Appendix A
Measurement Scales

The Hospital for Special Surgery (HSS)

Knee Society Score

Western Ontario and MacMaster University (WOMAC) Osteoarthritis Index

The Hospital for Special Surgery (HSS)

KNEE SERVICE

Knee Rating Sheet

Name_____ HSS#_____ Preoperative date_____

		LEFT						RIGHT					
	Score	pre	6 mo	1 yr	2 yr	3 yr	4 yr	pre	6 mo	1 yr	2 yr	3 yr	4 yr
PAIN (30 points)													
Walking: None	15												
Mild	10												
Moderate	5												
Severe	0												
At rest: None	15												
Mild	10												
Moderate	5												
Severe	0												
FUNCTION (22 points)													
Walk: Walking & standing unlimited	12												
5-10 blocks, standing > 30 min	10												
1-5 blocks, standing 15-30 min	8												
Walk <1 block	4												
Cannot walk	0												
Stairs: Normal	5												
With support	2												
Transfer: Normal	5												
With support	2												
ROM (18 points) Each 8° = 1 point													
MUSCLE STRENGTH (10 points)													
Cannot break quadriceps	10												
Can break quadriceps	8												
Can move through arc of motion	4												
Cannot move through arc of motion	0												
FLEXION DEFORMITY (10 points)													
None	10												
5-10°	8												
10-20°	5												
>20°	0												
INSTABILITY (10 points)													
None	10												
0-5°	8												
6-15°	5												
>15°	0												
TOTAL													
SUBSTRACTIONS:													
One cane	1												
One crutch	2												
Two crutches	3												
Extension of lag of 5°	2												
10°	3												
15°	5												
Deformity (5° = 1 point)													
Varus													
Valgus													
TOTAL SUBTRACTIONS													
KNEE SCORE													

Knee Society Score (KS)

Example Questionnaire

(Your Clinic Information Here)

Patient Name_____
Date of Birth_____ Date of Surgery_____

Patient Reporting

Thank you for taking the time to help us better understand how your knee problem affects your daily life.

Please circle the answer that best describes your knee:

1. How much pain do you have when you are walking?

- None
- Mild or Occasional
- Moderate
- Severe

2. How much pain does your knee cause when going up and down stairs?

- None
- Mild or Occasional
- Moderate
- Severe

3. How much pain does your knee cause when you are at rest?

- None
- Mild
- Moderate
- Severe

4. How does your knee affect your walking ability?

- I can walk unlimited distances.
- I can walk 10-20 blocks.
- I can walk 5-10 blocks.
- I can walk 1-5 blocks.
- I can walk less than one block.
- I cannot walk at all.

5. How do you go up stairs?

- I go up stairs normally one foot in front of the other.
- I use the hand rail for balance.
- I use the hand rail to pull myself up.
- I cannot climb stairs.

6. How do you go down stairs?

- I go down stairs normally one foot in front of the other.
- I use the hand rail for balance.
- I use the hand rail to support myself.
- I cannot come down stairs.

7. How do you get out of a chair?

- I get out of a chair normally without support.
- I use the arm rests for balance.
- I use the arm rests to push myself.
- I cannot get out of a chair.

8. What type of support do you use when walking?

- None
- Cane
- 2 Canes
- Crutches
- Walker

Clinical Assessment

9. Range of Motion

- _____ Degrees

10. Extension Lag

- _____ Degrees

11. Flexion Contracture

- _____ Degrees

12. Medial/Lateral Stability

- 0-5 mm
- 5-10 mm
- >10 mm

13. Anterior/Posterior Stability

- 0-5 mm
- 5-10 mm
- >10 mm

14. Alignment

- _____ Degrees

Calculating the Knee Score and the Functional Score

This scoring system is the version of the knee score as modified by Dr. John Insall in 1993. The scoring system combines a relatively objective Knee Score that is based on the clinical parameters and a Functional Score based on how the patient perceives that the knee functions with specific activities.

The maximum Knee Score is 100 points and the maximum Functional Score is 100 points.

To calculate the two scores the answers to the questions and the findings on the examination are given a value based on the results. To obtain the Knee Score and the Functional Score the result of each question is totaled. Notice that some results are negative to denote that they are deductions to the score.

Knee Findings

Pain	50 (Maximum)

Walking

(Insert the value associated with the results of question 1)

None	35
Mild or occasional	30
Moderate	15
Severe	0

Stairs
(Result of question 2)

None	15
Mild or occasional	10
Moderate	5
Severe	0

R.O.M. 25 (Maximum)

(Result of question 9)

8º= 1 point

Stability 25 (Maximum)

Medial/Lateral
(Result of question 12)

0-5 mm	15
5-10 mm	10
> 10 mm	5

Anterior/Posterior
(Result of question 13)

0-5 mm	10
5-10 mm	8
> 10 mm	5

Deductions

Extension lag
(Result of question 10)

None	0
<4 degrees	-2
5-10 degrees	-5
>11 degrees	-10

Flexion Contracture
(Result of question 11)

< 5 degrees	0
6-10 degrees	-3
11-20 degrees	-5
> 20 degrees	-10

Malalignment
(Result of question 14)

5-10 degrees (5º = -2 points)	0

Pain at rest
(Result of question 3)

Mild	-5
Moderate	-10
Severe	-15
Symptomatic plus objective	0

(Now, simply total the scores of each of these questions to obtain the total Knee Score for the patient.)

Knee Score 100 (Maximum) =

Functional Findings

Walking
(Result of question 4)

Unlimited	55
10-20 blocks	50
5-10 blocks	35
1-5 blocks	25
< block	15
Cannot	0

Stairs Up
(Result of question 5)

Normal	15
Hands balance	12
Hands pull	5
Cannot or bizarre	0

Stairs Down
(Result of question 6)

Normal	15
Hands balance	12
Hands hold	5
Cannot or bizarre	0

Chair
(Result of question 7)

Normal	15
Hands balance	12
Hands pull	5
Cannot	0

Functional Deductions
(Result of question 8)

Cane	-2
Crutches	-10
Walker	-10

Functional Score 100 (Maximum) =

Western Ontario and MacMaster University (WOMAC) Osteoarthritis Index

1. The following questions concern the amount of pain you are currently experiencing in your knee. For each situation, please enter the amount of pain you have experienced in the past 48 hours.

	None	Mild	Moderate	Severe	Extreme
a. Walking on a flat surface					
b. Going up or down stairs					
c. At night while in bed					
d. Sitting or lying					
e. Standing upright					

The following questions concern the amount of joint stiffness (not pain) you have experienced in the last 48 hours in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your joints.

	None	Mild	Moderate	Severe	Extreme
2 How severe is your stiffness after first waking in the morning?					

	None	Mild	Moderate	Severe	Extreme
3. How severe is your stiffness after sitting, lying, or resting later in the day?					

4. The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities, please indicate the degree of difficulty you have experienced in the last 48 hours in your knee.

What degree of difficulty do you have with:	None	Mild	Moderate	Severe	Extreme
a. Descending (going down) stairs					
b. Ascending (going up) stairs					
c. Rising from sitting					
d. Standing					
e. Bending to the floor					
f. Walking on a flat surface					
g. Getting in and out of a car					
h. Going shopping					
i. Putting on socks/stockings					
j. Rising from bed					
k. Taking off socks/stockings					
l. Lying in bed					
m. Getting in/out of bath					
n. Sitting					
o. Getting on/off toilet					
p. Heavy domestic duties (such as mowing the lawn, lifting heavy grocery bags, vacuuming)					
q. Light domestic duties (such as tidying a room, dusting, cooking)					

Appendix B
Technical Expert Panel Members and Reviewers

Evidence Based Practice Center (EPC) – Total Knee Arthroplasty Technical Expert Panel Members

We are indebted to the Technical Expert Panel Members for providing both consultation during the development of this project and feedback on the initial draft.

