data of the study subjects are presented in Table 1. The distribution of parameters were presented in Figure 7. The intra- and inter-observer reliability and multicollinearity between the parameters are presented in Table 2. All the ICCs (>0.8) indicated a considerable degree of reliability between the investigators. All the VIFs (<10) indicated that the degree of multicollinearity among the parameters was low, suggesting that the interactions were considerably low.

LD, LH, and LFI were excluded during logistic transformation, and RI was excluded as the CIs of odds contained 1.00. Additionally, the constant was omitted owing to the presence of a p value (0.139). The final logistic regression model was as follows (Table 3):

$$\ln\left(\frac{Kt}{1-Kt}\right) = (0.175 \times LTA) + (-0.375 \times UV) + (0.060 \times LCI) + (-0.121 \times SI)$$

*Kt* = radiological tendency of Kienböck's disease

The *Kt* of the wrist with a mean radiological value was 0.66 in the Kienböck's disease group and was 0.32 in the control group. Therefore, the radiologic tendency for the development of Kienböck's disease was two times higher in the Kienböck's disease group than in the control group.

	<b>Kienböck's disease group</b>	<b>Control group</b>
	<b>(n = 53)</b>	<b>(n = 53)</b>
<b>Gender</b>		
<b>Male, n (%)</b>	25 (47.2)	25 (47.2)
<b>Female, n (%)</b>	28 (52.8)	28 (52.8)
<b>Age (years)</b>		
<b>Mean (SD)</b>	45.7 (16.4)	46.1 (16.5)
<b>Median (minimum, maximum)</b>	46 (18, 76)	48 (17, 76)

SD, standard deviation

Table 1. Demographic information of the study subjects.

	<b>Kienböck's disease group</b>	<b>Control group</b>	<b>ICC for intra-observer reliability (95% CI)</b>	<b>ICC for inter-observer reliability (95% CI)</b>	<b>VIF</b>
	<b>Mean (SD)</b>	<b>Mean (SD)</b>			
<b>LD (mm)</b>	14.0 (1.7)	14.1 (2.1)	0.985 (0.974–0.991)	0.860 (0.780–0.915)	2.237
<b>LH (mm)</b>	10.2 (1.4)	10.5 (1.2)	0.980 (0.965–0.988)	0.893 (0.830–0.934)	2.392
<b>LTA (°)</b>	17.8 (4.8)	14.1 (5.2)	0.957 (0.926–0.975)	0.955 (0.929–0.973)	1.372
<b>UV (mm)</b>	0.7 (1.6)	1.3 (1.4)	0.979 (0.964–0.988)	0.987 (0.980–0.992)	1.118
<b>LFI</b>	14.2 (3.6)	15.0 (4.0)	0.883 (0.797–	0.877 (0.806–	2.113

(°)			0.932)	0.925)	
<b>RI</b> (°)	25.8 (3.7)	26.1 (3.2)	0.931 (0.880– 0.960)	0.926 (0.883– 0.955)	2.335
<b>LCI</b>	66.1 (8.3)	63.9 (10.0)	0.924 (0.869– 0.956)	0.831 (0.733– 0.897)	1.472
(%)					
<b>SI</b>	50.8 (4.5)	54.3 (6.3)	0.846 (0.733– 0.911)	0.881 (0.813– 0.928)	1.400
(%)					

ICC, intra-class correlation coefficient; VIF, variance inflation factor; CI, confidence interval; SD, standard deviation; LD, lunate diameter; LH, lunate height; LTA, lunate tilting angle; UV, ulnar variance; LFI, lunate covering index; RI, radial inclination; LCI, lunate covering index; SI, Ståhl's index

Table 2. Results of the radiological parameters and reliability of the measurements

	<b>B</b>	<b>p-value</b>	<b>Exp (B) (95% CI)</b>	<b>Hosmer-Lemeshow test</b>
<b>LTA</b>	0.175	<0.001	1.191 (1.087–1.304)	p = 0.932
<b>UV</b>	-0.375	0.017	0.687 (0.506–0.934)	
<b>LCI</b>	0.060	0.007	1.062 (1.017–1.110)	
<b>SI</b>	-0.121	<0.001	0.886 (0.833–0.943)	

LTA, lunate tilting angle; UV, ulnar variance; LCI, lunate covering index; SI, Ståhl's index

Table 3. Results of binary logistic regression analysis assessing the influence of each parameter on Kienböck's disease

## Discussion

Several mechanical factors have been reported to be involved in the development of Kienböck's disease. Lluch et al. classified these into extrinsic factors and intrinsic factors [19]. The radiological parameters assessed in the present study were extrinsic factors, which can be corrected with surgical treatment. For instance, a joint levelling procedure can be performed to correct negative UV, and radial closed wedge osteotomy can be used to correct RI. However, only minimal information is available to determine the extent to which each parameter should be modified. The identified model indicates the extent to which each anatomical parameter contributes to the odds of developing Kienböck's disease. The four parameters had low multicollinearity (VIFs <10); therefore, the effect of each parameter should be discussed independently. Based on our model, we concluded that a high LTA and LCI, and low UV and SI increased the radiological tendency of Kienböck's disease (Kt). This is only a theoretical value that can only tell us a tendency, not an exact risk of Kienböck's disease. But this could be used to establish a clinical model for the influence of extrinsic factors on Kienböck's disease, although it may not be associated with the results of surgical treatment.

As there are risk factors other than radiological parameters, the Kt does not indicate the actual probability of developing Kienböck's disease. Therefore,

we can only compare certain Kt values with others. In our study, the Kt of the wrist with a mean radiological value was compared between the Kienböck's disease group and the control group.

<b>Authors</b>	<b>Group</b>	<b>Methods</b>	<b>Countr y</b>	<b>Race</b>	<b>Mean age (years)</b>	<b>Gender (M/F)</b>	<b>mean UV (SD)  mm</b>
<b>Hulten (1928)</b>	Normal	Project-a- line technique	Sweden	Swedish	Unknow n	Unknown	-0.065 (1.09)
	Patient	Project-a- line technique	Sweden	Swedish	Unknow n	Unknown	-2.04 (1.72)
<b>Chan et al. (1971)</b>	Normal	Project-a- line technique	China	Chinese	Unknow n	Unknown	+0.67 (1.34)
<b>Gelberma n et al. (1975)</b>	Normal	Project-a- line technique	America	Of African descent	Unknow n	Unknown	+0.7 (1.73)
	Normal	Project-a- line technique	America	Caucasi an	Unknow n	Unknown	+0.27 (1.69)
	Patient	Project-a- line technique	America	Caucasi an	Unknow n	Unknown	-1.4 (1.18)
<b>Beckenba ugh et al.</b>	Patient	Undefined	America	Undefin ed	(median ) 32	35/11	-1.81 (1.60)

