Chapter 7

Retrieval Study

7.1 INTRODUCTION

The fact that the SKI prosthesis was designed with a replaceable UHMWPE tibial insert made the study as described in this chapter possible. Apart from the problems with loosening of the screw that fixed the insert to the tibial tray, the modularity of the prosthesis made it possible to retrieve the PE insert and study the phenomena of wear in all its forms – this without having to sacrifice the fixation of the tibial component, thereby introducing the danger of having to deal with a far bigger and more complicated operation than the mere changing of the insert proved to be. In this way we were able, next to the total prosthesis revisions, to collect a series of isolated tibial inserts while maintaining the stability of the total knee prosthesis after insertion of a new and often thicker insert.

The aim of this study was to study the wear characteristics of retrieved implants. Therefore the tibial inserts, femoral components and tibial trays that were revised due to wear or aseptic loosening were analyzed. The wear rate was calculated (see section 7.4.1.1). The damage of the polyethylene was located and quantified (see sections 7.4.1.2 to 7.4.1.10). The results were correlated with the primary diagnosis (see section 7.4.1.11), body weight (see section 7.4.1.12) and the service life of the implant (see section 7.4.1.13). The metal components were judged for damage due to metal-on-metal contact or screw loosening and other signs of damage (see sections 7.4.2 and 7.4.3).

In Chapters 3 and 5 (sections 3.3.9 and 5.5) we found more wear and a higher wear rate in knees with screw loosening. To analyze the consequences of screw loosening, we analyzed the wear rate, wear modes and amount of wear in all sections of the polyethylene in knees that had had screw loosening and knees that had not (see sections 7.4.1.14 and 7.4.1.15).

In recent years, researchers have observed wear on the backside of retrieved polyethylene inserts [91;92]. The backside of the retrieved inserts of the SKI prosthesis was analyzed for the presence of wear, and the patterns of wear were studied (see section 7.4.1.16).

7.2 MATERIAL AND METHODS

7.2.1 Patient characteristics

From July 1984 to October 2001, 47 revisions due to wear or aseptic loosening were performed (19 total revisions due to aseptic loosening, one total revision due to wear and 27 PE exchanges). Of all tibial inserts, 40 were available for further analysis. In six cases the patient's name could not be traced, leaving 34 (72.3%) tibial inserts (31 patients) available for analysis. The mean service life of the prostheses was 12.1 years ± 3.0 (6.2-17.9). Most of the prostheses available for retrieval analysis were size 3 (47.1%) or 4 (50.0%), with an insert thickness size 7 (82.6%) (see Appendix 1). The characteristics of the patients are described in Appendix 2. The reason for revision was wear in 23 cases and aseptic loosening in 11 cases. In 17 knees there had been a loosening of the screw, in 15 knees the screw was fixed until revision, and in two knees it was not known whether there had been a loosening of the screw.

Of the 20 removed femoral and tibial components, 11 (55%) femoral components and 12 metal tibial trays (60%) were available for further analysis. No patellar components were available for analysis.

7.2.2 Wear rate

The thickness of the loaded area of all retrieved tibial inserts was measured on the medial and lateral sides with a Vernier calliper. These values were subtracted from the original thickness of the polyethylene insert, giving the wear in mm. The annual wear rate was calculated by dividing the amount of wear of the most affected side by the service life of the prosthesis.

7.2.3 Modes of damage

To quantify the wear, the scoring system described by Hood et al. [85] was used. All tibial inserts were examined using 10x light stereomicroscopy. Seven modes of surface degradation were identified:

- Burnishing: areas that have become highly polished [218;219] (see Figure 7.1).
- Scratching: indented lines generally found in an anteroposterior direction and in the areas of wear. Scratches were differentiated from marks made by instruments during removal of the component. Such marks usually do not coincide with the wear areas or they do not occur in the correct direction (see Figure 7.2).
- Pitting (or crater formation): depressions in the articulating surface, measuring 2-3 mm across and 1-2 mm deep [220] (see Figure 7.3).
- Surface deformation: areas with permanent deformation occurring on or around the articulating surface, presumably caused by cold flow and/or creep (see Figure 7.4).

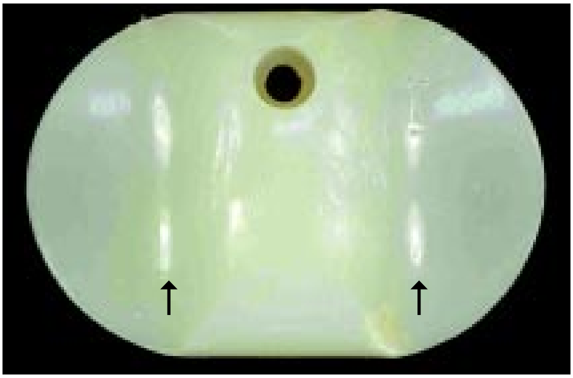

Figure 7.1. *Burnishing. The medial and lateral sides of this retrieved PE insert have become highly polished.*

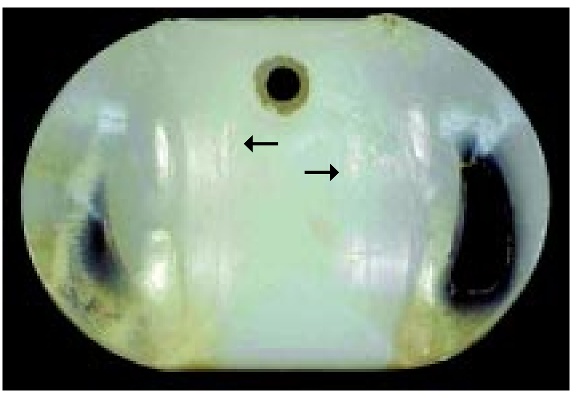

Figure 7.2. *Scratching: indented lines generally found in an antero-posterior direction and in the areas of wear.*

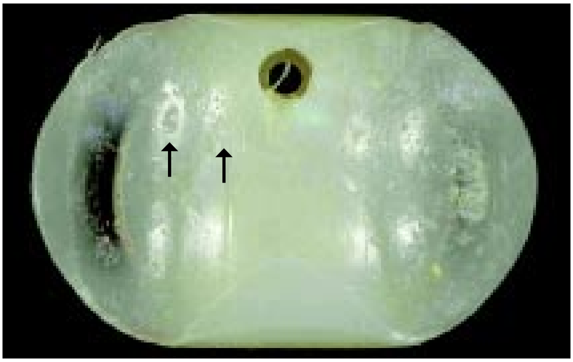

Figure 7.3. *Pitting: depressions in the articulating surface, measuring 2-3 mm across and 1-2 mm deep.*

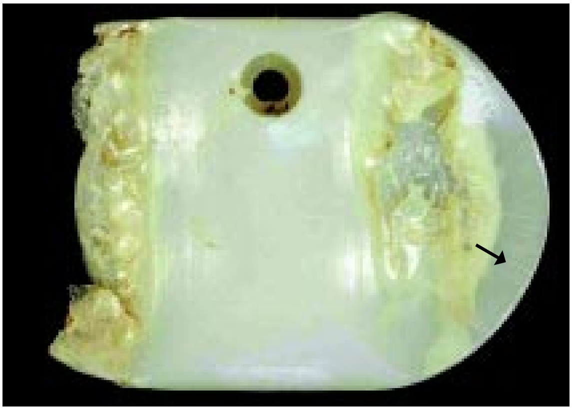

Figure 7.4. *Surface deformation: areas with permanent deformation occurring on or around the articula-ting surfaces, presumably caused by cold flow and /or creep.*