Chris Callahan, MD
Indiana University School of Medicine
Regenstrief Institute
Indianapolis, IN

John Fitzgerald, MD
UCLA Medical Center
Los Angeles, CA

Richard Iorio, MD (Abstractor)
Lahey Clinic
Burlington MA

William Macaulay, MD (Abstractor)
Orthopaedic Surgery
Columbia University
New York, NY

John Melvin, MD
Department of Rehabilitation Medicine
Jefferson Medical College of Thomas Jefferson University
Philadelphia, PA

Patrick Murray, MD
MetroHealth Medical Center
Case Western Reserve University
Cleveland, OH

Charles. Nelson, MD (Abstractor)
Orthopaedic Surgery
University of Pennsylvania
Philadelphia PA

Cecil Rorabeck, MD
President, Knee Society
London, Ontario
CANADA

Roby Thompson, MD
University of Minnesota Medical School
Minneapolis, MN

Peter Tugwell, MD
Centre for Global Health
University of Ottawa
Ottawa, Ontario
CANADA

Evidence Based Practice Center (EPC) – Total Knee Arthroplasty Reviewers

We are grateful for the constructive feedback provided by the following individuals who reviewed the initial draft of this report. Acknowledgements are made with the explicit statement that this does not constitute endorsement of the report.

David Atkins, MD
Agency for Health Care Policy and Research
Rockville, MD

Kevin Bozic, MD
University of California, San Francisco
San Francisco, CA

David Heck, MD
Indiana University
Indianapolis, IN

E. Anthony Rankin, MD
Providence Hospital
Washington, DC

Aaron Rosenberg, MD
Rush Presbyterian Medical College, Chicago
Chicago, IL

Appendix C
Exact Search Strings

Search Strings for Total Knee Arthroplasty (TKA) Outcomes

The literature search was done using the following combination of MeSH headings, keywords, and publication types:

(arthroplasty, replacement, knee [mh] OR
knee prosthesis [mh] OR
"knee replacement" OR
"knee implant" OR
((TKAR OR prosthesis design [mh]) AND
(knee [mh] OR knee injuries [mh] OR knee joint [mh])))

AND

(meta-analysis [pt] OR
clinical trial [pt] OR
controlled clinical trial [pt] OR
randomized controlled trial [pt] OR
review [pt] OR
review literature [pt] OR
review, multicase [pt] OR
multicenter study [pt] OR
guideline [pt] OR
practice guideline [pt] OR
consensus development conference [pt] OR
evaluation studies [pt] OR
validation studies [pt] OR
clinical trials [mh] OR
controlled clinical trials [mh] OR
cohort studies [mh] OR
retrospective studies [mh] OR
prospective studies [mh] OR
followup studies [mh] OR
cross-sectional studies [mh] OR
double-blind method [mh] OR
comparative stud y[mh] OR
questionnaires [mh] OR
outcome assessment (health care) [mh] OR
treatment outcome [mh] OR
statistics [mh] OR
small-area analysis [mh] OR
cross-cultural comparison [mh] OR
cross-over studies [mh] OR
epidemiologic studies [mh] OR
longitudinal studies [mh] OR
multicenter studies [mh] OR
nursing evaluation research [mh] OR

multivariate analysis [mh] OR
psychometrics [mh] OR
evaluation studies [mh] OR
empirical research [mh] OR
data collection [mh] OR
"systematic review*" OR
"systematic literature review*" OR
meta-analysis OR
meta-analysis OR
meta-analyses OR
evidence-based OR
"case series")

Search Strings for Total Knee Arthroplasty Access

The literature search was done via PubMed using the following combination of MeSH headings and keywords:

knee prosthesis/ut

OR

((arthroplasty, replacement, knee [mh] OR
knee prosthesis [mh])

AND

(gender OR
race OR
bias OR
prejudice OR
disparity OR
physician's practice pattern [mh]))

Search Strings for Total Knee Arthroplasty Revisions

The search consisted of the following combination of MeSH headings and keywords:

((arthroplasty, replacement, knee[mh] OR
knee prosthesis[mh])

AND
(reoperation [mh] OR
revision, joint [mh])).

Appendix D
Abstracting Form

Total Knee Replacement Article Abstraction Form
(Data search from 1995 through 2002)

Author: _____ Study Unique Identifier:_____

Journal: _____

Year Publication: _____

Country: _____
(where study performed)

Reviewer: _____

Funding Source: Government Pharmaceutical Private
Non-funded Unknown

VERIFICATION/SELECTION OF STUDY ELIGIBILITY

Reported on primary total knee arthroplasty	Yes	No	Unclear
Reported any postoperative outcomes	Yes	No	Unclear
Experimental or Quasi-experimental	Yes	No	Unclear
Study sample 100 or > knees	Yes	No	Unclear
Baseline data provided	Yes	No	Unclear

Stop if any of the above is "NO"

Reported on revision knee procedures only	*Yes*	*No*	*Unclear*

Stop if "Yes"

TYPE OF STUDY *(circle one)*

SPECIAL POPULATION (write in):_____
(*examples age (<50 or >80), trauma, hemophiliacs, patients with CHD*)

1. Quasi-experimental cohort: (investigator studies the effect of intentionally altering 1 or more factors under controlled conditions) Retrospective vs. Prospective
2. Case Control
3. Randomized controlled trial
4. Other _____

ASSESSMENT OF STUDY QUALITY *(based on "Systems to Rate the Strength of Scientific Evidence, AHRQ Publication No. 02-E016, April 2002*)

Score each domain on a scale of 0 (poor, not defined) to 5 (excellent, clearly defined)

Observational Studies Quality Domains/Elements	Score
Study question clearly focused and appropriate *Notes:*	
Description of Study Population *Notes:*	
Clear definition of intervention *Notes:*	
Primary/secondary outcomes defined *Notes:*	
Statistical Analysis: Assessment of confounding attempted Did the analysis adjust for or examine the effects of various factors (i.e., population baseline characteristics, characteristics of surgeons, training, surgical procedures, types of prostheses mentioned/ incorporated into the analyses) *Notes:*	
Statistical methods used to take into account the effect of more than one variable on the outcome such as multiple regression, multivariate analysis, regression modeling -*see methods in paper* *Notes:*	
Measure of effect for outcomes and appropriate measure of precision *Notes:*	
Conclusions supported by results with possible bias and limitations taken into consideration *Notes:*	
Single versus Multi-site study (*note one of the other*) *Notes:*	
Patients evaluated with radiographs for outcomes *Notes:*	
Comorbidities mentioned *Notes:*	
Comorbidities incorporated in the analyses *Notes:*	
Attrition accounted for *Notes:*	
Death rates recorded *Notes:*	

Patient characteristics

	Group Values	***Noted but no values provided***	***Not Indicated***	***Variable used in the analysis (yes/no)***
Total Number of Subjects				
Number of subjects lost to attrition				
Number of subjects that died				
Subjects examined in the clinic				
Subjects evaluated with questionnaire and readiographs and not in the clinic				
Total # Knees				
Patients with bilateral knee surgeries				
Age, average and range % by age group <55 55-64 65-74 75-85 85				
Women, # and %				
Men, # and %				
Race/ethnicity: White # and %				
Race/ethnicity: Black # and %				
Race/ethnicity: Asian # and %				
Race/ethnicity: Hispanic # and %				
Height				
Weight				
Body Mass Index (BMI)				
# of Obese subjects				
Prior history, # and % With previous knee surgery				
Prior history, # and % With previous joint surgery				
Rheumatoid arthritis, # and %				

	Group Values	***Noted but no values provided***	***Not Indicated***	***Variable used in the analysis (yes/no)***
Osteoarthritis, # and %				
Severity/ e xtent of OA in other joints - degree of involvement in	other knee: hips: spine: other:			
Comorbidities, diabetes				
Comorbidities, stroke				
Comorbidities, neuro-muscular disease				
Comorbidities, CHD				
Comorbidities, CHF				
Comorbidities, HTN				
Comorbidities, COPD				
Comorbidities, other				

Patient characteristics: Knee factors

	Group Values	***Noted but no values provided***	***Not Indicated/ Reported***	***Variable used in the analysis (yes/no)***
Preoperative range of motion				
Tibio-femoral angle, in degrees)				
Extensor mechanism integrity *quadriceps tear, patellar fracture or, tendon rupture*				
Ligament integrity Medial Lateral	intact stretched not intact			