<b>(1980)</b>							
<b>Park et al. (1982)</b>	Normal	Project-a-line technique	Korea	Korean	Unknown	195/101	+0.69 (2.07)
	Patient	Project-a-line technique	Korea	Korean	Unknown	Unknown	+0.3 (1.5)
<b>Kristensen et al. (1986)</b>	Normal	Modified Palmer's technique	Denmark	Undefined	Unknown	Unknown	-0.84 (1.23)
	Patient	Modified Palmer's technique	Denmark	Undefined	31.2	35/9	-1.42 (1.72)
<b>Mirabello et al. (1987)</b>	Patient	Method of perpendiculars	America	Caucasian	31	41/9	-1.10 (1.78)
	<b>Chen et al. (1990)</b>	Patient	Palmer's technique	Taiwan	Chinese	37.5	14/4
Normal		Palmer's technique	Taiwan	Chinese	42.3	527/473	+0.31 (1.27)
<b>Nakamura et al. (1991)</b>	Normal	Palmer's technique	Japan	Japanese	35.7	203/122	+0.20 (1.39)
	Patient	Palmer's technique	Japan	Japanese	37.3	29/12	-0.37 (1.69), Affected -0.19 (1.69) Unaffected

							ed
<b>Matsushita et al. (1992)</b>	Patient	Palmer's technique	America	Undefined	Unknown	Unknown	-2.89 (1.45)
<b>Tsuge et al. (1993)</b>	Patient	Palmer's technique	Japan	Japanese	34.1	41/0	-0.0 (1.1)
	Normal	Palmer's technique	Japan	Japanese	32.2	66/0	-0.1 (1.9)
<b>D'hoore et al. (1994)</b>	Normal	Palmer's technique	Belgium	Undefined	36	67/58	-0.42 (1.5)
	Patient	Palmer's technique	Belgium	Undefined	35	29/23	-0.8 (1.38)
<b>Hollevoet et al. (2000)</b>	Normal	Project-a-line technique	Belgium	Undefined	41.7	16/34	-0.4 (1.7)
		Project-a-line technique	Belgium	Undefined			-0.3 (1.4)
<b>Thienpont et al. (2004)</b>	Normal	Method of perpendiculars (modified)	Belgium	Undefined	36	68/58	-0.42 (1.4)
	Patient	Method of perpendiculars (modified)	Belgium	Undefined	35	31/23	-0.89 (0.9)
<b>Afshar et al.</b>	Normal	Project-a-line	Iran	Iranian	28.9	286/114	+0.7 (1.5)

<b>al. (2013)</b>		technique					
	Patient	Project-a-	Iran	Iranian	26.7	35/25	-1.1
		line					(1.7)
		technique					
<b>The present study</b>	Normal	Method of	Korea	Korean	46.1	25/28	+1.3
		perpendicula					(1.4)
		rs					
	Patient	Method of	Korea	Korean	45.7	25/28	+0.7
		perpendicula					(1.6)
		rs					

Table 4. Variable results according to different measurement methods, country, race, age, and gender in studies of ulnar variance in Kienböck's disease

Negative UV was first proposed as a risk factor of Kienböck's disease by Hulten, and it has been investigated by many researchers (Table 4) [3,5-14,17,20-23]. The number of studies that performed a direct comparison of previous data was low for the following reasons. First, although the UV was measured as a continuous value, some studies divided this value into categories such as negative, neutral, and positive UV. Second, the UV is thought to differ according to race, age, and sex; therefore, the results obtained from a study are only applicable to a population with similar demographic characteristics as those of the study population. Third, the studies used three different measuring methods. Many comparative studies have consistently reported that the UV is lower in the Kienböck disease group

than in the control group [3,6,7,10,12,20,22]. However, in three studies in the Caucasian population, the mean UV in the control group was negative [10,12,14]. Moreover, in a previous study in a Korean population, the UV was positive in both the control and patient groups [24]. In the present study, the UV was lower in the Kienböck disease group than in the control group, although the value was positive. A previous study that used the same measurement technique also indicated that the mean UV value of the Korean population was positive [25]. Therefore, we believe that this relatively low UV may be an actual risk factor as compared with a negative UV.

The roles of lunate morphology (LD, LH, and SI) and the tilting angle (LTA) have been described previously. As part of the central column theory, Taleisnik stated that the lunate had an important mechanical role in the proximal carpal row [26]. A low LD and LH have been shown to be related with Kienböck's disease, which suggests that a small lunate in the coronal plane may be associated with a high risk of the disease [11,12]. In the present study, LD and LH from posteroanterior radiographs were not associated with a significant decrease in the risk of Kienböck's disease and only an increase in the SI was associated with a significant decrease in the risk of the disease. As the SI represents lunate thickness from lateral radiographs, a thin lunate in the sagittal plane may indicate a high tendency for the development of Kienböck's disease. Moreover, the LTA was significantly associated with the disease. The risk of Kienböck's disease increased with an increase in the LTA,

which has been reported in previous studies [11,12]. This suggests that the vertical inclination of the lunate increased, and we believe that this may have led to a change in the lunate contact area or mechanical load shearing.

The area of the lunate covered by the radius has been reported to be associated with Kienböck's disease. Razemon reported that, in cases with a high LCI, the pressure on the lunate may be more widely distributed, and hence, the risk of Kienböck's disease is minimal [18]. In contrast, Thienpont et al. indicated that the LCI was not an important factor in Kienböck's disease [12]. In these two studies, a line extending from the distal radioulnar joint was used to bisect the lunate. However, the distal radioulnar joint has three basic configurations, and the LCI value would change depending on the configuration [27]. Therefore, we chose a line from the distal radioulnar joint that was parallel to the radial axis. In the present study, a large coverage of the lunate by the radius was highly associated with Kienböck's disease.

The coronal articular slopes of the radius (RI and LFI) have been examined previously. Mirabello et al. reported that patients with a low RI showed early onset of Kienböck's disease [5]. Tsuge et al. and Thienpont et al. reported a significant relationship between the flattened radius and Kienböck's disease; however, Thienpont et al. did not report any relationship between the LFI and Kienböck's disease [11,12]. Contrary to the anatomical findings of the RI, the clinical results of radial closed wedge osteotomy were good [28]. On biomechanical analysis, Watanabe et al. and Garcia-Elias et al. reported that

the lunate was appropriately unloaded using lateral closed wedge osteotomy [28, 29]; however, Werner et al. and Kam et al. reported contrasting results in a cadaver model [30,31]. We believe that the use of a finite element model was a limitation of the former studies, and hence, the results of the latter studies are more reliable. The inconsistencies between the radiological findings and the clinical results, as well as the controversy regarding the biomechanical studies, indicate that other factors, besides simple lunate unloading, influence Kienböck's disease.

The present study has some limitations. First, the parameters of the contralateral wrist might not reflect the parameters of the affected wrist. Although previous reports found no significant differences between the right and left wrists in a normal population, the characteristics of the intact contralateral wrist might differ from those of the affected side. Second, the size of the control group was too small to represent the normal Korean population. As the difference in age between the groups was large, only a 1:1 ratio could be used during matching. Third, disease onset could not be estimated, and most patients visited the clinic only when they experienced symptoms. As the findings of wrist radiography can change with an increase in age, the time of disease onset may be crucial. We believe that the delay from onset to diagnosis may be due to time-related bias [13]. Fourth, we primarily focused on the osseous structures and not on the surrounding soft tissues. Fifth, the subjects were matched for sex and age. Hence, the results

may have limited value as a diagnostic tool. However, wrists with a high radiological risk can be evaluated early.

A high LTA and LCI, and low UV and SI on plain radiography might be associated with Kienböck's disease in the Korean population. The radiological probability of Kienböck's disease could be assessed from the radiological parameters quantitatively. With further assessments of standard radiological findings, our results could provide supportive information for the diagnosis of Kienböck's disease, particularly in the early stage.