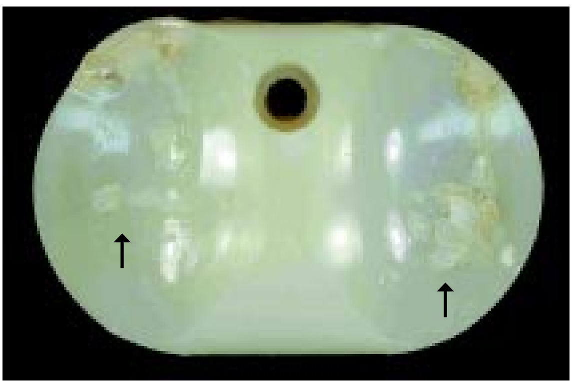

Figure 7.5. *Delamination: areas with evidence of a subsurface failure mechanism occurring parallel to the articulating surface.*

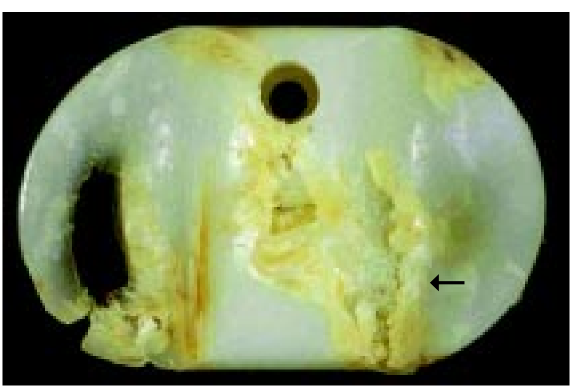

Figure 7.6. *Abrasion: a shredded or tufted appearance of the polyethylene (caused by direct contact with bone or PMMA).*

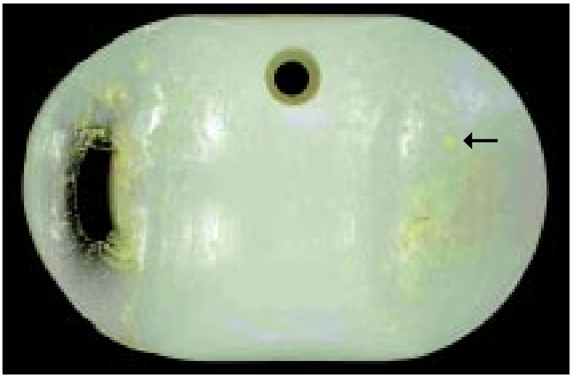

Figure 7.7. *Bone-cement debris: embedded PMMA or bone debris, recognized by the color and/or texture difference between PMMA, bone and polyethylene.*

- Delamination: areas in which a large sheet of polyethylene has been removed, with evidence around the periphery of a subsurface failure mechanism occurring parallel to the articulating surface (see Figure 7.5).
- Abrasion: a shredded or tufted appearance of the polyethylene (caused by direct contact with bone or PMMA) [219;221] (see Figure 7.6).
- Bone-cement debris: embedded PMMA or bone debris, recognized by the color and/or texture difference between PMMA, bone and polyethylene, varying from rough particles pressed into the polyethylene surface (but still protruding from the surface) to particles pressed into the surface and polished even with it (see Figure 7.7).

7.2.4 Location of wear
To define the location on the insert where the damage occurred, each tibial component was divided into ten different sections (see Figure 7.8).

7.2.5 Severity of wear
To quantitate the presence and severity of each mode of surface damage in each section, a subjective grading system was used:
- Grade 0: the damage mode is absent from the section.
- Grade 1: the damage mode is evident in less than 10% of the surface area of the section.
- Grade 2: the damage mode is evident in 10-50% of the surface area of the section.
- Grade 3 the damage mode is evident in more than 50% of the surface area of the section.

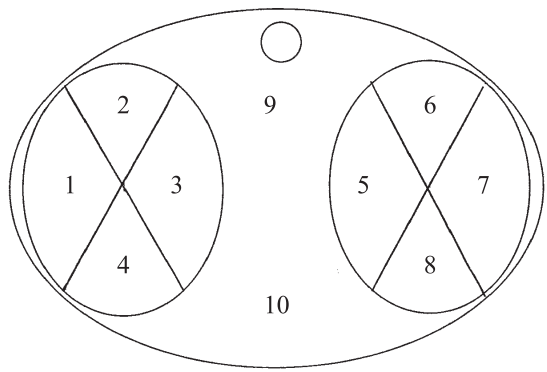

Figure 7.8. *Sections 1 to 10 of the polyethylene insert, used to locate the damage.*

The severity of the seven different modes of surface damage for each tibial insert was determined by counting the scores of all ten zones. The severity for each mode of surface damage can vary from 0 (concerning mode of damage is not seen at the insert) to 30 (concerning mode of damage is seen in all ten zones in more than 50% of the surface area of each section).

Each tibial insert was given a total surface damage score by summing the scores for all seven modes of damage for all sections. The score ranges from 0 (no damage) to 210 (grade 3 for each of the seven degradation modes for each of the ten sections).

7.2.6 Marks of the screw

Impingement of the screw in case of loosening may leave marks or scratches in the polyethylene or on the femoral component. All tibial inserts and femoral components were analyzed for marks of the screw. The location and number of the screw marks on each tibial insert will be described.

7.2.7 Backside wear

Backside wear can be assessed by evaluating manufacturer's stamped markings on the inferior polyethylene surface [222;223]. The tibial insert of the SKI prosthesis does not have these markings on the backside. Therefore, the backside of the retrieved tibial inserts was only evaluated for the presence and location of wear. When wear was seen at the backside of the insert, we analyzed the patterns of wear.

7.2.8 Analysis of the metal tibial baseplates and the femoral components
The metal tibial baseplates and femoral components were judged for damage due to metal-on-metal contact and other signs of damage.

7.3 STATISTICAL ANALYSIS

The influence of body weight on the amount of wear and on the wear rate, and the influence of the service life on the amount of wear were analyzed with a linear regression analysis. We considered the influence significant if the p-value was <0.05.

The differences in wear rate and amount of damage in patients with degenerative arthritis and rheumatoid arthritis were analyzed with an independent samples t-test. We considered differences significant if the p-value was <0.05.

The difference in the seven modes of surface damage and in location of damage in knees with and without screw loosening was analyzed with an independent samples t-test. In the sections with a significant difference in the amount of surface damage, the difference in the modes of surface damage was analyzed with an independent samples t-test. We considered differences significant if the p-value was <0.05.

7.4 RESULTS

7.4.1 Analysis of retrieved polyethylene inserts
7.4.1.1 Wear rate
The mean annual wear rate of the retrieved inserts was 0.19 mm ± 0.11 (0.04-0.49). The mean annual wear rate on the medial side was 0.17 mm ± 0.10 (0.02-0.49). The mean annual wear rate on the lateral side was 0.12 mm ± 0.11 (0.01-0.47). Although the wear rate on the medial side was higher compared to the lateral side, the difference was not significant (paired samples t-test, p=0.057).