Prosthesis Characteristics

	Group Values	***Noted but no values provided)***	***Not Indicated/ Reported***	***Variable used in the analysis (yes/no)***
Material Cobalt/chromium Titanium Polyethelene				
Fixation tibia uncemented cemented stem femur uncemented cemented stem				
Augmentation • Augments on femur posterior anterior • Augments on tibia medial lateral • allograft morsellized structural				
Type of knee prosthesis • posterior cruciate (PS) ligament substitution • posterior cruciate retaining (CR) • semi constrained • constrained /rotating hinge • unicondylar				

Surgical Factors

	Group Values	***Noted but no values provided***	***Not Indicated/ Reported***	***Variable used in the analysis (yes/no)***
Experience (years of practice)				
Volume				
Hospital volume				
Hospital training program				
Surgical approach • extensile • rectus snip • v-y turndown • tibial tubercle turndown • paprapatellar • tourniquet use				
Type of anesthetic • regional • general				

Postoperative Conditions/Complications

	Group Values	***Noted but no values provided***	***Not Indicated/ Reported***	***Variable used in the analysis (yes/no)***
Total # of complications				
Pulmonary embolus				
DVTs				
Pneumonia				
Cardiac infarct				
Stroke				
Other				
Other				
Other				
Other				

Knee-Related Postoperative Conditions/Complications

	Group Values	***Noted but no values provided***	***Not Indicated/ Reported***	***Variable used in the analysis (yes/no)***
Total # of complications				
Death, related to the procedure				
Percent required revision/failed				
Wound infection Superficial Deep Early, ≤3 months Late, >3 months				
Bleeding				
Delayed wound healing				
Wound drainage				
Hematoma				
Knee effusions				
Aspetic loosening				
Other				
Other				

Postoperative Interventions

	Group Values	***Noted but no values provided***	***Not Indicated/ Reported***	***Variable used in the analysis (yes/no)***
Anticoagulation • when				
Prophylactic antibiotics				
Vena caval filters				
TEDS				
Physical Therapy • when (pod)*				
Occupational Therapy • when (pod)				

	Group Values	***Noted but no values provided***	***Not Indicated/ Reported***	***Variable used in the analysis (yes/no)***
CPM (Continuous flexion machine)				
Anti-inflammatory				
Preop medical optimization (i.e., cardiac, pulmonary, glucose control) ♦ when				
Postoperative medical management	Routine: Consult:			
Weight loss ♦ when				
Blood loss				
Erythropoietin				
Preop patient education				
Other				
Other				

Pod = post operative day

Radiographic Findings

	Variable recorded (yes/no)	***Variable used in the analysis (yes/no)***
Extremity alignment, mechanical axis		
Component – Tibia alignment		
Component – Femur alignment		
Tibiofemoral angle		

Outcome Scores: If more than one followup is reported, record and note each time interval.
Postop (Postoperative) Followup: please indicate years, or months

Outcome Scores

	Group Values (record standard deviations or errors, range and p-values if provided)	***Number of Subjects analyzed if provided***	***Noted but no values provided***
Global Knee Scale (GKS) (*write in %s for each* Poor: xx% Fair/Satisfactory: xx% Good: xx% Excellent: xx%	**Baseline** Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____ ***Postop Followup (write in):*** _____ Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____		
Knee Society (KS) (*measures pain and function-walking and stair climbing)* (*write in %s for each* Poor: xx% Fair/Satisfactory: xx% Good: xx% Excellent: xx%	Clinical/Pain (indicate whether just pain was recorded): Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ Functional: Baseline score:_____ ***Postop Followup (write in):*** _____(yrs, mos.) Score:_____ Total Score: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____		

	Group Values (record standard deviations or errors, range and p-values if provided)	***Number of Subjects analyzed if provided***	***Noted but no values provided***
Hospital for Special Surgery (HSS): 0-100 points *write in %s for each* Poor: xx% Fair/Satisfactory: xx% Good: xx% Excellent: xx%	Baseline: Score:_____ ***Postop Followup (write in):*** _____ Score:_____ Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____		
Western Ontario McMaster Osteoarthritis Index (WOMAC)	**<u>Function</u>:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **<u>Stiffness</u>:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **<u>Pain</u>:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Total Score:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		

	Group Values (record standard deviations or errors, range and p-values if provided)	*Number of Subjects analyzed if provided*	*Noted but no values provided*
Short Form Health Survey (SF-36)	**General health:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Body pain**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Role emotional**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Mental health**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Physical function**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Role physical**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Social function**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Vitality**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		

	Group Values (record standard deviations or errors, range and p-values if provided)	***Number of Subjects analyzed if provided***	***Noted but no values provided***
	Combined physical: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Combined mental**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		
Other, write in name of scale_____ Measures:_____ *(function, pain, walking, etc.)*	Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		
Other, write in name of scale_____ Measures:_____ *(function, pain, walking etc.)*	Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		

Subgroup Outcome Scores (attach additional sheets if necessary)

***Subgroup (write in)*:**_____

	Group Values (record standard deviations or errors, range and p-values if provided)	***Number of Subjects analyzed if provided***	***Noted but no values provided***
Global Knee Scale (GKS) (*write in %s for each* Poor: xx% Fair/Satisfactory: xx% Good: xx% Excellent: xx%	**Baseline** Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____ ***Postop Followup (write in):*** _____ Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____		
Knee Society (KS) **(*measures pain and function-walking and stair climbing)*** (*write in %s for each* Poor: xx% Fair/Satisfactory: xx% Good: xx% Excellent: xx%	Clinical/Pain (indicate whether just pain was recorded): Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ Functional: Baseline score:_____ ***Postop Followup (write in):*** _____(yrs, mos.) Score:_____ Total Score: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____		

	Group Values (record standard deviations or errors, range and p-values if provided)	***Number of Subjects analyzed if provided***	***Noted but no values provided***
Hospital for Special Surgery (HSS): 0-100 points *write in %s for each* Poor: xx% Fair/Satisfactory: xx% Good: xx% Excellent: xx%	Baseline: Score:_____ ***Postop Followup (write in):*** _____ Score:_____ Poor: # and %:_____ Fair/Satisfactory: # and %:_____ Good: # and %:_____ Excellent: # and %:_____		
Western Ontario McMaster Osteoarthritis Index (WOMAC)	**Function:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Stiffness:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Pain:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Total Score:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		

	Group Values (record standard deviations or errors, range and p-values if provided)	*Number of Subjects analyzed if provided*	*Noted but no values provided*
Short Form Health Survey (SF-36)	**General health:** Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Body pain**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Role emotional**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Mental health**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Physical function**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Role physical**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Social function**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Vitality**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		

	Group Values (record standard deviations or errors, range and p-values if provided)	***Number of Subjects analyzed if provided***	***Noted but no values provided***
	Combined physical: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____ **Combined mental**: Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		
Other, write in name of scale_____ Measures:_____ *(function, pain, walking, etc.)*	Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		
Other, write in name of scale_____ Measures:_____ *(function, pain, walking etc.)*	Baseline score:_____ ***Postop Followup (write in):*** _____ Score:_____		

Appendix E

Functional Outcome Following Total Knee Arthroplasty Revision: A Meta-analysis

Functional Outcome Following Total Knee Arthroplasty Revision: A Meta-analysis

Khaled J. Saleh, MD, MSc, FRCSC [*1,2,3], Daryll C. Dykes, MD, PhD [1,2] Richard L. Tweedie, PhD DSc [4], Khadeeja Mohamed [4], Ashwin Ravichandran [1], Raied M. Saleh[1], Terence J. Gioe, MD [1,3], David A. Heck MD[5]

* Correspondence
Phone: 612/626-3973 / Fax: 612/626-6032
saleh002@umn.edu

1 Department of Orthopaedic Surgery
University of Minnesota School of Medicine
420 Delaware Street SE, MMC 492
Minneapolis, Minnesota 55455

2 Clinical Outcomes Research Center
University of Minnesota School of Medicine
420 Delaware Street SE, MMC 492
Minneapolis, Minnesota 55455

3 Minneapolis Veterans Affair Medical Center
I Veterans Dive
Minneapolis Minnesota 55417

4 Division of Biostatistics, School of Public Health
University of Minnesota
420 Delaware Street SE
Minneapolis, Minnesota 55455