## References

1. Kienböck R. Über traumatische malazie des mondbeins und ihre folgezustände: Entartungsformen und kompressionsfrakturen. Fortschr Röntgenstr. 1910;16:77-103.
2. Stahl S, Stahl AS, Meisner C, Rahmanian-Schwarz A, Schaller HE, Lotter O. A systematic review of the etiopathogenesis of Kienbock's disease and a critical appraisal of its recognition as an occupational disease related to hand-arm vibration. BMC Musculoskelet Disord. 2012 Nov 21;13:225.
3. Hulthen O. Über anatomische variationen der handgelenkknochen. Acta Radiologica. 1928;9(2):155-68.
4. Stahl S, Reis N. Traumatic ulnar variance in Kienböck's disease. J Hand Surg Am. 1986 Jan;11(1):95-7.
5. Mirabello SC, Rosenthal DI, Smith RJ. Correlation of clinical and radiographic findings in Kienbock's disease. J Hand Surg Am. 1987 Nov;12(6):1049-54.
6. Chen WS, Shih CH. Ulnar variance and Kienbock's disease. An investigation in Taiwan. Clin Orthop Relat Res. 1990 Jun;(255):124-7.
7. Afshar A, Aminzadeh-Gohari A, Yekta Z. The association of Kienbock's disease and ulnar variance in the Iranian population. J Hand Surg Eur Vol. 2013 Jun;38(5):496-9.

8. Chan KP, Huang P. Anatomic variations in radial and ulnar lengths in the wrists of Chinese. *Clin Orthop Relat Res.* 1971 Oct.;80:17-20.
9. Kristensen SS, Thomassen E, Christensen F. Ulnar variance in Kienbock's disease. *J Hand Surg Br.* 1986 Jun;11(2):258-60.
10. D'Hoore K, De Smet L, Verellen K, Vral J, Fabry G. Negative ulnar variance is not a risk factor for Kienböck's disease. *J Hand Surg Am.* 1994 Mar;19(2):229-31.
11. Tsuge S, Nakamura R. Anatomical risk factors for Kienbock's disease. *J Hand Surg Br.* 1993 Feb;18(1):70-5.
12. Thienpont E, Mulier T, Rega F, De Smet L. Radiographic analysis of anatomical risk factors for Kienbock's disease. *Acta Orthop Belg.* 2004 Oct;70(5):406-9.
13. Nakamura R, Tanaka Y, Imaeda T, Miura T. The influence of age and sex on ulnar variance. *J Hand Surg Br.* 1991 Feb;16(1):84-8.
14. Hollevoet N, Van Maele G, Van Seymortier P, Verdonk R. Comparison of palmar tilt, radial inclination and ulnar variance in left and right wrists. *J Hand Surg Br.* 2000 Oct;25(5):431-3.
15. Davies AM, Grainger AJ, James SJ. *Imaging of the hand and wrist.* Springer; 2013.
16. Mann F, Wilson A, Gilula L. Radiographic evaluation of the wrist: what does the hand surgeon want to know? *Radiology.* 1992 Jul;184(1):15-24.

17. Matsushita K, Firrell JC, Tsai T-M. X-ray evaluation of radial shortening for Kienböck's disease. *J Hand Surg Am.* 1992 May;17(3):450-5.
18. Razemon J. Pathological study of Kienboeck's disease. *Ann Chir Main.* 1982;1(3):240-2.
19. Lluch A, Garcia-Elias M. Etiology of Kienböck disease. *Tech Hand Up Extrem Surg.* 2011 Mar;15(1):33-7.
20. Gelberman RH, Salamon PB, Jurist JM, Posch JL. Ulnar variance in Kienbock's disease. *J Bone Joint Surg Am.* 1975 Jul;57(5):674-6.
21. Beckenbaugh RD, Shives TC, Dobyns JH, Linscheid RL. Kienbock's disease: the natural history of Kienbock's disease and consideration of lunate fractures. *Clin Orthop Relat Res.* 1980 Jun;(149):98-106.
22. Park S, Shon W. Ulnar Variance of the Normal Wrists and Kienbock's disease in Korean. *J Korean Orthop Assoc.* 1982 Apr;17(2):277-82.
23. Kristensen SS, Thomassen E, Christensen F. Ulnar variance determination. *J Hand Surg Br.* 1986 Jun;11(2):255-7.
24. Park M, Lim J, Kim J, Kang H. The Influence of Ulnar Variance on Kienböck's Disease in Korean. *J Korean Soc Surg Hand.* 2005 Mar;10(1):9-13.
25. Jung J, Baek G, Kim J, Lee Y, Chung M. Changes in ulnar variance in relation to forearm rotation and grip. *J Bone Joint Surg Br.* 2001 Sep;83(7):1029-33.

26. Taleisnik J. The ligaments of the wrist. *J Hand Surg Am.* 1976 Sep;1(2):110-8.
27. Tolat A, Stanley J, Trail I. A cadaveric study of the anatomy and stability of the distal radioulnar joint in the coronal and transverse planes. *J Hand Surg Br.* 1996 Oct;21(5):587-94.
28. Garcia-Elias M, An K, Cooney W, Linscheid R. Lateral closing wedge osteotomy for treatment of Kienböck's disease: A clinical and biomechanical study of the optimum correcting angle. *Chir Main.* 1998;17(4):283-90
29. Watanabe K, Nakamura R, Horii E, Miura T. Biomechanical analysis of radial wedge osteotomy for the treatment of Kienböck's disease. *J Hand Surg Am.* 1993 Jul;18(4):686-90.
30. Werner F, Palmer A. Biomechanical evaluation of operative procedures to treat Kienböck's disease. *Hand Clin.* 1993 Aug;9(3):431.
31. Kam B, Topper SM, McLoughlin S, Liu Q. Wedge osteotomies of the radius for Kienbock's disease: a biomechanical analysis. *J Hand Surg Am.* 2002 Jan;27(1):37-42.

## 국문 초록

**서론:** 키엔백 병(Kienböck' s disease)에 이환된 손목은 특징적인 방사선학적 소견을 보이는데, 이는 나라마다 조금씩 다른 양상으로 보고된다. 이 연구에서는 한국인을 대상으로 키엔백 병에 이환된 손목이 가지는 방사선학적 특징을 분석하고 각 지표가 어느 정도 연관되어 있는지를 알아보려고 한다.

**방법:** 2000년에서 2013년까지 서울대병원에 방문한 사람들 중 키엔백 병으로 진단된 환자들 53명과 대조군 53명을 선정하여 이들의 손목에 대해 후향적 비교 대조 연구를 하였다. 이환된 손목에 대해서 정확히 측정하기 어렵기 때문에 계측은 이환되지 않은 반대쪽 손목을 사용하였다.

**결 과:** 월상골 경사(lunate tilting angle)과 월상골 포함지수(lunate covering index)가 클수록, 그리고 척골변이(ulnar variance)와 스탈 지수(Ståhl' s index)가 작을수록 키엔백 병에 이환될 확률이 높았다.

**결 론:** 한국인에서 월상골경사, 월상골 포함지수가 클수록, 척골변이, 스탈 지수가 작을수록 키엔백 병과 밀접하게 연관되어

있었으며 정량적 방사선학적 계측을 통한 키엔백 병과의 연관 정도를 측정할 수 있었다. 이 방사선학적 계측은 한국인에게 보다 조기에 키엔백 병 환자를 예측하고 진단하는 데에 도움이 될 수 있을 것이다.