7.4.1.2 Modes of damage, severity and location
The mean total score for damage of all retrieved tibial inserts was 109.9 points ± 33.0 (56-193). The severity of each mode of damage and the number of inserts with the respective mode of damage are listed in Table

7.1. Burnishing, scratching and pitting were seen in all retrieved implants. Burnishing (mean score 23.4 points ± 4.2) and scratching (mean score 22.1 points ± 5.2) were the modes of damage with the highest scores.

Table 7.1. Mean scores for all seven modes of damage and number (%) of inserts with the respective mode of damage (n=34).

Mode of damage	Mean score ± sd (min-max)	n*	*(%)*
Burnishing	23.4 ± 4.2 (12-29)	34	*(100.0)*
Scratching	22.1 ± 5.2 (10-29)	34	*(100.0)*
Pitting	16.6 ± 5.7 (5-30)	34	*(100.0)*
Surface deformation	14.9 ± 8.7 (0-30)	31	*(91.2)*
Delamination	14.4 ± 8.5 (0-27)	31	*(91.2)*
Abrasion	9.5 ± 6.8 (0-23)	31	*(91.2)*
Bone-Cement debris	9.0 ± 8.0 (0-29)	27	*(79.4)*

* *n = number of polyethylene inserts with concerning mode of damage*

7.4.1.3 Burnishing

Burnishing was seen in all sections, but less in the center of the insert, especially on the posterior side (section 10) (see Figure 7.9).

7.4.1.4 Scratching

Scratching was seen in all sections, most on the medial side in zones 1, 2 and 4 and less in the center on the posterior side of the insert in section 10 (see Figure 7.10).

7.4.1.5 Pitting

Pitting was seen in all sections, most on the medial side in zones 3 and 4 and less in the center of the insert in sections 9 and 10 (see Figure 7.11).

7.4.1.6 Surface deformation

Surface deformation was seen in all sections. It was seen the most on the medial and posteromedial sides in sections 1 and 4, and least in the center on the posterior side in section 10 (see Figure 7.12).