5 Department of Orthopaedic Surgery
Indiana University
541 Clinical Dr, Suite 600
Indianapolis Indiana 46202-5111

Running Title: Revision Knee Arthroplasty

Acknowledgement

Funded in part by The American Geriatric Society, The Minnesota Medical Foundation and The Orthopaedic Research and Education Foundation

Functional Outcome Following Total Knee Arthroplasty Revision: A Meta-analysis

ABSTRACT

Objective- The objective of this study was to perform a systematic literature review to describe patient outcomes following Total Knee Arthroplasty Revision (TKAR) procedures using various Global Knee Score (GKS) ratings. **Data Sources**-English Language articles published from 1966 through 2000, were identified through a computerized literature search and bibliography review. **Study selection**-A multistage assessment was used to determine those articles containing data that could meet our objective. **Analysis**- Meta-analyses of Global Knee Scores were undertaken using a fixed effects model with the assumption that the variances of each individual measurement were identical across studies. **Results**- 58 articles with a total of 1965 patients met the initial inclusion criteria. Forty-two articles comprising 45 unique patient cohorts and a total of 1515 patients had sufficient GKS data for analysis and were used in the meta-analyses. **Conclusions**- Revision total knee arthroplasty is an effective procedure for failed knee replacements based on global knee rating scales.

INTRODUCTION

Arthritis is generally a slowly progressive disease that afflicts more than two-thirds (68%) of Americans older than 55 years of age.[1] It becomes increasingly prevalent with advancing age.[2,3]. At present, 43 million individuals have arthritis. By the year 2020, it is estimated that 59.4 million persons will be affected by this disease.[1] The high prevalence of arthritis in the population is reflected in the high cost of treatment and has been estimated to cost 95 billion dollars (US) per year.[1]In 1996 over 607,000 hip and knee replacements were performed in the U.S.[6] By the year 2030, it is estimated that there will be an 85 % increase in knee replacements and an 80% increase in hip replacements[7]

Like all biomedical devices, total knee replacements can fail over time.[16] Coincident with the increased incidence of primary TKA, there has also been an increase in the number of total knee arthroplasty revision (TKAR) procedures.[17] In 1995, 19,138 TKAR procedures were performed in the U.S.[18] Using Ontario 1989-94 discharge data, Coyte[18] derived an annual growth rate of 14.1% for TKAR procedures. The number of TKAR procedures is expected to continue to grow as a result of complications associated with TKA, including infection, fracture and time-dependent implant failure that necessitate re-operation.[21].

Unfortunately, long-term TKAR outcome data reporting knee specific or Global Knee Scores (GKS) in the arthroplasty literature is deficient. Callahan et al[24] defined a Global Knee Score as "an instrument that measured patient outcomes in the domains of pain, function, and range of motion and combined these domains in a summary scale." Examples of such scales include the Hospital for Special Surgery score (HSS) and Knee Society (KS) score. The specific aim of this study was to perform a systematic literature review to describe patient outcomes following TKAR procedures by using GKS to examine the following questions:

- Is there a significant increase from the preoperative GKS to the postoperative GKS?
- Is there correlation between preoperative GKS and the increase in the postoperative scores?
- What proportion of TKAR subjects attains excellent/good (E/G) results postoperatively, and what proportion attains satisfactory/poor (S/P) results?
- Does the proportion of E/G, or the postoperative values of HSS and KS scores, vary with the length of followup, the year of study publication, or preoperative diagnosis (i.e., infection, loosening, etc.)?

Arthritis tends to involve multiple joints, and as a result we wanted to examine the outcome of cohorts with subjects that had multiple knees revised versus cohorts that were comprised of subjects who only had a single knee revised:

- Is there a difference between the multiple and single knee cohorts in the percentage of subjects that attain E/G postoperatively?
- Is there a difference between the multiple and single knee cohorts in the preoperative HSS or KS scores or the score increases?

Finally we considered the entire data set of studies in order to assess the rates of complication following TKAR.

METHODS

Literature Search

We performed a computerized literature search using Medline to identify all citations concerning prosthetic knee procedures published from 1966 through 2000 using the MeSH terms "knee", "prosthesis" and "replacement". We obtained a copy of the abstracts for each identified English-language citation. We then used a multistage assessment similar to Callahan et al.[24] to identify articles relevant to our questions. At the first stage, two study investigators (KS and TG) each reviewed the abstracts to determine which articles 1) reported any postoperative outcomes 2) reported on revision knee procedures and 3) had a study sample greater than five subjects. At the second stage, these articles were then extracted and reviewed. The bibliography sections in all review articles were examined and missed citations were retrieved. At the third stage of assessment the same investigator excluded any study articles that did not report results using a global knee rating scale.

Data Abstraction

Data entry was carried out by two trained data abstractors (AR and RS). We analyzed variables that were reported across the majority of studies. Difficulties in abstracting data came from non-reported information or data that were reported on only a subset of the studies. Variables that were not consistently reported included: race, weight, medical comorbidities, previous numbers of surgeries on the index knee, time elapsed since the previous knee replacement, method of anesthesia, operative techniques (such as exposure, component removal, cement use, type of prosthesis, treatment of cruciate ligaments and allograft or metal augmentation), perioperative antibiotics, thrombosis prophylaxis, and postoperative rehabilitation course. Studies also showed variability in reporting complication rates; hence local complications including delayed wound healing, wound drainage, hematoma, knee effusions, and pressure sores could not be evaluated. Systemic complications including cardiac, gastrointestinal, neurologic, urologic, also could not be analyzed. Variables such as prosthetic design and source of research funding also were not consistently reported. Finally, the specifics of score administration methodology were not consistently reported.

Data Analysis

For both KS (functional, clinical and averaged) and HSS scales, the preoperative and postoperative scores and the mean differences between preoperative and postoperative scores, were meta-analyzed to provide overall estimates for these values. Similar meta-analyses were carried out on the number of years of followup, age of patients, and other variables.

These meta-analyses were all "fixed effects"[25] carried out under the assumption that the variances of each individual measurement are identical across studies. This assumption, also made by Callahan et al.[24] is needed since information on variances is usually not given in these studies. Improving on the methodology of Callahan et al.,[24] the variance of the overall estimate

was derived under this model using the between-study variability, leading to a 95% confidence interval (CI) on each overall estimate.

This analysis calculates a weighted average of the values in each study, where the weights are the study sizes, as in Callahan et al.[24] Study size was taken to be the reported number of subjects in each study minus the number reported as lost to followup. In some studies it was not clear if the size of study used in calculating the mean was the original number enrolled or the number minus those lost to followup. Therefore we also carried out the majority of the analyses using the total enrolled to see if this affected the overall answers. No changes of any importance occurred as a result.

Many studies also contained a classification into excellent/good (E/G) results versus satisfactory/poor (S/P) results, and a fixed effects meta-analysis of these E/G proportions (corrected for zero counts) was also carried out. The variances in this context were estimated using binomial methods, again allowing estimation of a 95% CI.

For further analysis the studies were divided into two groups: those with the "number of knees" reported as greater than the number of subjects, and those with the same number of subjects and knees reported. These groups were analyzed separately for each of the variables above. The hypothesis that the groups were different was tested, using single sample t-tests on the meta-analyzed values.

The dependence of the results on the number of years of followup was investigated. After consideration of the data, separate regressions were fitted to the studies that carried out followup for less than 60 months versus those that had longer followup periods. These results are exploratory, since this cut-off was subjective and accordingly we could not formally test the hypothesis that the periods were different.

Temporal trends in the data were analyzed against the mid-year of the stated study period to assess changes in results as newer methods were introduced. There were limited data to carry out this investigation, but there was no evidence of any secular trend in any of the measured scores. Studies also were grouped into those where all patients were treated because of infection and compared to those where < 10% were treated because of infection, and the proportions scoring E/G were compared. There were too few articles to allow a meaningful comparison for the KSS and HS scores. Finally, complications were tabulated and categorized into systemic and mechanical failure requiring re-revision.