-----  
**색인 단어:** 키엔백 병, 방사선학적 지수, 한국인, 척골변이, 월상골  
경사

**학 번:** 2009-23498



저작자표시-비영리-변경금지 2.0 대한민국

이용자는 아래의 조건을 따르는 경우에 한하여 자유롭게

- 이 저작물을 복제, 배포, 전송, 전시, 공연 및 방송할 수 있습니다.

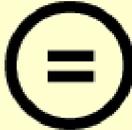
다음과 같은 조건을 따라야 합니다:



저작자표시. 귀하는 원저작자를 표시하여야 합니다.



비영리. 귀하는 이 저작물을 영리 목적으로 이용할 수 없습니다.



변경금지. 귀하는 이 저작물을 개작, 변형 또는 가공할 수 없습니다.

- 귀하는, 이 저작물의 재이용이나 배포의 경우, 이 저작물에 적용된 이용허락조건을 명확하게 나타내어야 합니다.
- 저작권자로부터 별도의 허가를 받으면 이러한 조건들은 적용되지 않습니다.

저작권법에 따른 이용자의 권리는 위의 내용에 의하여 영향을 받지 않습니다.

이것은 [이용허락규약\(Legal Code\)](#)을 이해하기 쉽게 요약한 것입니다.

[Disclaimer](#)

의학석사 학위논문

한국 사람 중 Kienböck 질병으로  
진단된 손목에 대한 방사선학적 위험  
요소의 정량적 분석

2016년 2월

서울대학교 대학원

의학과 정형외과학 전공

곽 상 호

**Radiological characteristics of  
Kienböck's disease in the Korean  
population**

February, 2016

**Seoul National University**

**College of Medicine**

**Orthopedic Surgery**

**Sang Ho Kwak**

한국 사람 중 Kienböck 질병으로  
진단된 손목에 대한 방사선학적 위험  
요소의 정량적 분석

지도교수 강 승 백

이 논문을 의학석사 학위논문으로 제출함.

2016년 1월

서울대학교 대학원  
의학과 정형외과학 전공  
곽 상 호

곽상호의 의학석사 학위논문을 인준함.

2016년 1월

위 원 장                백구현           (인)

부위원장                강승백           (인)

위      원                최자영           (인)

# **Radiological characteristics of Kienböck's disease in the Korean population**

by

**Sang Ho Kwak, M.D.**

A thesis submitted to the Department of Medicine in partial fulfillment of the requirements for the Degree of Master of Science in Medicine (Orthopedic Surgery) at the Seoul National University College of Medicine

January, 2014

**Approved by Thesis Committee**

**Professor Goo Hyun Baek Chairman**

**Professor Seung-Baik Kang Vice chairman**

**Professor Ja-Young Choi**

## **Abstract**

**Introduction:** In Kienböck's disease, the wrist displays certain characteristic radiological parameters, which have been reported to differ among countries. In the present study, we aimed to determine whether patients with Kienböck's disease have specific radiological features and to determine the extent of the association of each parameter with the disease in the Korean population.

**Methods:** This retrospective comparative study assessed the radiological parameters of patients with Kienböck's disease ( $n = 53$ ) and controls ( $n = 53$ ) who visited our institution between January 2000 and May 2013. As the affected wrists could not be appropriately evaluated, the radiological parameters were measured in the contralateral wrist of each patient.

**Results:** We observed that wrists with a high lunate tilting angle (LTA) and lunate covering index (LCI), and low ulnar variance (UV) and Ståhl's index (SI) had a tendency to develop Kienböck's disease. The radiological tendency of Kienböck's disease ( $Kt$ ) was expressed using these parameters.

**Conclusion:** A high LTA and LCI, and low UV and SI on plain radiography might be associated with Kienböck's disease in the Korean population. The radiological probability of Kienböck's disease could be assessed from the radiological parameters quantitatively. These radiological characteristics might help in the

detection of Kienböck's disease by physicians at an early stage in the Korean population.

-----  
**Key Words:** Kienböck's disease; radiological parameter; Korean; ulnar variance; lunate tilting angle

*Student number:* 2009-23498

## **Contents**

<b>Introduction</b> .....	1
<b>Methods</b> .....	3
<b>Results</b> .....	11
<b>Discussion</b> .....	14
<b>References</b> .....	23
국문 초록 .....	27

## List of Table

<b>Table 1.</b> Demographic information of the study subjects .....	12
<b>Table 2.</b> Results of the radiological parameters and reliability of the measurements.....	12, 13
<b>Table 3.</b> Results of binary logistic regression analysis assessing the influence of each parameter on Kienböck's disease.....	13
<b>Table 4.</b> Variable results according to different measurement methods, country, race, age, and gender in studies of ulnar variance in Kienböck's disease.....	15-18

## List of Figures

<b>Figure 1.</b> Measurement of the ulnar variance (UV) .....	5
<b>Figure 2.</b> Measurement of the radial inclination (RI) and lunate fossa inclination (LFI).....	6
<b>Figure 3.</b> Measurement of the lunate diameter (LD) and lunate height (LH).....	6
<b>Figure 4.</b> Measurement of the lunate tilting angle (LTA).....	7
<b>Figure 5.</b> Measurement of the lunate covering index (LCI).....	7
<b>Figure 6.</b> Measurement of the Ståhl's index (SI) .....	8
<b>Figure 7.</b> Distribution of each parameters .....	10

## **Introduction**

Kienböck was the first to describe the avascular necrosis of the lunate as lunatomalacia in 1910 [1]; however, the etiology of this disease remains unclear. A negative ulnar variance (UV), primary arterial ischemia, trauma, and hand-arm vibration are considered possible risk factors for Kienböck's disease, and among these risk factors, negative UV appears to be the most commonly reported risk factor [2]. In fact, since Hulth first reported the relationship between negative UV and Kienböck's disease [3], several studies have confirmed this relationship [4-7]. However, some studies have reported contrasting results [8-10]. In particular, Afshar et al. suggested that the presence of negative UV as a risk factor for Kienböck's disease may vary depending on the country of origin of the patient [7].

Other radiological parameters have been shown to be associated with Kienböck's disease. Mirabello et al. indicated that the carpal index, lunate deformation, and radial slope are clinically related parameters in patients with Kienböck's disease [5]. Two recent studies reported that the lunate diameter (LD), lunate height (LH), and lunate tilting angle (LTA) are significantly associated with Kienböck's disease, and Thienpont et al. indicated that wrists with certain characteristic radiological features may have a high risk of developing Kienböck's disease [11,12].

Although many radiological parameters have been studied, the influence of

each parameter in Kienböck's disease has not been estimated quantitatively. Therefore, in the present study, we aimed to determine whether patients with Kienböck's disease have specific radiological features and to determine the extent of the association of each parameter with the disease in the Korean population.

## Methods

This retrospective case control study enrolled 91 consecutive patients diagnosed with Kienböck's disease based on radiography and magnetic resonance imaging findings at our institution between January 2000 and May 2013. The study was approved by the institutional review board of our institution (IRB number: H-1404-009-569). The exclusion criteria were bilateral Kienböck's disease (n = 7), concomitant inflammatory arthritis (n = 6), wrist or hand tumor (n = 3), wrist infection (n = 3), previous trauma, such as carpal bone fracture (n = 4) and distal radius fracture (n = 8), history of forearm fracture (n = 2), and severe deformities of the unaffected wrist and forearm (n = 5). Therefore, 53 patients were finally included in the Kienböck's disease group. The control group included patients who visited our institution with distal radius fracture during the study period. We confirmed the absence of previous trauma on the contralateral wrist, inflammatory arthritis, infection, tumor, and severe deformities of the unaffected wrist and forearm. As UV has been reported to differ according to age and sex [13], we believed that other radiological parameters may also be influenced by age and sex. Therefore, we matched each patient from the Kienböck's disease group to a control subject from the control group according to age and sex, with a 1:1 ratio.