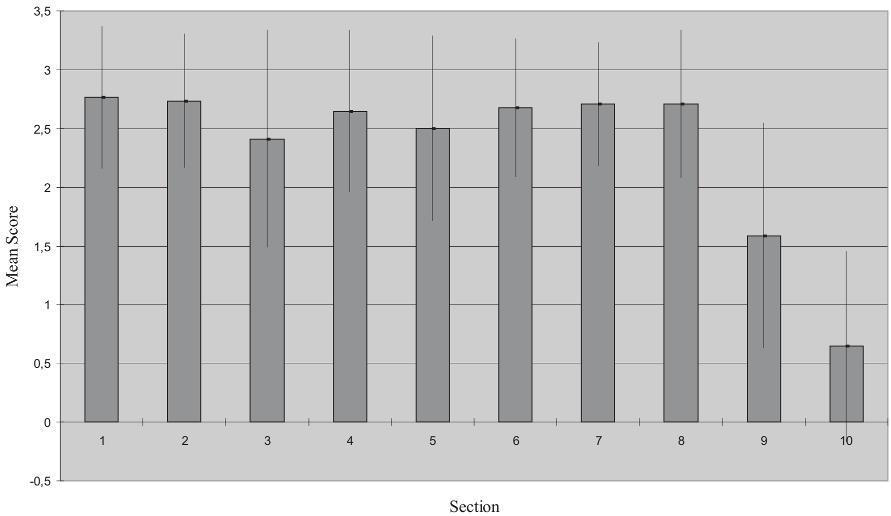

Figure 7.9. *Burnishing: mean score ± sd for each section.*

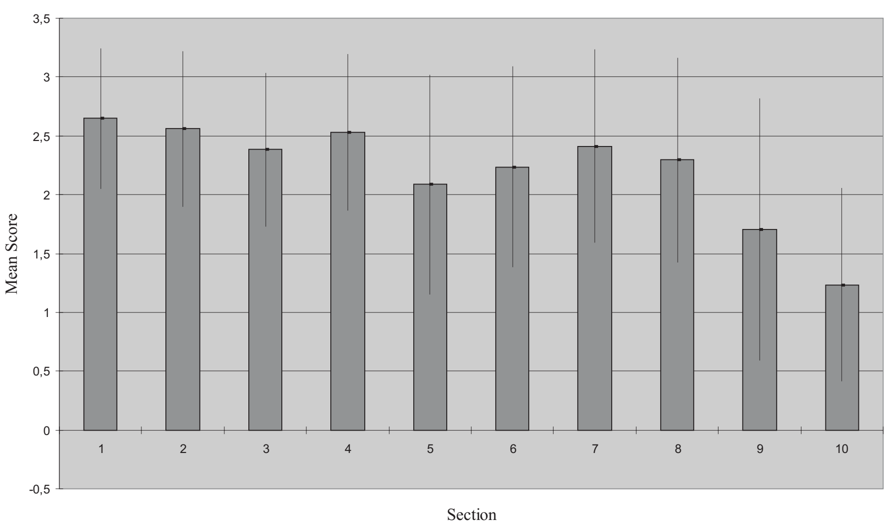

Figure 7.10. *Scratching: mean score ± sd for each section.*

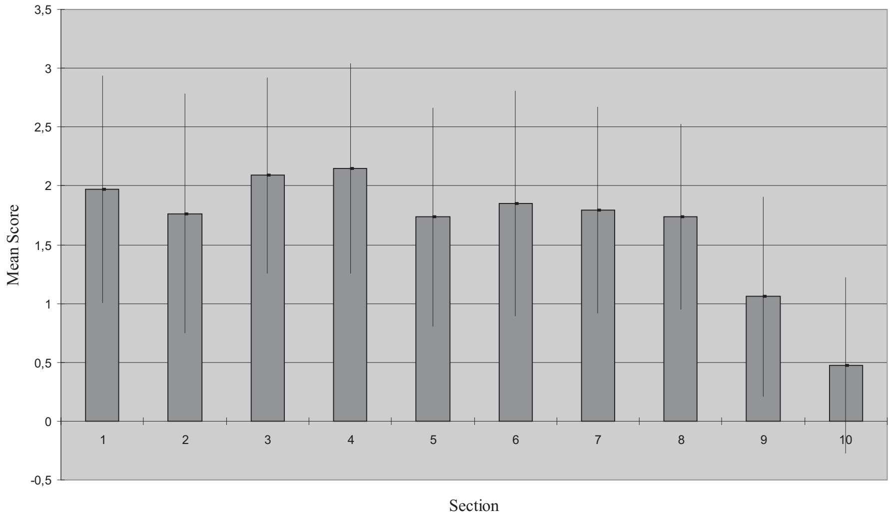

Figure 7.11. *Pitting: mean score ± sd for each section.*

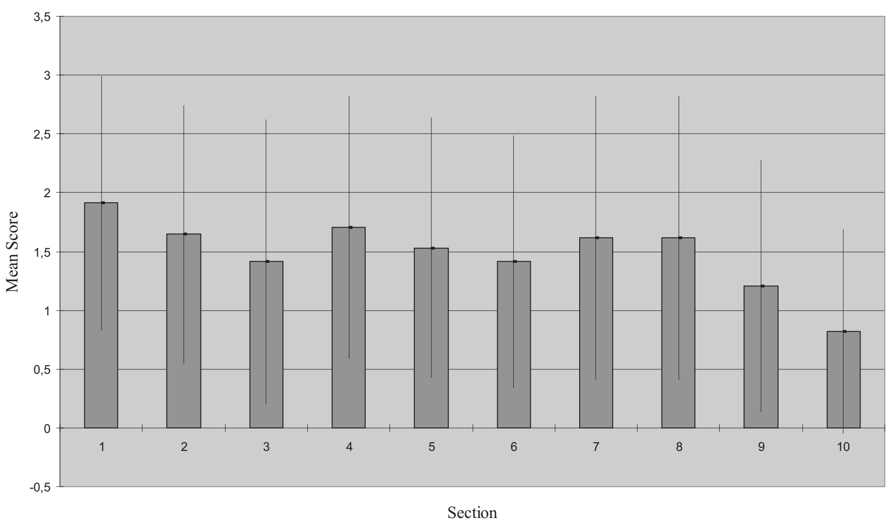

Figure 7.12. *Surface deformation: mean score ± sd for each section.*

7.4.1.7 Delamination

Delamination was seen the most on the medial and posteromedial sides in sections 1 and 4, and on the lateral and posterolateral sides in sections 7 and 8 (see Figure 7.13).

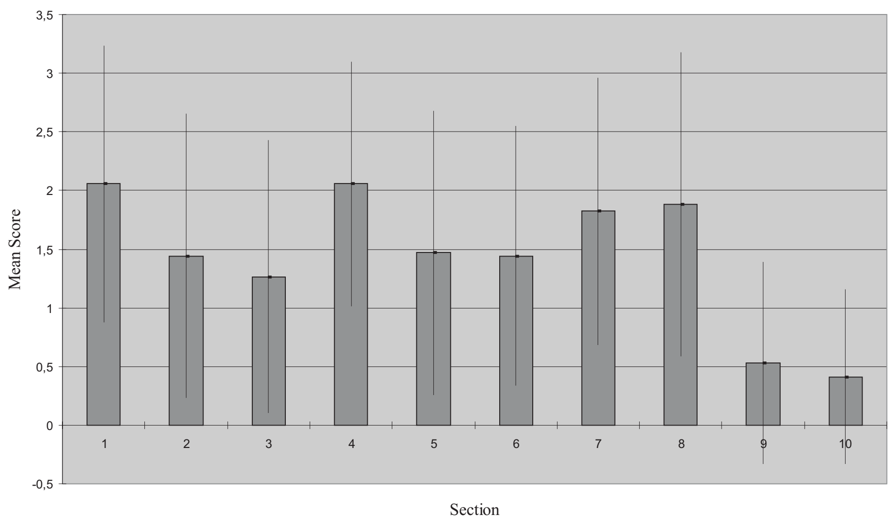

Figure 7.13. *Delamination: mean score ± sd for each section.*

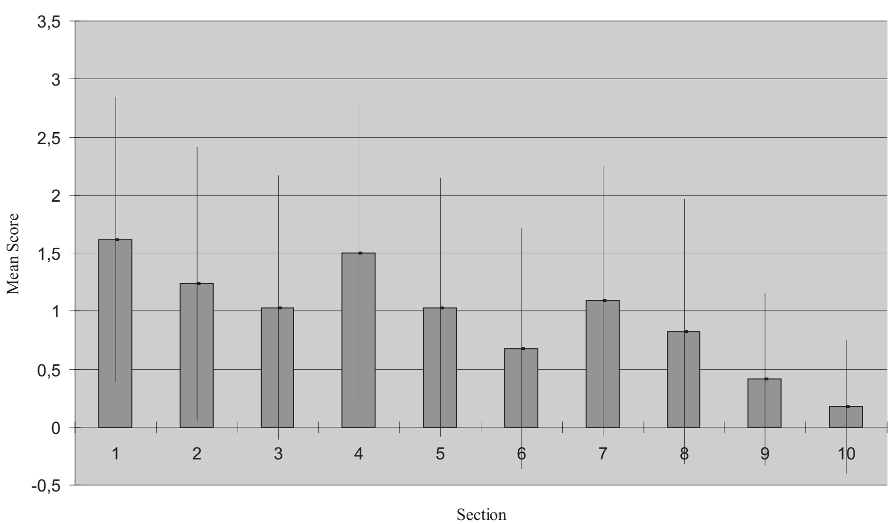

Figure 7.14. *Abrasion: mean score ± sd for each section.*

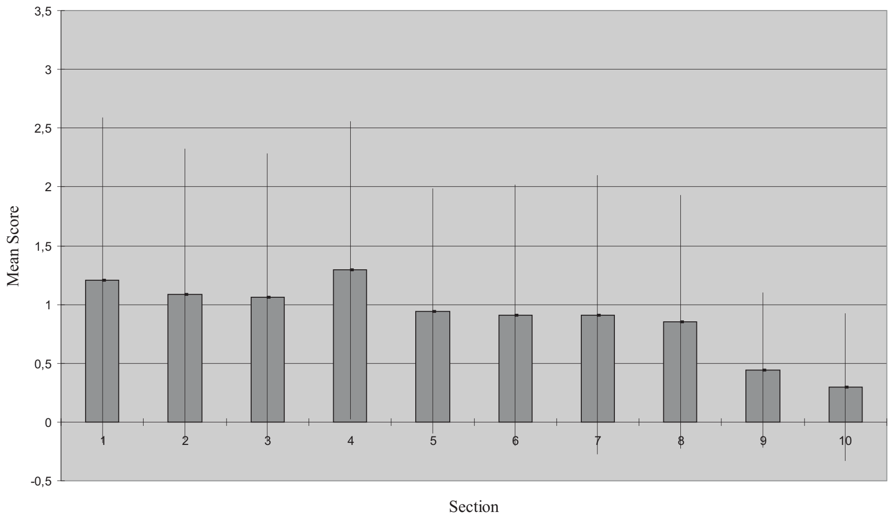

Figure 7.15. *Bone-Cement debris: mean score ± sd for each section.*

7.4.1.8 Abrasion

Abrasion was seen the most on the medial and posteromedial sides in sections 1 and 4 (see Figure 7.14).

7.4.1.9 Bone-Cement debris

Bone and cement debris was seen the most on the medial and posteromedial sides in sections 1 and 4, and least at the center in sections 9 and 10 (see Figure 7.15).

7.4.1.10 Total Score for each section

The mean score of damage for each section was 11.0 ± 3.1 (4.1-14.2). Most damage was seen on the medial and posteromedial sides in sections 1 and 4. The non-loaded area in the center of the tibial insert (sections 9 and 10) had the lowest amount of damage (see Figure 7.16).