RESULTS

Literature Description

A total of 2780 abstracts were identified in the literature using the above MeSH terms. Two hundred eighty-seven proceeded to the second stage after the abstracts were retrieved and examined. We then obtained a copy of the 287 articles and the bibliographies were reviewed for additional citations. The bibliographic review resulted in the addition of two studies to the candidate pool of articles. Fifty-eight of the 289 articles passed through the final filter and became the final data set.

These 58 articles from thirty-one different academic institutions were published from 1973 through 1994 (Appendix E-1). Pre- and postoperative KS scores were reported in fifteen studies (Table E-1), and HSS scores in seventeen (Table E-2). Two of these studies reported both KS and HSS data. Thirty-five studies reported a pre- and postoperative categorical outcome data that were stratified into four groups as: excellent, good, satisfactory, and poor (Table E-3). Overall, 46 unique patient cohorts from 42 articles had sufficient data to enable analysis of KS scores, HSS scores, or categorical E/G outcome data. The remainder had a variety of other global scores, with not enough of any one to support systematic analysis.

Patient Characteristics

For the 58 studies extracted there were a total of 1965 patients. A subgroup of 42 papers with 1,515 patients was used in the main analyses (Appendix E-1). The mean patient age across these 42 papers was 66.6 years. Approximately 61% of the enrolled subjects were women (based on thirty-seven studies who reported the gender data). This ranged from a minimum of 28% to a maximum of 82%. Osteoarthritis was the primary reason for the index knee replacement. The average number of months of followup for the studies reporting KS was 53.1 (95% CI 44.5-61.7) and for HSS was 55.2 (95% CI 47.4-63.0); this difference was not statistically significant ($p>0.1$). The patients' race and socio-economic status were not systematically reported.

Summary of Findings

Is there a significant increase from the preoperative GKS to the postoperative GKS?

The preoperative combined mean KS score was 35.4 (95% CI 30.7-39.9) and there was a highly significant increase of 30.8 (95% CI 26.6-35.0) points to 66.2 (95% CI 61.8-70.2) points postoperatively ($p<0.0001$). The preoperative functional mean KS score was 30.4 (95% CI 22.8-37.9) with a highly significant increase of 27.0 (95% CI 21.8-32.2) points to 57.4 (95% CI 51.6-62.7) points postoperatively ($p<0.0001$); the preoperative clinical mean KS score was 32.8 (95% CI 25.5-40.0) with a highly significant increase of 42.1 (95% CI 39.2-45.0) points to 74.9 (95% CI 68.6-80.8) points postoperatively ($p<0.0001$). Note that the latter two subscales were on a subset of the 15 studies on which combined results could be calculated. The preoperative mean HSS score was 51.5 (95% CI 48.9-54.1) and there was a highly significant increase of 28.3 (95% CI 25.3-31.2) points to 79.8 (95% CI 76.4-83.1) points postoperatively ($p < 0.0001$).

Is there correlation between preoperative GKS and the increase in the postoperative scores?

There is no significant correlation between the preoperative score and the amount of improvement in either the overall KS ($r = -0.09$, $p > 0.7$) or the HSS ($r = -0.263$, $p > 0.3$) studies.

Is there a difference in the preoperative scores between the multiple and single knee cohorts?

Although there was no difference in age or gender between the multiple and single knee reports, there was a significant difference in preoperative HSS scores, multiple knee (49.5, 95% CI 45.9-53.2) and the single knee (54.5, 95% CI 51.4-57.5) studies ($p<0.1$). The preoperative combined mean KS score in the multiple knees group was, in contrast, higher (77.0, 95% CI 64.2-89.8) than the single knee group (59.85, 95% CI 45.2-74.5), which is just significant ($p>0.1$) in the other direction. This result is, however, heavily influenced by a preoperative combined score of only 4.2 in one fairly large study. These results indicate that the multiple knee cohorts may be more severe preoperatively then their counterparts, although this is not conclusive.

Is there a difference in the increase in KS or HSS scores between the multiple and single knee groups?

The meta-analyzed averaged KS mean difference between pre- and postoperative scores was statistically not significant between the multiple knee (60.0, 95% CI 49.4-70.5) and single knee (64.4, 95% CI 50.3-78.5) studies. The meta-analyzed HSS mean difference between pre- and postoperative scores was statistically not significant between the multiple knee (28.9, 95% CI 25.5-32.3) and single knee (27.2, 95% CI 22.5-32.0) studies.

Does the increase in HSS or KS scores vary with the length of followup?

On an exploratory basis, the mean difference increases on both GKS scores up to around 60 months, thereafter KS (Figure E-1) and the HSS score marginally declines (Figure E-2).

What proportion of TKAR subjects attains excellent/good (E/G) results on the GKS postoperatively, and what proportion attains satisfactory/poor results?

The percentage of subjects attaining an excellent/good postoperatively was 77.7% (95% CI 75.2-80.2).

Is there a difference in the percentage of subjects that attain E/G ratings postoperatively on the GKS between the multiple and single knee cohorts?

The percentage of subjects attaining E/G was 72.7% (95% CI 69.5-76.3) in studies reporting on cohorts where some subjects had both knees revised, compared to 82.6% (95% CI 79.1-86.3) in studies reporting on cohorts where no subjects were reported to have had multiple knees revised. This difference is significant ($p < 0.05$). Those patients in whom single revision knee replacements were performed had better postoperative scores.

Does the proportion of E/G vary with the length of followup?

On an exploratory basis, the percentage of E/G subjects increase up to around 60 months (Figure E-3).

Does the proportion of E/G vary with the presence of infection as a proximate cause for revision?

There was a significant difference in the proportion of E/G outcomes between those articles in which a higher percentage of patients with infection as the proximate cause for revision as compared to those in which fewer patients were infected. ($p < 0.05$) Uninfected patient series do better with the proportion of E/G outcomes equal to 78.5% (95% CI 74.7%-82.3%). The greater proportion of infected patient series have worse outcomes with the proportion E/G equal to 67.5% (95% CI 61.5%-73.4%).

What is the complication rate following TKAR?

Forty-four of 46 (95.7%) cohorts reported complication data on 1,683 subjects who incurred 443 complications (26.3%). It was not possible to determine which or how many complications occurred in any given patient or patient subset (Table E-4). There were a total of 217 knee complications in 1,683 subjects necessitating re-revision (12.9%). Callahan et al. found a 30% overall complication rate and a 7.2% revision rate in 18 bicompartmental knee arthroplasty reports which 884 enrolled patients and an 18.5 overall complication rate and a 9.2% revision rate in 46 unicompartmental knee arthroplasty reports which 2,391enrolled patients.[27]

DISCUSSION

Ideally, clinical information is gathered through large, carefully controlled and randomized prospective studies. However, such studies are technically and logistically complex, expensive, and often impractical or impossible. Meta-analysis, which is less complex, specifically increased the statistical power of our study and reduced the chance of type II statistical errors.[24] In this situation, the results produced meaningful information that was not apparent on the basis of the smaller studies alone. It is not always the case that there is perfect concordance between the results of meta-analyses and subsequent randomized controlled trials.[26] However, this technique is helpful in allowing an investigator to better design and appropriately power subsequent clinical trials.

In the case of TKAR, epidemiological studies have clearly demonstrated a rapidly growing demand for this surgery.[7] However, knowledge regarding its outcomes has been lacking. In this communication, we report the results of a systematic review of the literature concerning patient outcomes following TKAR. Although TKAR is among the most technically challenging orthopaedic procedures, it is clear from these results that patients attain favorable outcomes following this procedure.