The parameters of the affected wrists were difficult to measure owing to the

presence of lunate deformity and secondary arthritis. Previous studies have shown that radiological parameters do not significantly differ between the right and left wrists [11,14]. Therefore, the unaffected wrists of the patients were assessed in the present study.

### **Projection technique of the wrist**

Standard posteroanterior wrist radiographs were obtained with the shoulder abducted to 90°, elbow flexed to 90°, forearm in the neutral position, and hand flat on a table-top. Moreover, lateral radiographs were obtained with the elbow flexed to 90° and hand rotated to 90° in the sitting position [15]. All the images were obtained in a digital format using a Picture Archiving and Communication System (PACS).

### **Radiological parameters**

For measuring the UV, the long axis of the radius was identified by bisecting its medullary width at 2 cm and 5 cm proximal to the distal radial cortex (Fig. 1) [16]. The UV was measured using the method of perpendiculars. A line was drawn perpendicular to the radial axis through the ulnar most point of the articular surface of the radius. The distance between this line and the distal cortex of the ulna was measured.

For measuring the radial inclination (RI), a line was drawn from the ulnar aspect of the carpal surface of the radius to the radial styloid process (Fig. 2).

The angle between this line and the line perpendicular to the radial axis was measured [16].

For measuring the lunate fossa inclination (LFI), a line was drawn from the ulnar aspect of the carpal surface of the radius to the radial prominence of the lunate fossa (Fig. 2). The angle between this line and the line perpendicular to the radial axis was measured [17].

For measuring the LD, a line was drawn from the ulnar tip of the distal facet to the radial tip (Fig. 3). Using this line as a base (the baseline of the lunate), the distance between the ulnar border of the lunate and the radial border was measured as the LD [11].



Figure 1. Measurement of the ulnar variance (UV)



Figure 2. Measurement of the radial inclination (RI) and lunate fossa inclination (LFI)



Figure 3. Measurement of the lunate diameter (LD) and lunate height (LH)



Figure 4. Measurement of the lunate tilting angle (LTA)



Figure 5. Measurement of the lunate covering index (LCI)



Figure 6. Measurement of the Ståhl's index (SI)

For determining the LH, from the baseline of the lunate, the distance between the distal border of the lunate and the radial border was measured (Fig. 3) [11].

To determine the LTA, the angle between the baseline of the lunate and the line perpendicular to the radial axis was measured (Fig. 4) [12].

To determine the lunate covering index (LCI), the lunate was divided with a longitudinal line from the radial side of the distal radioulnar joint, which was parallel to the radial axis (Fig. 5). The ratio of the lunate on the radius to the entire lunate was defined as the LCI [18], and the LCI was represented as a percentage value for convenience.

Ståhl's index (SI) was defined as the ratio of the longitudinal height to the

dorsopalmar width of the lunate in lateral radiographs (Fig. 6) [11], and the SI was represented as a percentage value for convenience.

### **Data measurements**

All the parameters were measured up to the first decimal place. The inter-observer reliability of the measurements was assessed by three orthopedic specialists. The intra-observer reliability was investigated by the first author, and was reassessed twice, at intervals of three weeks.

### **Statistical analysis**

We evaluated the intra- and inter-observer reliability for each parameter using the intra-class correlation coefficient (ICC) with 95% confidence intervals (CIs). An ICC of 1 indicates perfect reliability, and an ICC of 0 indicates no reliability. The multicollinearity between the parameters was determined using the variance inflation factor (VIF). A VIF of >10 indicates high multicollinearity, and a VIF of 1 indicates no multicollinearity. A radiological risk factor model was established using a binary logistic regression model with the backward elimination method. The level of significance was set at  $p < 0.05$ , and the CIs of odds containing 1.00 were excluded.

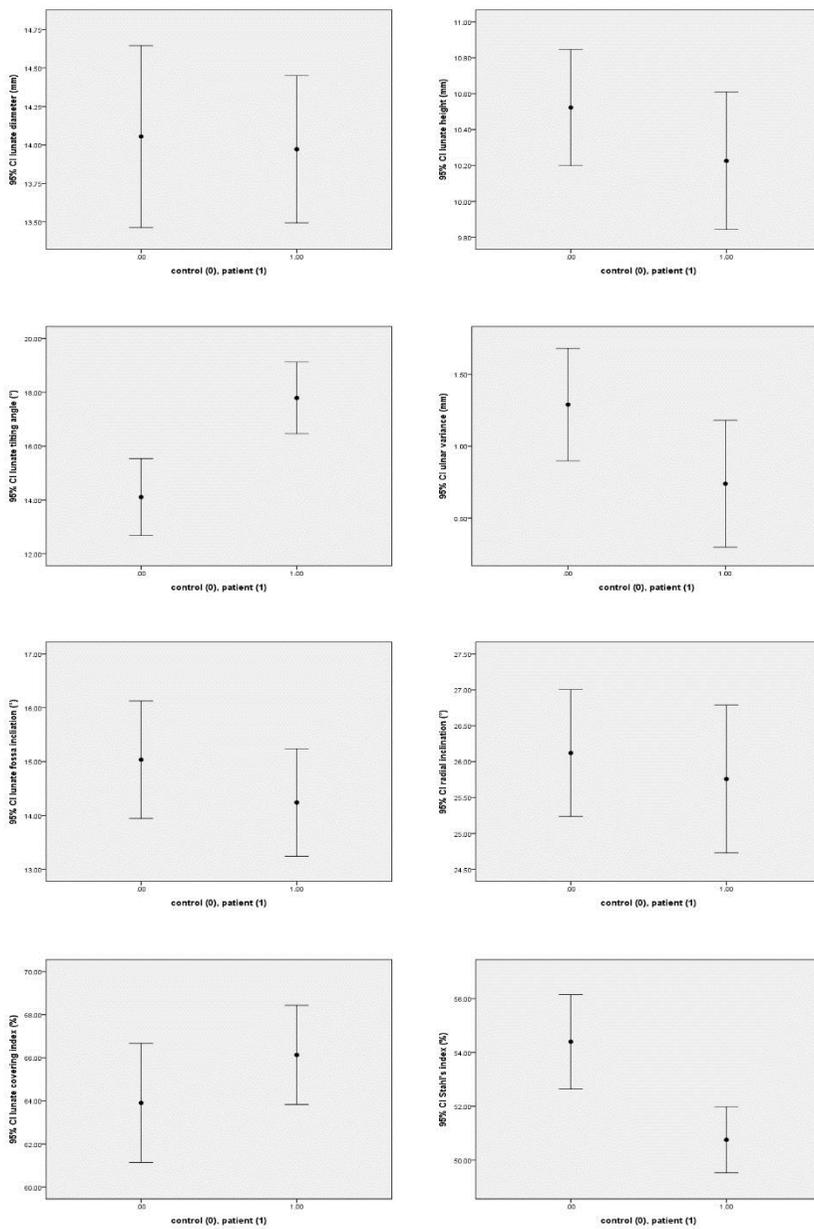


Figure 7. Distribution of each parameters. The mean values (black dots) and 95% of confidence intervals were displayed.