7.4.1.11 Wear and primary diagnosis

The mean annual wear rate in patients with degenerative arthritis was 0.24 mm ± 0.13, and in patients with rheumatoid arthritis 0.12 ± 0.04. Patients with degenerative arthritis had a significantly higher wear rate compared to patients with rheumatoid arthritis (independent samples t-test, p=0.005). Patients with degenerative arthritis had a higher amount of damage compared to patients with rheumatoid arthritis (113.7± 36.1 versus 91.7± 18.7), but the difference was not significant (independent samples t-test, p=0.079).

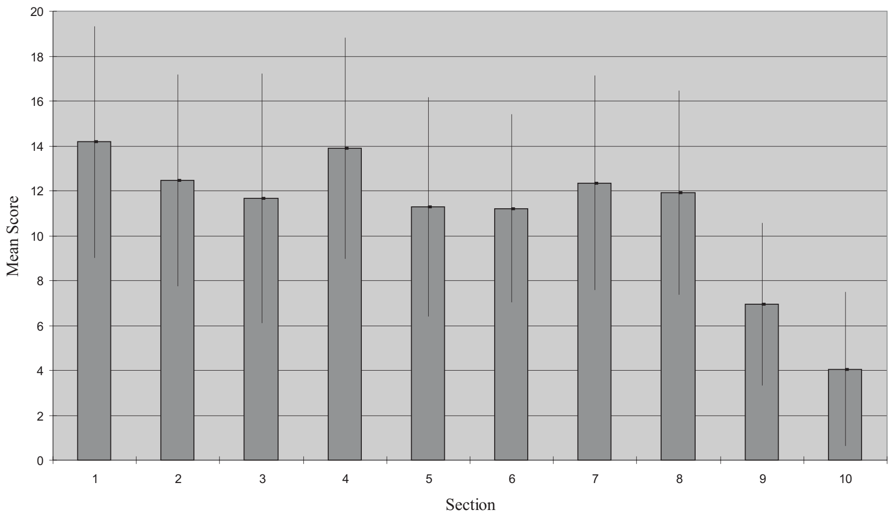

Figure 7.16. *Total Score: mean score ± sd for each section.*

Table 7.2. Wear rate and total wear score in patients with degenerative arthritis and rheumatoid arthritis. Patients with degenerative arthritis had a significantly higher wear rate compared to patients with rheumatoid arthritis.

	Degenerative arthritis *(n=15)*	**Rheumatoid arthritis** *(n=11)*	**p-value**[1]
Wear rate (mm/year) mean ± sd (min-max)	0.24 ± 0.13 (0.13-0.49)	0.12 ± 0.04 (0.04-0.18)	**0.005**
Total score of damage mean ± sd (min-max)	113.7± 36.1 (56-193)	91.7± 18.7 (67-140)	0.079

[1] *Independent samples t-test*

7.4.1.12 Wear and body weight

The body weight of the patient had a significant influence on the wear rate, but not on the total amount of wear. Heavier patients had a significantly higher wear rate (linear regression analysis, B=0.004, p=0.004). Heavier patients seemed to have a higher amount of wear, but the influence of body weight on the total score of damage was not significant (linear regression analysis, B=0.848, p=0.078) (see Figure 7.17).

7.4.1.13 Wear and service life

There was no significant relation between service life and the amount of damage (linear regression analysis, B=-0.042, p=0.983) (see Figure 7.18).

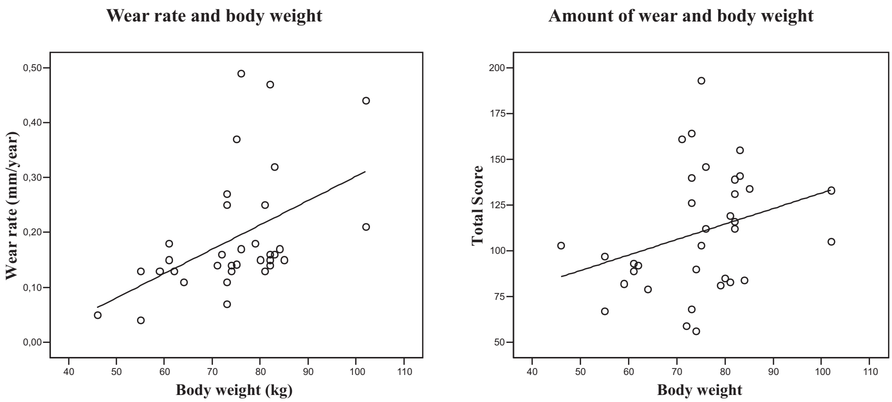

Figure 7.17. *Wear rate, amount of wear and body weight. Heavier patients had a significantly higher wear rate (linear regression analysis B=0.004, p=0.004) (left). Heavier patients seemed to have a higher amount of damage, but the relation was not significant (linear regression analysis, B=0.848, p=0.078).*

Figure 7.18. *Score of damage and service life. Inserts with a longer service life did not have a higher total score of damage (linear regression analysis, B=-0.042, p=0.983).*

7.4.1.14 Marks of the screw

Screw marks were seen as striated impressions in the polyethylene in seven (41.2%) of the 17 prostheses with loosening of the screw (see Figure 7.19).

Most of the screw marks were seen on the anterior side in sections 6, 9 and 2 (in five, four and four inserts respectively). No impressions of the screw were seen in the medial and posteromedial sides in zones 1 and 4 (see Figure 7.20).

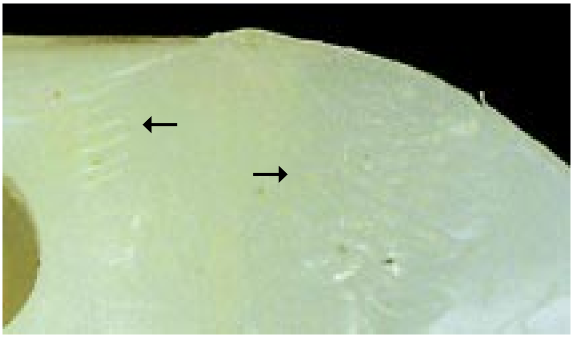

Figure 7.19. *Screw marks were seen as striated impressions in the poly-ethylene (arrows).*

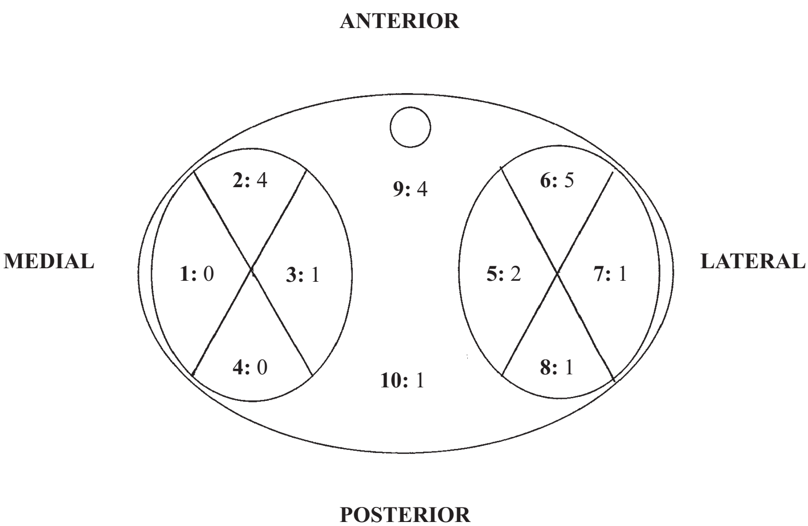

Figure 7.20. *Number of inserts with screw impressions in the ten different sections of the tibial insert.*

The number of sections with screw marks on the inserts varied from one to eight. In two inserts screw marks were seen in only one section, in three inserts screw marks were seen in two sections, in one insert screw marks were seen in three sections, and in one insert screw marks were seen in eight sections (see Table 7.3).