The majority of patients reported significant improvement in GKS following TKA. Patients reported mean postoperative KS and HSS scores which were 87.3% and 49.2% greater than their respective preoperative values, with slightly greater than three-quarters (77.7%) of patients reporting “excellent” or “good” outcomes. While this study supports the common belief that

revision arthroplasty surgery is generally less successful than primary procedures, these data compare favorably with those reported in meta-analyses of primary knee replacement outcomes. Using literature synthesis data, Callahan et al. reported mean improvements in global rating scale scores of 63%, 93%, and 100%, and good or excellent outcomes in 80%, 73%, and 90% of patients following primary unicompartmental,[27] bicompartmental,[12], and tricompartmental knee arthroplasty,[24] respectively. Cohorts consisting exclusively of single-knee TKAR subjects had significantly higher proportions of subjects reporting E/G outcomes than those that included subjects with bilateral TKAR. However, although patients in the bilateral knee cohorts had slightly lower mean preoperative HSS scores and slightly higher mean preoperative KS scores, we found no significant difference in the degree to which patients improved following single-knee TKAR or revision surgery of both knees. This finding, which has not been previously observed, is consistent with our general finding that preoperative GKS does not appear to affect the magnitude of the reported success of the procedures. A thorough assessment of any clinical procedure must weigh the benefits of the procedure against its complications.

There was insufficient data reported to analyze the rates of preoperative or postoperative mortality. However, the majority (95.7%) of studies included in this analysis reported at least some complication data, with an overall complication rate of 26.3%. While the rates of most TKAR complications were consistent with those reported for primary TKA, an unusually high incidence of patellar component failure (11.1%), arterial injuries (10.3%), fracture of the proximal tibia (7.1%), and deep wound infection (6.7%) was identified in this study. This effect may have been falsely inflated secondary to our study-rule that assumes all complications were not screened for and only reported when they arose, artificially deflating the denominator and increasing the rate. The subgroup of patients with infection as a proximate cause for revision appears particularly challenging as their likelihood of achieving excellent or good outcomes is reduced.

Certain limitations are inherent to meta-analysis methodology. The results of data synthesis from multiple publications is limited by the quality and quantity of data reported in the included studies. In this analysis, we discovered considerable variation in the existing TKAR literature with respect to study size and design, followup period, and the authors' style of reporting many salient variables. As in previous meta-analyses, insufficient data were present to assess the impact of patient demographic characteristics, socio-economic status, implant characteristics, details of the surgical procedures, or postoperative care regimens on the outcome of TKAR. Accordingly, although we demonstrate significant overall favorable outcomes following TKAR surgery, we are unable to identify those particular factors that lead to improvement in postoperative

Scores. Similarly, complication data were only variably reported and particular complications were seldom attributable to particular patients.

CONCLUSION

TKAR appears to be an effective treatment for most patients facing the painful, disabling and clinically challenging effects of failed knee arthroplasty. Clearly, the existing literature regarding outcome of TKAR is deficient, in experimental methodology and longer-term results. Future studies investigating the results of TKAR should utilize better experimental design, including validated assessment tools, independent assessment of outcomes, larger patient samples, and

longer followup. Additionally, future reports must adhere to improved reporting standards, including better reporting of loss to followup information, surgical and implant details, outcome measures, complications and patient characteristics including socioeconomic status, comorbidity, proximate cause for revision, and extent of local disease at the time of revision.

Appendix E-1

58 Articles identified in the literature search which were included in the final Meta-analytic data set

A1. Bargar, W. L., Cracchiolo, A., III, and Amstutz, H. C.: Results with the constrained total knee prosthesis in treating severely disabled patients and patients with failed total knee replacements. Journal of Bone & Joint Surgery - American Volume. 62:504-512, 1980.

A2. Barrack, R. L., Matzkin, E., Ingraham, R., Engh, G., and Rorabeck, C.: Revision knee arthroplasty with patella replacement versus bony shell. Clinical Orthopaedics & Related Research.139-143, 1998.

A3. Barrack, R. L., Rorabeck, C., Burt, M., and Sawhney, J.: Pain at the end of the stem after revision total knee arthroplasty. Clin. Orthop.216-225, 1999.

A4. Barrett, W. P. and Scott, R. D.: Revision of failed unicondylar unicompartmental knee arthroplasty. Journal of Bone & Joint Surgery - American Volume. 69:1328-1335, 1987.

A5. Bradley, G. W.: Revision total knee arthroplasty by impaction bone grafting. Clinical Orthopaedics & Related Research.113-118, 2000.

A6. Cameron, H. U., Hunter, G. A., Welsh, R. P., and Bailey, W. H.: Revision of total knee replacement. Canadian Journal of Surgery. 24:418-420, 1981.

A7. Chakrabarty, G., Newman, J. H., and Ackroyd, C. E.: Revision of unicompartmental arthroplasty of the knee. Clinical and technical considerations. J. Arthroplasty. 13:191-196, 1998.

A8. Chotivichit, A. L., Cracchiolo, A., III, Chow, G. H., and Dorey, F.: Total knee arthroplasty using the total condylar III knee prosthesis. Journal of Arthroplasty. 6:341-350, 1991.

A9. Donaldson, W. F., III, Sculco, T. P., Insall, J. N., Ranawat, C. S., Tew, M., Forster, I. W., Rand, J. A., Chao, E. Y., and Stauffer, R. N.: Total condylar III knee prosthesis. Long-term followup study effect of knee replacement on flexion deformity
Kinematic rotating-hinge total knee arthroplasty. Clinical Orthopaedics & Related Research. 69:21-28, 1988.

A10. Dorr, L. D., Ranawat, C. S., Sculco, T. A., McKaskill, B., and Orisek, B. S.: Bone graft for tibial defects in total knee arthroplasty. Clinical Orthopaedics & Related Research.153-165, 1986.

A11. Elia, E. A. and Lotke, P. A.: Results of revision total knee arthroplasty associated with significant bone loss. Clinical Orthopaedics & Related Research.114-121, 1991.

A12. Engh, G. A., Herzwurm, P. J., and Parks, N. L.: Treatment of major defects of bone with bulk allografts and stemmed components during total knee arthroplasty. Journal of Bone & Joint Surgery - American Volume. 79:1030-1039, 1997.

A13. Fehring, T. K. and Griffin, W. L.: Revision of failed cementless total knee implants with cement. Clin. Orthop.34-38, 1998.

A14. Gill, T., Schemitsch, E. H., Brick, G. W., and Thornhill, T. S.: Revision total knee arthroplasty after failed unicompartmental knee arthroplasty or high tibial osteotomy. Clinical Orthopaedics & Related Research.10-18, 1995.

A15. Goldberg, V. M., Figgie, M. P., Figgie, H. E., III, and Sobel, M.: The results of revision total knee arthroplasty. Clinical Orthopaedics & Related Research.86-92, 1988.

A16. Goldman, R. T., Scuderi, G. R., and Insall, J. N.: 2-stage reimplantation for infected total knee replacement. Clinical Orthopaedics & Related Research.118-124, 1996.

A17. Gustilo, T., Comadoll, J. L., and Gustilo, R. B.: Long-term results of 56 revision total knee replacements. Orthopaedics (Thorofare. , NJ). 19:99-103, 1996.

A18. Haas, S. B., Insall, J. N., Montgomery, W., III, and Windsor, R. E.: Revision total knee arthroplasty with use of modular components with stems inserted without cement. Journal of Bone & Joint Surgery - American Volume. 77:1700-1707, 1995.

A19. Hanssen, A. D. and Rand, J. A.: A comparison of primary and revision total knee arthroplasty using the kinematic stabilizer prosthesis. Journal of Bone & Joint Surgery - American Volume. 70:491-499, 1988.

A20. Hanssen, A. D., Rand, J. A., and Osmon, D. R.: Treatment of the infected total knee arthroplasty with insertion of another prosthesis. The effect of antibiotic-impregnated bone cement. Clinical Orthopaedics & Related Research.44-55, 1994.

A21. Hartford, J. M., Goodman, S. B., Schurman, D. J., and Knoblick, G.: Complex primary and revision total knee arthroplasty using the condylar constrained prosthesis: an average 5-year followup. Journal of Arthroplasty. 13:380-387, 1998.

A22. Hirakawa, K., Stulberg, B. N., Wilde, A. H., Bauer, T. W., and Secic, M.: Results of 2-stage reimplantation for infected total knee arthroplasty. J. Arthroplasty. 13:22-28, 1998.

A23. Ikezawa, Y. and Gustilo, R. B.: Clinical outcome of revision of the patellar component in total knee arthroplasty. A 2- to 7-year followup study. J. Orthop. Sci. 4:83-88, 1999.