## Results

The demographic data of the study subjects are presented in Table 1. The distribution of parameters were presented in Figure 7. The intra- and inter-observer reliability and multicollinearity between the parameters are presented in Table 2. All the ICCs (>0.8) indicated a considerable degree of reliability between the investigators. All the VIFs (<10) indicated that the degree of multicollinearity among the parameters was low, suggesting that the interactions were considerably low.

LD, LH, and LFI were excluded during logistic transformation, and RI was excluded as the CIs of odds contained 1.00. Additionally, the constant was omitted owing to the presence of a p value (0.139). The final logistic regression model was as follows (Table 3):

$$\ln\left(\frac{Kt}{1-Kt}\right) = (0.175 \times LTA) + (-0.375 \times UV) + (0.060 \times LCI) + (-0.121 \times SI)$$

*Kt* = radiological tendency of Kienböck's disease

The *Kt* of the wrist with a mean radiological value was 0.66 in the Kienböck's disease group and was 0.32 in the control group. Therefore, the radiologic tendency for the development of Kienböck's disease was two times higher in the Kienböck's disease group than in the control group.

	<b>Kienböck's disease group</b>	<b>Control group</b>
	<b>(n = 53)</b>	<b>(n = 53)</b>
<b>Gender</b>		
<b>Male, n (%)</b>	25 (47.2)	25 (47.2)
<b>Female, n (%)</b>	28 (52.8)	28 (52.8)
<b>Age (years)</b>		
<b>Mean (SD)</b>	45.7 (16.4)	46.1 (16.5)
<b>Median (minimum, maximum)</b>	46 (18, 76)	48 (17, 76)

SD, standard deviation

Table 1. Demographic information of the study subjects.

	<b>Kienböck's disease group</b>	<b>Control group</b>	<b>ICC for intra-observer reliability (95% CI)</b>	<b>ICC for inter-observer reliability (95% CI)</b>	<b>VIF</b>
	<b>Mean (SD)</b>	<b>Mean (SD)</b>			
<b>LD (mm)</b>	14.0 (1.7)	14.1 (2.1)	0.985 (0.974–0.991)	0.860 (0.780–0.915)	2.237
<b>LH (mm)</b>	10.2 (1.4)	10.5 (1.2)	0.980 (0.965–0.988)	0.893 (0.830–0.934)	2.392
<b>LTA (°)</b>	17.8 (4.8)	14.1 (5.2)	0.957 (0.926–0.975)	0.955 (0.929–0.973)	1.372
<b>UV (mm)</b>	0.7 (1.6)	1.3 (1.4)	0.979 (0.964–0.988)	0.987 (0.980–0.992)	1.118
<b>LFI</b>	14.2 (3.6)	15.0 (4.0)	0.883 (0.797–	0.877 (0.806–	2.113

(°)			0.932)	0.925)	
<b>RI</b> (°)	25.8 (3.7)	26.1 (3.2)	0.931 (0.880– 0.960)	0.926 (0.883– 0.955)	2.335
<b>LCI</b>	66.1 (8.3)	63.9 (10.0)	0.924 (0.869– 0.956)	0.831 (0.733– 0.897)	1.472
(%)					
<b>SI</b>	50.8 (4.5)	54.3 (6.3)	0.846 (0.733– 0.911)	0.881 (0.813– 0.928)	1.400
(%)					

ICC, intra-class correlation coefficient; VIF, variance inflation factor; CI, confidence interval; SD, standard deviation; LD, lunate diameter; LH, lunate height; LTA, lunate tilting angle; UV, ulnar variance; LFI, lunate covering index; RI, radial inclination; LCI, lunate covering index; SI, Ståhl's index

Table 2. Results of the radiological parameters and reliability of the measurements

	<b>B</b>	<b>p-value</b>	<b>Exp (B) (95% CI)</b>	<b>Hosmer-Lemeshow test</b>
<b>LTA</b>	0.175	<0.001	1.191 (1.087–1.304)	p = 0.932
<b>UV</b>	-0.375	0.017	0.687 (0.506–0.934)	
<b>LCI</b>	0.060	0.007	1.062 (1.017–1.110)	
<b>SI</b>	-0.121	<0.001	0.886 (0.833–0.943)	

LTA, lunate tilting angle; UV, ulnar variance; LCI, lunate covering index; SI, Ståhl's index

Table 3. Results of binary logistic regression analysis assessing the influence of each parameter on Kienböck's disease

## Discussion

Several mechanical factors have been reported to be involved in the development of Kienböck's disease. Lluch et al. classified these into extrinsic factors and intrinsic factors [19]. The radiological parameters assessed in the present study were extrinsic factors, which can be corrected with surgical treatment. For instance, a joint levelling procedure can be performed to correct negative UV, and radial closed wedge osteotomy can be used to correct RI. However, only minimal information is available to determine the extent to which each parameter should be modified. The identified model indicates the extent to which each anatomical parameter contributes to the odds of developing Kienböck's disease. The four parameters had low multicollinearity (VIFs <10); therefore, the effect of each parameter should be discussed independently. Based on our model, we concluded that a high LTA and LCI, and low UV and SI increased the radiological tendency of Kienböck's disease (Kt). This is only a theoretical value that can only tell us a tendency, not an exact risk of Kienböck's disease. But this could be used to establish a clinical model for the influence of extrinsic factors on Kienböck's disease, although it may not be associated with the results of surgical treatment.

As there are risk factors other than radiological parameters, the Kt does not indicate the actual probability of developing Kienböck's disease. Therefore,

we can only compare certain Kt values with others. In our study, the Kt of the wrist with a mean radiological value was compared between the Kienböck's disease group and the control group.

<b>Authors</b>	<b>Group</b>	<b>Methods</b>	<b>Countr y</b>	<b>Race</b>	<b>Mean age (years)</b>	<b>Gender (M/F)</b>	<b>mean UV (SD)  mm</b>
<b>Hulten (1928)</b>	Normal	Project-a- line technique	Sweden	Swedish	Unknow n	Unknown	-0.065 (1.09)
	Patient	Project-a- line technique	Sweden	Swedish	Unknow n	Unknown	-2.04 (1.72)
<b>Chan et al. (1971)</b>	Normal	Project-a- line technique	China	Chinese	Unknow n	Unknown	+0.67 (1.34)
<b>Gelberma n et al. (1975)</b>	Normal	Project-a- line technique	America	Of African descent	Unknow n	Unknown	+0.7 (1.73)
	Normal	Project-a- line technique	America	Caucasi an	Unknow n	Unknown	+0.27 (1.69)
	Patient	Project-a- line technique	America	Caucasi an	Unknow n	Unknown	-1.4 (1.18)
<b>Beckenba ugh et al.</b>	Patient	Undefined	America	Undefin ed	(median ) 32	35/11	-1.81 (1.60)