In three femoral components marked scratches were seen, probably due to impingement of a screw. In one femoral component marks of the thread of the screw were found on the anterior flange of the metal component (see Figure 7.21).

Table 7.3. Number of inserts and number of sections with impressions of the screw.

Number of sections with screw impressions	Number of inserts
1	2
2	3
3	1
8	1

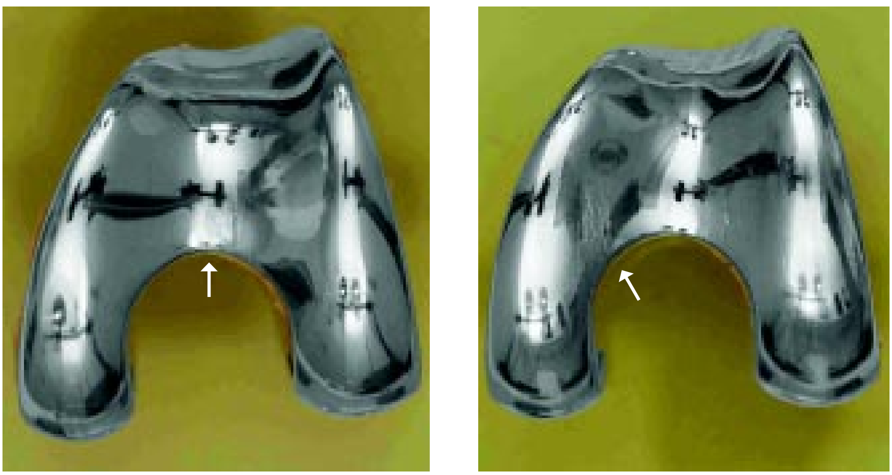

Figure 7.21. *Marks of the screw were seen as marks of the thread of the screw in one femoral component (left) or marked scratches (right).*

7.4.1.15 Wear and screw loosening

The mean annual wear rate in knees without screw loosening was 0.14 mm ± 0.07. The mean annual wear rate in knees that had had a loosened screw was 0.23 mm ± 0.13. Knees with a loosened screw had a significantly higher wear rate compared to knees without screw loosening (independent samples t-test, p=0.020).

The mean total score of damage in knees without screw loosening was 95.1 points ± 26.2, and in knees with screw loosening 122.1 points ± 33.1. Knees with screw loosening had a significantly higher total score of damage compared to knees that had no screw loosening (independent samples t-test, p=0.017) (see Table 7.4).

Table 7.4. Wear rate and total wear score in knees with and without screw loosening. Knees with screw loosening had a significantly higher wear rate and total score for damage.

	No screw loosening *(n=15)*	**Screw loosening** *(n=17)*	**p-value[1]**
Wear rate (mm/year) mean ± sd (min-max)	0.14 ± 0.07 (0.04-0.32)	0.23 ± 0.13 (0.11-0.49)	**0.020**
Total score of damage mean ± sd (min-max)	95.1± 26.2 (56-141)	122.1± 33.1 (82-193)	**0.017**

[1] Independent samples t-test

The mean scores for the seven different modes of damage in knees with and without screw loosening are listed in Table 7.5. The mean scores for all seven modes of damage were higher in knees with screw loosening compared to knees without screw loosening. Significantly more scratching, surface deformation and bone-cement debris were seen in knees with screw loosening compared to knees without screw loosening (see Table 7.5).

Table 7.5. Scores for the seven modes of damage in knees with and without screw loosening. Significantly more scratching, surface deformation and bone-cement debris were seen in knees with screw loosening.

Modes of damage	**No screw loosening** *(n=15)* **mean score ± sd (min-max)**	**Screw loosening** *(n=17)* **mean score ± sd (min-max)**	**p-value[1]**
Burnishing	23.1 ± 4.0 (14-29)	24.2 ± 3.8 (16-29)	0.453
Scratching	19.9 ± 5.5 (10-28)	23.9 ± 4.0 (17-29)	**0.022**
Pitting	15.1 ± 5.3 (5-24)	17.6 ± 5.9 (7-30)	0.216
Surface deformation	9.9 ± 9.5 (0-27)	18.2 ± 5.5 (10-30)	**0.007**
Delamination	13.5 ± 9.0 (0-26)	15.4 ± 8.3 (1-27)	0.528
Abrasion	7.9 ± 6.5 (0-19)	10.9 ± 7.4 (1-23)	0.234
Bone-Cement debris	5.8 ± 6.7 (0-20)	11.8 ± 8.2 (0-29)	**0.033**

[1]Independent samples t-test

The mean scores of damage for all ten sections in knees with and without screw loosening are listed in Table 7.6. The mean scores of damage in all ten sections were higher in knees with screw loosening compared to knees without screw loosening. In knees with screw loosening, significantly more damage was seen in section 1 (the medial part of the medial side of the insert) and section 5 (the medial part of the lateral side of the insert). The difference in all other zones was not significant.

Table 7.6. Scores of damage in all ten sections in knees with and without screw loosening. In sections 1 and 5, significantly more damage was seen in knees with screw loosening.

Sections	**No screw loosening** *(n=15)* **mean score ± sd (min-max)**	**Screw loosening** *(n=17)* **mean score ± sd (min-max)**	p-value[1]
1	11.9 ± 5.1 (7-21)	15.9 ± 4.6 (8-21)	**0.023**
2	11.8 ± 4.6 (6-21)	12.8 ± 5.0 (5-21)	0.556
3	9.9 ± 5.4 (3-21)	13.0 ± 5.6 (4-21)	0.126
4	12.1 ± 5.0 (8-21)	15.3 ± 4.4 (10-21)	0.063
5	9.3 ± 3.7 (1-15)	12.8 ± 4.9 (5-21)	**0.034**
6	10.0 ± 2.7 (5-14)	12.3 ± 4.9 (6-21)	0.109
7	10.7 ± 3.4 (7-18)	13.9 ± 5.5 (6-21)	0.055
8	10.3 ± 3.2 (6-16)	13.1 ± 5.2 (5-21)	0.083
9	6.0 ± 3.0 (1-10)	7.8 ± 4.2 (2-17)	0.171
10	3.1 ± 2.0 (0-8)	5.1 ± 4.3 (0-18)	0.114

[1]*Independent samples t-test*

The scores for all seven modes of damage in sections 1 and 5 in knees with and without screw loosening are listed in the Tables 7.7 and 7.8. In sections 1 and 5, all scores for the seven modes of damage were higher in the knees with screw loosening compared to knees without screw loosening. In section 1 significantly more surface deformation, delamination and abrasion were seen in knees with screw loosening compared to knees without screw loosening. The differences in scores for the other modes of damage were not significant.