A24. Insall, J. N. and Dethmers, D. A.: Revision of total knee arthroplasty. Clinical Orthopaedics & Related Research.123-130, 1982.

A25. Jackson, M., Sarangi, P. P., Newman, J. H., Hanssen, A. D., Rand, J. A., and Osmon, D. R.: Revision total knee arthroplasty. Comparison of outcome following primary proximal tibial osteotomy or unicompartmental arthroplasty. Journal of Arthroplasty. 9:539-542, 1994.

A26. Jacobs, M. A., Hungerford, D. S., Krackow, K. A., and Lennox, D. W.: Revision total knee arthroplasty for aseptic failure. Clinical Orthopaedics & Related Research.78-85, 1988.

A27. Jacobs, M. A., Hungerford, D. S., Krackow, K. A., and Lennox, D. W.: Revision of septic total knee arthroplasty. Clinical Orthopaedics & Related Research.159-166, 1989.

A28. Karpinski, M. R. and Grimer, R. J.: Hinged knee replacement in revision arthroplasty. Clinical Orthopaedics & Related Research.185-191, 1987.

A29. Kim, Y. H.: Salvage of failed hinge knee arthroplasty with a Total Condylar III type prosthesis. Clin. Orthop.272-277, 1987.

A30. Knight, J. L., Atwater, R. D., and Guo, J.: Early failure of the porous coated anatomic cemented unicompartmental knee arthroplasty. Aids to diagnosis and revision. Journal of Arthroplasty. 12:11-20, 1997.

A31. Kraay, M. J., Goldberg, V. M., Figgie, M. P., and Figgie, H. E., III: Distal femoral replacement with allograft/prosthetic reconstruction for treatment of supracondylar fractures in patients with total knee arthroplasty. Journal of Arthroplasty. 7:7-16, 1992.

A32. Lachiewicz, P. F., Falatyn, S. P., Greis, P. E., and Steadman, J. R.: Clinical and radiographic results of the Total Condylar III and Constrained Condylar total knee arthroplasty revision of failed prosthetic anterior cruciate ligament reconstruction. [Review] [34 refs]. Journal of Arthroplasty. 11:916-922, 1996.

A33. Lai, C. H. and Rand, J. A.: Revision of failed unicompartmental total knee arthroplasty. Clinical Orthopaedics & Related Research.193-201, 1993.

A34. Mnaymneh, W., Emerson, R. H., Borja, F., Head, W. C., and Malinin, T. I.: Massive allografts in salvage revisions of failed total knee arthroplasties. Clinical Orthopaedics & Related Research.144-153, 1990.

A35. Mow, C. S. and Wiedel, J. D.: Noncemented revision total knee arthroplasty. Clinical Orthopaedics & Related Research.110-115, 1994.

A36. Murray, P. B., Rand, J. A., and Hanssen, A. D.: Cemented long-stem revision total knee arthroplasty. Clinical Orthopaedics & Related Research.116-123, 1994.

A37. Nicholls, D. W. and Dorr, L. D.: Revision surgery for stiff total knee arthroplasty. Journal of Arthroplasty. 5 Suppl:S73-S77, 1990.

A38. Otte, K. S., Larsen, H., Jensen, T. T., Hansen, E. M., and Rechnagel, K.: Cementless AGC revision of unicompartmental knee arthroplasty. Journal of Arthroplasty. 12:55-59, 1997.

A39. Padgett, D. E., Stern, S. H., and Insall, J. N.: Revision total knee arthroplasty for failed unicompartmental replacement. Journal of Bone & Joint Surgery - American Volume. 73:186-190, 1991.

A40. Pagnano, M. W., Hanssen, A. D., Lewallen, D. G., and Stuart, M. J.: Flexion instability after primary posterior cruciate retaining total knee arthroplasty. Clin. Orthop.39-46, 1998.

A41. Pagnano, M. W., Trousdale, R. T., and Rand, J. A.: Tibial wedge augmentation for bone deficiency in total knee arthroplasty. A followup study. Clinical Orthopaedics & Related Research.151-155, 1995.

A42. Palmer, S. H., Morrison, P. J., and Ross, A. C.: Early catastrophic tibial component wear after unicompartmental knee arthroplasty. Clinical Orthopaedics & Related Research.143-148, 1998.

A43. Partington, P. F., Sawhney, J., Rorabeck, C. H., Barrack, R. L., Moore, J., Shaw, J. A., and Chung, R.: Joint line restoration after revision total knee arthroplasty
Febrile response after knee and hip arthroplasty. Clinical Orthopaedics & Related Research.165-171, 1999.

A44. Peters, C. L., Hennessey, R., Barden, R. M., Galante, J. O., and Rosenberg, A. G.: Revision total knee arthroplasty with a cemented posterior-stabilized or constrained condylar prosthesis: a minimum 3-year and average 5-year followup study. Journal of Arthroplasty. 12:896-903, 1997.

A45. Rand, J. A.: Revision total knee arthroplasty using the total condylar III prosthesis. Journal of Arthroplasty. 6:279-284, 1991.

A46. Rand, J. A. and Bryan, R. S.: Results of revision total knee arthroplasties using condylar prostheses. A review of fifty knees. Journal of Bone & Joint Surgery - American Volume. 70:738-745, 1988.

A47. Rand, J. A., Chao, E. Y., and Stauffer, R. N.: Kinematic rotating-hinge total knee arthroplasty. Journal of Bone & Joint Surgery - American Volume. 69:489-497, 1987.

A48. Ritter, M. A., Carr, K. D., Keating, E. M., Faris, P. N., Bankoff, D. L., and Ireland, P. M.: Revision total joint arthroplasty: does Medicare reimbursement justify time spent? Orthopaedics (Thorofare, NJ). 19:137-139, 1996.

A49. Rooser, B., Boegard, T., Knutson, K., Rydholm, U., and Lidgren, L.: Revision knee arthroplasty in rheumatoid arthritis. Clinical Orthopaedics & Related Research.169-173, 1987.

A50. Rosenberg, A. G., Verner, J. J., and Galante, J. O.: Clinical results of total knee revision using the Total Condylar III prosthesis. Clinical Orthopaedics & Related Research.83-90, 1991.

A51. Shaw, J. A., Balcom, W., and Greer, R. B., III: Total knee arthroplasty using the kinematic rotating hinge prosthesis. Orthopaedics (Thorofare. , NJ). 12:647-654, 1989.

A52. Shin, D. S., Weber, K. L., Chao, E. Y., An, K. N., and Sim, F. H.: Reoperation for failed prosthetic replacement used for limb salvage. Clin. Orthop.53-63, 1999.

A53. Takahashi, Y. and Gustilo, R. B.: Nonconstrained implants in revision total knee arthroplasty. Clinical Orthopaedics & Related Research.156-162, 1994.

A54. van Loon, C. J., Wijers, M. M., Waal Malefijt, M. C., Buma, P. and Veth, R. P.: Femoral bone grafting in primary and revision total knee arthroplasty. Acta Orthop. Belg. 65:357-363, 1999.

A55. Waal Malefijt, M. C., van Kampen, A., and Slooff, T. J.: Bone grafting in cemented knee replacement. 45 primary and secondary cases followed for 2-5 years. Acta Orthop. Scand. 66:325-328, 1995.

A56. Whiteside, L. A. and Bicalho, P. S.: Radiologic and histologic analysis of morselized allograft in revision total knee replacement. Clinical Orthopaedics & Related Research.149-156, 1998.

A57. Wilde, A. H. and Ruth, J. T.: Two-stage reimplantation in infected total knee arthroplasty. Clinical Orthopaedics & Related Research.23-35, 1988.

A58. Wilde, A. H., Schickendantz, M. S., Stulberg, B. N., and Go, R. T.: The incorporation of tibial allografts in total knee arthroplasty. Journal of Bone & Joint Surgery - American Volume. 72:815-824, 1990.