<b>(1980)</b>							
<b>Park et al. (1982)</b>	Normal	Project-a-line technique	Korea	Korean	Unknown	195/101	+0.69 (2.07)
	Patient	Project-a-line technique	Korea	Korean	Unknown	Unknown	+0.3 (1.5)
<b>Kristensen et al. (1986)</b>	Normal	Modified Palmer's technique	Denmark	Undefined	Unknown	Unknown	-0.84 (1.23)
	Patient	Modified Palmer's technique	Denmark	Undefined	31.2	35/9	-1.42 (1.72)
<b>Mirabello et al. (1987)</b>	Patient	Method of perpendiculars	America	Caucasian	31	41/9	-1.10 (1.78)
	<b>Chen et al. (1990)</b>	Patient	Palmer's technique	Taiwan	Chinese	37.5	14/4
Normal		Palmer's technique	Taiwan	Chinese	42.3	527/473	+0.31 (1.27)
<b>Nakamura et al. (1991)</b>	Normal	Palmer's technique	Japan	Japanese	35.7	203/122	+0.20 (1.39)
	Patient	Palmer's technique	Japan	Japanese	37.3	29/12	-0.37 (1.69),
							Affected -0.19 (1.69) Unaffected

							ed
<b>Matsushita et al. (1992)</b>	Patient	Palmer's technique	America	Undefined	Unknown	Unknown	-2.89 (1.45)
<b>Tsuge et al. (1993)</b>	Patient	Palmer's technique	Japan	Japanese	34.1	41/0	-0.0 (1.1)
	Normal	Palmer's technique	Japan	Japanese	32.2	66/0	-0.1 (1.9)
<b>D'hoore et al. (1994)</b>	Normal	Palmer's technique	Belgium	Undefined	36	67/58	-0.42 (1.5)
	Patient	Palmer's technique	Belgium	Undefined	35	29/23	-0.8 (1.38)
<b>Hollevoet et al. (2000)</b>	Normal	Project-a-line technique	Belgium	Undefined	41.7	16/34	-0.4 (1.7)
		Project-a-line technique	Belgium	Undefined			-0.3 (1.4)
<b>Thienpont et al. (2004)</b>	Normal	Method of perpendiculars (modified)	Belgium	Undefined	36	68/58	-0.42 (1.4)
	Patient	Method of perpendiculars (modified)	Belgium	Undefined	35	31/23	-0.89 (0.9)
<b>Afshar et al.</b>	Normal	Project-a-line	Iran	Iranian	28.9	286/114	+0.7 (1.5)

<b>al. (2013)</b>		technique					
	Patient	Project-a-	Iran	Iranian	26.7	35/25	-1.1
		line					(1.7)
		technique					
<b>The present study</b>	Normal	Method of	Korea	Korean	46.1	25/28	+1.3
		perpendicula					(1.4)
		rs					
	Patient	Method of	Korea	Korean	45.7	25/28	+0.7
		perpendicula					(1.6)
		rs					

Table 4. Variable results according to different measurement methods, country, race, age, and gender in studies of ulnar variance in Kienböck's disease

Negative UV was first proposed as a risk factor of Kienböck's disease by Hulten, and it has been investigated by many researchers (Table 4) [3,5-14,17,20-23]. The number of studies that performed a direct comparison of previous data was low for the following reasons. First, although the UV was measured as a continuous value, some studies divided this value into categories such as negative, neutral, and positive UV. Second, the UV is thought to differ according to race, age, and sex; therefore, the results obtained from a study are only applicable to a population with similar demographic characteristics as those of the study population. Third, the studies used three different measuring methods. Many comparative studies have consistently reported that the UV is lower in the Kienböck disease group

than in the control group [3,6,7,10,12,20,22]. However, in three studies in the Caucasian population, the mean UV in the control group was negative [10,12,14]. Moreover, in a previous study in a Korean population, the UV was positive in both the control and patient groups [24]. In the present study, the UV was lower in the Kienböck disease group than in the control group, although the value was positive. A previous study that used the same measurement technique also indicated that the mean UV value of the Korean population was positive [25]. Therefore, we believe that this relatively low UV may be an actual risk factor as compared with a negative UV.

The roles of lunate morphology (LD, LH, and SI) and the tilting angle (LTA) have been described previously. As part of the central column theory, Taleisnik stated that the lunate had an important mechanical role in the proximal carpal row [26]. A low LD and LH have been shown to be related with Kienböck's disease, which suggests that a small lunate in the coronal plane may be associated with a high risk of the disease [11,12]. In the present study, LD and LH from posteroanterior radiographs were not associated with a significant decrease in the risk of Kienböck's disease and only an increase in the SI was associated with a significant decrease in the risk of the disease. As the SI represents lunate thickness from lateral radiographs, a thin lunate in the sagittal plane may indicate a high tendency for the development of Kienböck's disease. Moreover, the LTA was significantly associated with the disease. The risk of Kienböck's disease increased with an increase in the LTA,

which has been reported in previous studies [11,12]. This suggests that the vertical inclination of the lunate increased, and we believe that this may have led to a change in the lunate contact area or mechanical load shearing.

The area of the lunate covered by the radius has been reported to be associated with Kienböck's disease. Razemon reported that, in cases with a high LCI, the pressure on the lunate may be more widely distributed, and hence, the risk of Kienböck's disease is minimal [18]. In contrast, Thienpont et al. indicated that the LCI was not an important factor in Kienböck's disease [12]. In these two studies, a line extending from the distal radioulnar joint was used to bisect the lunate. However, the distal radioulnar joint has three basic configurations, and the LCI value would change depending on the configuration [27]. Therefore, we chose a line from the distal radioulnar joint that was parallel to the radial axis. In the present study, a large coverage of the lunate by the radius was highly associated with Kienböck's disease.

The coronal articular slopes of the radius (RI and LFI) have been examined previously. Mirabello et al. reported that patients with a low RI showed early onset of Kienböck's disease [5]. Tsuge et al. and Thienpont et al. reported a significant relationship between the flattened radius and Kienböck's disease; however, Thienpont et al. did not report any relationship between the LFI and Kienböck's disease [11,12]. Contrary to the anatomical findings of the RI, the clinical results of radial closed wedge osteotomy were good [28]. On biomechanical analysis, Watanabe et al. and Garcia-Elias et al. reported that

the lunate was appropriately unloaded using lateral closed wedge osteotomy [28, 29]; however, Werner et al. and Kam et al. reported contrasting results in a cadaver model [30,31]. We believe that the use of a finite element model was a limitation of the former studies, and hence, the results of the latter studies are more reliable. The inconsistencies between the radiological findings and the clinical results, as well as the controversy regarding the biomechanical studies, indicate that other factors, besides simple lunate unloading, influence Kienböck's disease.

The present study has some limitations. First, the parameters of the contralateral wrist might not reflect the parameters of the affected wrist. Although previous reports found no significant differences between the right and left wrists in a normal population, the characteristics of the intact contralateral wrist might differ from those of the affected side. Second, the size of the control group was too small to represent the normal Korean population. As the difference in age between the groups was large, only a 1:1 ratio could be used during matching. Third, disease onset could not be estimated, and most patients visited the clinic only when they experienced symptoms. As the findings of wrist radiography can change with an increase in age, the time of disease onset may be crucial. We believe that the delay from onset to diagnosis may be due to time-related bias [13]. Fourth, we primarily focused on the osseous structures and not on the surrounding soft tissues. Fifth, the subjects were matched for sex and age. Hence, the results

may have limited value as a diagnostic tool. However, wrists with a high radiological risk can be evaluated early.

A high LTA and LCI, and low UV and SI on plain radiography might be associated with Kienböck's disease in the Korean population. The radiological probability of Kienböck's disease could be assessed from the radiological parameters quantitatively. With further assessments of standard radiological findings, our results could provide supportive information for the diagnosis of Kienböck's disease, particularly in the early stage.