In section 5 significantly more scratching, surface deformation and bone-cement debris were seen in knees with screw loosening compared to knees without screw loosening. The differences in scores for the other modes of damage were not significant.

Table 7.7. Section 1: scores for the seven modes of damage in knees with and without screw loosening. Significantly more surface deformation, delamination and abrasion were seen in knees with screw loosening.

Modes of damage	**No screw loosening** *(n=15)* **mean score ± sd (min-max)**	**Screw loosening** *(n=17)* **mean score ± sd (min-max)**	**p-value**[1]
Burnishing	2.7±0.5(2-3)	2.8±0.7(0-3)	0.683
Scratching	2.5±0.7(1-3)	2.8±0.4(2-3)	0.188
Pitting	1.7±1.0(0-3)	2.1±0.9(1-3)	0.276
Surface deformation	1.5±1.1(0-3)	2.2±1.0(0-3)	**0.047**
Delamination	1.6±1.4(0-3)	2.5±0.9(0-3)	**0.044**
Abrasion	1.1±1.2(0-3)	2.0±1.1(0-3)	**0.032**
Bone-Cement debris	0.8±1.4(0-3)	1.5±1.3(0-3)	0.138

[1]*Independent samples t-test*

Table 7.8. Section 5: scores for the seven modes of damage in knees with and without screw loosening. In knees with screw loosening, significantly more scratching, surface deformation and bone-cement debris were seen.

Modes of damage	**No screw loosening** *(n=15)* **mean score ± sd (min-max)**	**Screw loosening** *(n=17)* **mean score ± sd (min-max)**	**p-value**[1]
Burnishing	2.3 ± 0.9 (0-3)	2.7 ± 0.6 (1-3)	0.171
Scratching	1.7 ± 1.0 (0-3)	2.4 ± 0.8 (1-3)	**0.037**
Pitting	1.6 ± 0.9 (0-3)	1.8 ± 1.0 (0-3)	0.625
Surface deformation	0.9 ± 1.1 (0-3)	2.0 ± 0.9 (0-3)	**0.002**
Delamination	1.4 ± 1.1 (0-3)	1.5 ± 1.3 (0-3)	0.765
Abrasion	0.9 ± 1.0 (0-3)	1.1 ± 1.2 (0-3)	0.520
Bone-Cement debris	0.5 ± 0.9 (0-3)	1.2 ± 1.0 (0-3)	**0.045**

[1]*Independent samples t-test*

7.4.1.16 Backside wear

In fourteen (82.4%) of the 17 knees that had had screw loosening, a wear pattern was seen that may be caused by rotational movement of the insert (see Figure 7.22). None of the inserts with a fixed screw had this pattern of wear. This rotational wear pattern was also found on seven metal tibial trays. Five of the knees with this wear pattern at the tibial tray had had loosening of the screw, and in two cases it was not known whether the screw was loose or not, because the name of the patient was missing.

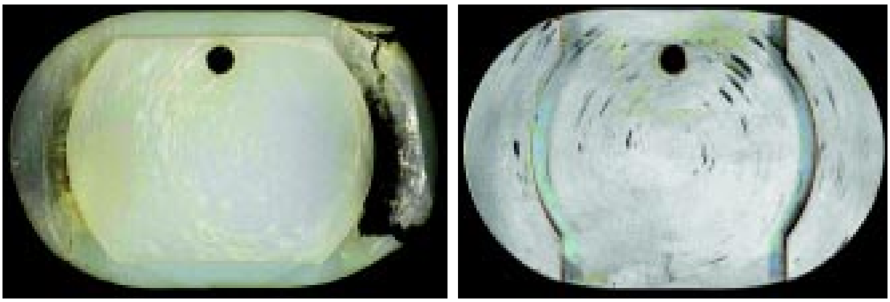

Figure 7.22. *A rotational pattern of wear was seen on the backside of the polyethylene insert (left) and on the metal tibial tray (right). This pattern of wear was only seen in knees that had had loosening of the screw.*

In 30 (93.8%) of the tibial inserts available for examination of wear was surface deformation seen on the backside of the insert at the medial and lateral edges (see Figure 7.23). In two cases surface deformation was only seen at the medial edge, in two cases only at the lateral edge, and in 26 cases on both sides.

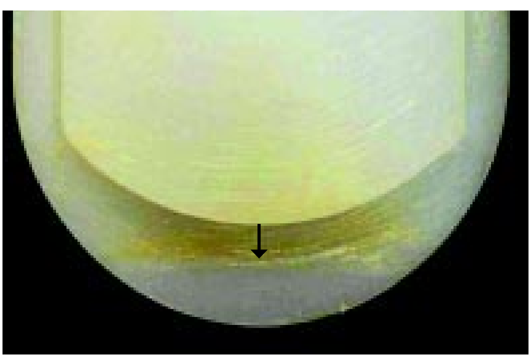

Figure 7.23. *In 93.8% of the inserts that were available for analysis, surface deformation was seen at the edge of the tibial insert on the backside.*

In knees that had no screw loosening, surface deformation at the edges on the backside was seen in 12 of the 13 inserts (92.3%). In knees with screw loosening, surface deformation at the edges on the backside was seen in 16 of the 17 available inserts (94.1%). This difference is not significant (independent samples t-test, p=0.850).

The thickness of the inserts that had no surface deformation at the edge on the backside was size 7 in one case and size 13 in the other (see Table 7.9). No significant relation was found between the thickness of the insert and wear at the edge on the backside (logistic regression analysis, B=-0.733, p=0.052).

Table 7.9. Thickness of the insert and wear at the edge on the backside. No significant relation was found between wear at the edge on the backside and PE thickness.

Thickness of the insert	n	Wear at the edge	No wear at the edge
7	27	26 (96.3%)	1 (3.7%)
9	3	3 (100%)	
11	1	1 (100%)	
13	1	0	1 (100%)

7.4.2 Analysis of retrieved metal tibial baseplates

In nine (75%) of the 12 retrieved tibial components, damage of the metal was seen due to metal-on-metal contact (see Figure 7.24). In seven cases the damage was seen on the medial side, in one case on the lateral side, and in one case on both sides. In six cases with damage due to metal-on-metal contact, the prosthesis was loose. In the other three cases this was not known because the name of the patient was missing.

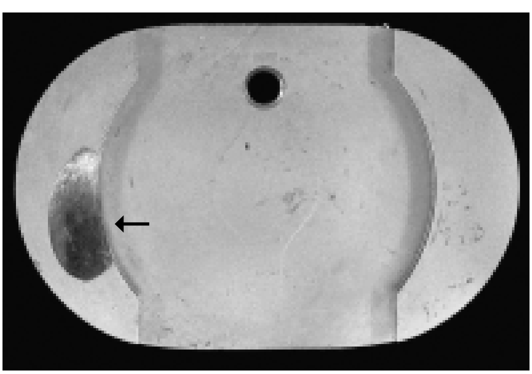

Figure 7.24. *Damage of the metal tibial baseplate due to metal-on-metal contact.*

7.4.3 Analysis of retrieved femoral components

In seven (63.6%) of the 11 retrieved femoral components, damage of the metal was seen due to metal-on-metal contact. In five components the damage was seen on the medial side, in one component the damage was seen on the lateral side, and in one component the damage was seen on the medial and lateral sides. In five cases with damage due to metal-on-metal contact, the prosthesis was loose. In the other two cases this was not known because the name of the patient was missing.