## References

1. Kienböck R. Über traumatische malazie des mondbeins und ihre folgezustände: Entartungsformen und kompressionsfrakturen. Fortschr Röntgenstr. 1910;16:77-103.
2. Stahl S, Stahl AS, Meisner C, Rahmanian-Schwarz A, Schaller HE, Lotter O. A systematic review of the etiopathogenesis of Kienbock's disease and a critical appraisal of its recognition as an occupational disease related to hand-arm vibration. BMC Musculoskelet Disord. 2012 Nov 21;13:225.
3. Hulthen O. Über anatomische variationen der handgelenkknochen. Acta Radiologica. 1928;9(2):155-68.
4. Stahl S, Reis N. Traumatic ulnar variance in Kienböck's disease. J Hand Surg Am. 1986 Jan;11(1):95-7.
5. Mirabello SC, Rosenthal DI, Smith RJ. Correlation of clinical and radiographic findings in Kienbock's disease. J Hand Surg Am. 1987 Nov;12(6):1049-54.
6. Chen WS, Shih CH. Ulnar variance and Kienbock's disease. An investigation in Taiwan. Clin Orthop Relat Res. 1990 Jun;(255):124-7.
7. Afshar A, Aminzadeh-Gohari A, Yekta Z. The association of Kienbock's disease and ulnar variance in the Iranian population. J Hand Surg Eur Vol. 2013 Jun;38(5):496-9.

8. Chan KP, Huang P. Anatomic variations in radial and ulnar lengths in the wrists of Chinese. *Clin Orthop Relat Res.* 1971 Oct.;80:17-20.
9. Kristensen SS, Thomassen E, Christensen F. Ulnar variance in Kienbock's disease. *J Hand Surg Br.* 1986 Jun;11(2):258-60.
10. D'Hoore K, De Smet L, Verellen K, Vral J, Fabry G. Negative ulnar variance is not a risk factor for Kienböck's disease. *J Hand Surg Am.* 1994 Mar;19(2):229-31.
11. Tsuge S, Nakamura R. Anatomical risk factors for Kienbock's disease. *J Hand Surg Br.* 1993 Feb;18(1):70-5.
12. Thienpont E, Mulier T, Rega F, De Smet L. Radiographic analysis of anatomical risk factors for Kienbock's disease. *Acta Orthop Belg.* 2004 Oct;70(5):406-9.
13. Nakamura R, Tanaka Y, Imaeda T, Miura T. The influence of age and sex on ulnar variance. *J Hand Surg Br.* 1991 Feb;16(1):84-8.
14. Hollevoet N, Van Maele G, Van Seymortier P, Verdonk R. Comparison of palmar tilt, radial inclination and ulnar variance in left and right wrists. *J Hand Surg Br.* 2000 Oct;25(5):431-3.
15. Davies AM, Grainger AJ, James SJ. *Imaging of the hand and wrist.* Springer; 2013.
16. Mann F, Wilson A, Gilula L. Radiographic evaluation of the wrist: what does the hand surgeon want to know? *Radiology.* 1992 Jul;184(1):15-24.

17. Matsushita K, Firrell JC, Tsai T-M. X-ray evaluation of radial shortening for Kienböck's disease. *J Hand Surg Am.* 1992 May;17(3):450-5.
18. Razemon J. Pathological study of Kienboeck's disease. *Ann Chir Main.* 1982;1(3):240-2.
19. Lluch A, Garcia-Elias M. Etiology of Kienböck disease. *Tech Hand Up Extrem Surg.* 2011 Mar;15(1):33-7.
20. Gelberman RH, Salamon PB, Jurist JM, Posch JL. Ulnar variance in Kienbock's disease. *J Bone Joint Surg Am.* 1975 Jul;57(5):674-6.
21. Beckenbaugh RD, Shives TC, Dobyns JH, Linscheid RL. Kienbock's disease: the natural history of Kienbock's disease and consideration of lunate fractures. *Clin Orthop Relat Res.* 1980 Jun;(149):98-106.
22. Park S, Shon W. Ulnar Variance of the Normal Wrists and Kienbock's disease in Korean. *J Korean Orthop Assoc.* 1982 Apr;17(2):277-82.
23. Kristensen SS, Thomassen E, Christensen F. Ulnar variance determination. *J Hand Surg Br.* 1986 Jun;11(2):255-7.
24. Park M, Lim J, Kim J, Kang H. The Influence of Ulnar Variance on Kienböck's Disease in Korean. *J Korean Soc Surg Hand.* 2005 Mar;10(1):9-13.
25. Jung J, Baek G, Kim J, Lee Y, Chung M. Changes in ulnar variance in relation to forearm rotation and grip. *J Bone Joint Surg Br.* 2001 Sep;83(7):1029-33.

26. Taleisnik J. The ligaments of the wrist. *J Hand Surg Am.* 1976 Sep;1(2):110-8.
27. Tolat A, Stanley J, Trail I. A cadaveric study of the anatomy and stability of the distal radioulnar joint in the coronal and transverse planes. *J Hand Surg Br.* 1996 Oct;21(5):587-94.
28. Garcia-Elias M, An K, Cooney W, Linscheid R. Lateral closing wedge osteotomy for treatment of Kienböck's disease: A clinical and biomechanical study of the optimum correcting angle. *Chir Main.* 1998;17(4):283-90
29. Watanabe K, Nakamura R, Horii E, Miura T. Biomechanical analysis of radial wedge osteotomy for the treatment of Kienböck's disease. *J Hand Surg Am.* 1993 Jul;18(4):686-90.
30. Werner F, Palmer A. Biomechanical evaluation of operative procedures to treat Kienböck's disease. *Hand Clin.* 1993 Aug;9(3):431.
31. Kam B, Topper SM, McLoughlin S, Liu Q. Wedge osteotomies of the radius for Kienbock's disease: a biomechanical analysis. *J Hand Surg Am.* 2002 Jan;27(1):37-42.

## 국문 초록

**서론:** 키엔백 병(Kienböck' s disease)에 이환된 손목은 특징적인 방사선학적 소견을 보이는데, 이는 나라마다 조금씩 다른 양상으로 보고된다. 이 연구에서는 한국인을 대상으로 키엔백 병에 이환된 손목이 가지는 방사선학적 특징을 분석하고 각 지표가 어느 정도 연관되어 있는지를 알아보려고 한다.

**방법:** 2000년에서 2013년까지 서울대병원에 방문한 사람들 중 키엔백 병으로 진단된 환자들 53명과 대조군 53명을 선정하여 이들의 손목에 대해 후향적 비교 대조 연구를 하였다. 이환된 손목에 대해서 정확히 측정하기 어렵기 때문에 계측은 이환되지 않은 반대쪽 손목을 사용하였다.

**결 과:** 월상골 경사(lunate tilting angle)과 월상골 포함지수(lunate covering index)가 클수록, 그리고 척골변이(ulnar variance)와 스탈 지수(Ståhl' s index)가 작을수록 키엔백 병에 이환될 확률이 높았다.

**결 론:** 한국인에서 월상골경사, 월상골 포함지수가 클수록, 척골변이, 스탈 지수가 작을수록 키엔백 병과 밀접하게 연관되어

있었으며 정량적 방사선학적 계측을 통한 키엔백 병과의 연관 정도를 측정할 수 있었다. 이 방사선학적 계측은 한국인에게 보다 조기에 키엔백 병 환자를 예측하고 진단하는 데에 도움이 될 수 있을 것이다.

-----  
**색인 단어:** 키엔백 병, 방사선학적 지수, 한국인, 척골변이, 월상골  
경사

**학 번:** 2009-23498