7.5 DISCUSSION

Wear is the abrasion of material, with the generation of wear particles, that occurs as a result of the relative motion between two opposing surfaces under load [224]. Most studies about polyethylene wear in total knee replacement are retrieval analyses. Benjamin et al. [194] found an average annual wear rate of 0.35 mm in 33 retrieved polyethylene inserts from three different posterior cruciate-retaining knee systems. Mikulak et al. [225] found an annual wear rate of 0.30 mm on the medial side and 0.16 mm on the lateral side at retrieval analysis of a posterior-cruciate substituting total knee replacement. In this study we found a mean annual wear rate of 0.19 mm at the retrieval analysis. We found a mean annual wear rate of 0.26 mm for prostheses with wear at radiographic analysis (see Chapter 5). The mean annual wear rate at the retrieval analysis may be lower because the majority (73.5%) of the inserts had a full thickness wear, while only 25.8% of the inserts at radiographic analysis had a full thickness wear. Measuring the wear rate in knees with full thickness wear may underestimate the wear rate. In addition, the knees at radiographic examination were different knees than those at retrieval analysis. Only five inserts were both available for radiographic and retrieval analysis. The mean annual wear rate at retrieval analysis for these inserts was 0.17 mm ± 0.08, and at radiographic examination 0.20 mm ± 0.13. The difference between the wear rate at retrieval analysis and at radiographic examination of these inserts was not significant (paired samples t-test, $p=0.770$). Unfortunately, we did not have enough fluoroscopically centralized radiographs of the retrieved implants to correlate the damage of the insert with the position of the prosthesis or the alignment of the leg.

Hood et al. [85] described wear of the articular surface in seven modes, four grades and ten sections. In this study of 34 retrieved tibial inserts, burnishing, pitting and scratching were seen in all tibial inserts in one or more sections. Burnishing and scratching contributed the most to the total amount of damage. Most damage was seen at the medial and posteromedial sides in sections 1 and 4, followed by the lateral and posterolateral sides in sections 7 and 8. Especially abrasion, delamination and surface deformation were seen in these sections. Abrasion may be caused by eccentric loading by the condyles of the femoral component, perhaps associated with rotational torques [85]. Delamination is thought to be caused by the high shear stresses occurring beneath the surfaces [226]. Surface deformation is presumably caused by cold flow and/or creep of the polyethylene [85]. The results of this study suggest that the posteromedial side of the SKI prosthesis carries most of the load, followed by the posterolateral side. The posterior part of the femoral component of the SKI prosthesis is sharply curved, which may cause more point-loading in flexion. This may cause more damage on the posterior side of the tibial insert.

Patients with degenerative arthritis had a significantly higher wear rate compared to patients with rheumatoid arthritis, but they did not have a higher amount of wear. Patients with degenerative arthritis had a higher activity level (see Chapter 4) and they were heavier (see Appendix 2) compared to patients with rheumatoid arthritis. This may explain the higher wear rate in patients with degenerative arthritis.

Hood et al. [85] found a significantly positive correlation for surface damage and body weight of the patient and the time the prosthesis was implanted. We found a significantly positive correlation for body weight and wear rate, but not for body weight and total amount of surface damage. In this study, prostheses with a longer service life did not have more damage.

In Chapter 3 we found that screw loosening was one of the factors that contributed to wear. In Chapter 5 (section 5.5) we found that knees with screw loosening had a significantly higher wear rate than knees without screw loosening. At retrieval analysis, knees with loosening of the screw had a significantly higher wear rate and significantly more damage. The higher amount of wear in knees with loosening of the screw might be caused by damage due to the screw itself. We found significantly more scratching in knees with screw loosening. Most of the screw marks were seen on the anterior part of the tibial insert in zones 2, 6 and 9. The screw of the SKI prosthesis is fixed on the anterior part of the tibial insert in zone 9. In most cases the screw will probably remain in the anterior part of the knee, but screw marks were also found in the posterior part in zones 8 and 10. In knees with screw loosening significantly more surface deformation and bone cement-debris were also seen. In section 1 significantly more abrasion, delamination and surface deformation were seen. In section 5 significantly more surface deformation and bone-cement debris were seen. We also found a rotational pattern of wear on the backside of the tibial polyethylene insert and on the metal tibial tray in knees with screw loosening. This rotational pattern of wear was not seen in knees with a fixed screw. El Nahass et al. [227] showed that a normal knee prosthesis should allow a mean rotation of 24 degrees. In knees with loosening of the screw, the polyethylene insert probably rotates in the metal tibial tray, causing more abrasion, delamination and surface deformation of the articular surface due to abnormal loading and a rotational pattern of wear on the backside.

In recent studies, wear was observed on the backside of retrieved modular components [92;222;223]. Micromotion between the polyethylene and the metal tray was found both at mechanical testing in vitro [91] and in vivo [119]. Furman et al. [222] found evidence of backside wear by removal of the stamped manufacturer's markings. They estimated that the mass of polyethylene debris from the backside of retrieved inserts exceeded debris from the articular surface twofold to hundredfold. The backside of the tibial insert of the SKI prosthesis does not have these stamped markings. Therefore, the contribution of backside wear to the total amount of wear could not be quantified, but if there is a rotational movement of the tibial insert on the metal tray it must be assumed that backside wear is an important issue in the SKI prosthesis. Polyethylene debris generated at the tibial insert undersurface has been related to tibial osteolysis [92;228;229]. It has been hypothesized that small, submicron particles may be a greater stimulus to the macrophage to produce inflammatory mediators that result in osteolysis [230-232]. The size of the particles generated by backside wear is generally smaller compared to the size of the particles generated at the articular surface in knee arthroplasty [233]. This may explain the finding in Chapter 6 that loosening of the screw was the only significant factor contributing to an increase in radiolucency around the prosthesis.

Damage due to metal-on-metal contact was seen in 63.6% of all retrieved femoral and in 75% of all tibial components. In all cases in which the name of the patient was known, these components were loose. In this series only one prosthesis with damage of the metal parts was revised, while it was still well-fixed (see Chapter 3). All other prostheses with damage of the metal parts were loose. Metal-on-metal contact may contribute to loosening of the prosthesis.

7.6 CONCLUSIONS

The mean annual wear rate at retrieval analysis was 0.19 mm. Heavier patients and patients with degenerative arthritis had a significantly higher wear rate, but they did not have a higher amount of damage. Most damage was seen on the medial and posteromedial sides in sections 1 and 4, followed by the lateral and posterolateral sides in sections 7 and 8.

In knees with screw loosening, significantly more scratching, abrasion, delamination and surface deformation were seen, especially in sections 1 and 5. A rotational pattern of wear was only seen on the backside of inserts and on the metal tibial baseplates of prostheses that had had screw loosening. In knees with screw loosening the polyethylene insert probably rotates, which may cause more backside wear and more surface damage at the articular surface, due to abnormal loading.

Metal-on-metal contact may contribute to aseptic loosening of the prosthesis.