References

1. Elders MJ. The increasing impact of arthritis on public health. J Rheumatol Suppl 2000; 60:6-8.
2. Acheson RM, Collart AB. New Haven survey of joint diseases. XVII. Relationship between some systemic characteristics and osteoarthrosis in a general population. Ann Rheum Dis 1975; 34(5):379-387.
3. Peyron JG. Osteoarthritis. The epidemiologic viewpoint. Clin Orthop 1986;(213):13-19.
4. Simon LS. Osteoarthritis: a review. Clin Cornerstone 1999; 2(2):26-37.
5. Felson DT. Epidemiology of Osteoarthritis: Prevalence and Risk Factors. 1995. American Academy of Orthopaedic Surgeons.
6. AHCPR 2001, Center for Organization and Delivery Studies, Health Care Cost and Utilization Project. Table 2: Statistics for 1996 HUP Nationwide Inpatient Sample, by Multilevel CCS Procedure.
7. National Center for Health Statistics. American Academy and American Association of Orthopaedic Surgeons Bulletin 1999; 47(3):14.
8. March LM, Cross MJ, Lapsley H, Brnabic AJ, Tribe KL, Bachmeier CJ et al. Outcomes after hip or knee replacement surgery for osteoarthritis. A prospective cohort study comparing patients' quality of life before and after surgery with age-related population norms. Med J Aust 1999; 171(5):235-238.
9. Schroder HM, Kristensen PW, Petersen MB, Nielsen PT. Patient survival after total knee arthroplasty. 5-year data in 926 patients. Acta Orthop Scand 1998; 69(1):35-38.
10. Gottlob CA, Pellissier JM, Chang RW, Wixson RL, Stern SH, Stulberg SD. Long-term cost effectiveness of total knee arthroplasty for the treatment of osteoarthritis. Presented at the American Academy of Orthopaedic Surgeons 63rd Annual Meeting, Atlanta, GA. 1996.
11. Current estimates from the National Health Interview Survey, 1988. Vital and Health Statistics Series 10[173, DHHS Pub No. (PHS) 89-1501], 89-1501. 2001. Hyattsville, MD, Public Health Service. 10-1-0089.
12. Rorabeck CH, Murray P. Cost effectiveness of revision total knee replacement. Instructional Course Lectures 1997; 46:237-240.
13. Saleh KJ, Wood KC, Gafni A, Gross AE. Immediate surgery versus waiting list policy in revision total hip arthroplasty. An economic evaluation. J Arthroplasty 1997; 12(1):1-10.
14. Iorio R, Healy WL, Richards JA. Comparison of the hospital cost of primary and revision total hip arthroplasty after cost containment. Orthopaedics 1999; 22(2):185-189.
15. Praemer A, Furner S, Rice D. Musculoskeletal conditions in the United States. 1992. American Academy of Orthopaedic Surgeons.
16. Insall JN, Dethmers DA. Revision of total knee arthroplasty. Clinical Orthopaedics & Related Research 1982;(170):123-130.
17. Mendenhall S. Get the lowdown on orthopaedic implants. Mater Manag Health Care 1996; 5(4):30-32.

18. Coyte PC, Young W, Williams JI. Devolution of hip and knee replacement surgery? Can J Surg 1996; 39(5):373-378.

19. Heck DA, Melfi CA, Mamlin LA, Katz BP, Arthur DS, Dittus RS et al. Revision rates after knee replacement in the United States. Med Care 1998; 36(5):661-669.

20. Johanson N, Michaels S, Burrows B. Results of revision knee replacement with standard, modular and constrained devices. In: Lotke T, Garino J, editors. Revision total knee arthroplasty. Philadelphia: Lippincott-Raven, 1999: 355-370.

21. Haas SB, Insall JN, Montgomery W, III, Windsor RE. Revision total knee arthroplasty with use of modular components with stems inserted without cement. Journal of Bone & Joint Surgery - American Volume 1995; 77(11):1700-1707.

22. Healy WL, Finn D. The hospital cost and the cost of the implant for total knee arthroplasty. A comparison between 1983 and 1991 for one hospital. J Bone Joint Surg Am 1994; 76(6):801-806.

23. Lavernia CJ, Drakeford MK, Tsao AK, Gittelsohn A, Krackow KA, Hungerford DS. Revision and primary hip and knee arthroplasty. A cost analysis. Clin Orthop 1995;(311):136-141.

24. Callahan CM, Drake BG, Heck DA, Dittus RS, Ritter MA, Faris PM et al. Patient outcomes following tricompartmental total knee replacement. A meta-analysis Postoperative alignment of total knee replacement. Its effect on survival. JAMA 1994; 271(17):1349-1357.

25. Cooper H, Hedges LV. The handbook of research synthesis. New York: Russell Sage Foundation, 1994.

26. LeLorier J, Gregoire G, Benhaddad A, Lapierre J, Derderian F. Discrepancies between meta-analyses and subsequent large randomized, controlled trials. N Engl J Med 1997; 337(8):536-542.

27. Callahan CM, Drake BG, Heck DA, Dittus RS. Patient outcomes following unicompartmental or bicompartmental knee arthroplasty. A meta-analysis. J Arthroplasty 1995; 10(2):141-150.

Table E-1. Fifteen studies reporting Knee Society (KS) scores

Paper	Number of Subjects	Number of Knees	Mean Age, years (range)	Average Followup (months)	Preoperative Clinical (or combined◆) KS Score	Postoperative Clinical (or combined◆) KS Score	Preoperative Functional KS Score	Postoperative Functional KS Score
Barrack et al., 1998	15	15	69.6 (NR)	NR	◆ 79	◆ 125	NR	NR
Barrack et al., 1998	51	51	71.3 (NR)	NR	◆ 97	◆ 138	NR	NR
Bradley, 2000	21	19	69 (43-89)	33	◆ 60	◆ 147	NR	NR
Elia et al., 1991	38	40	64.5 (22-91)	41	41	77.6	43	56
Hanssen et al., 1994	86	89	68 (28-85)	52	32.3	77	27.6	56
Hartford et al., 1998	16	16	NR	60	38	85	24	58
Kraay et al., 1992	7	7	74 (NR)	44	◆ 71	◆ 83	NR	NR
Lai et al., 1993	45	48	64 (45-84)	65	41	80	47	74
Murray et al., 1994	35	40	67.2 (47-92)	58.2	38	83.7	46.6	64.8
Pagnano et al., 1998	25	25	65 (NR)	37.2	45	90	42	75
Partington et al., 1999	99	107	68 (52-80)	44.4	◆ 86	◆ 131	NR	NR
Rand 1991	19	21	65 (56-71)	48	21	71	11	56
Takahashi et al., 1994	36	39	70.8 (56-91)	24	50.5	82.7	35.9	56.1
Van Loon et al., 1999	18	18	61 (38-79)	34.1	44.8	80.9	28.8	44.7
Whiteside et al., 1998	63	63	71 (57-91)	108	3.3	48.2	5	41.1
	574	598	67.7 (22-92)	53.1 (44.5-61.7)*	32.8 (25.5-40.0)*	74.9 (68.6-80.8)*	30.4 (22.8-37.9)*	57.4 (51.6-62.7)*

* weighted values (95% CI)
NR = not reported in article

Table E-2. Seventeen studies reporting Hospital for Special Surgery (HSS) scores

Paper	Number of Subjects	Number of Knees	Mean Age (range)	Average Followup (months)	Preoperative HSS	Post-operative HSS
Donaldson et al., 1988	14	14	68 (56-82)	NR	44.8	51.2
Engh et al., 1997	26	26	68.8 (31-87)	NR	54	86
Fehring et al., 1998	36	36	64 (45-84)	56	59	82
Fehring et al., 1998	27	27	62 (38-79)	44	62	88
Gustilo et al., 1996	51	56	68 (50-84)	99.6	54.7	79.3
Haas et al., 1995	76	78	54 (28-73)	42	49	76
Hanssen et al., 1988	53	53	NR	37	58	82
Insall et al., 1982	72	72	62 (22-88)	NR	49	83
Jackson et al., 1994	23	24	74 (38-90)	46	52	70
Kim, 1987	14	14	NR	50.4	58	81
Knight et al., 1997	12	12	65 (26-85)	27	56	86
Lai et al., 1993	45	48	NR	64.8	57	82
Mow et al., 1994	16	17	65 (56-71)	72	52	87
Peters et al., 1997	55	57	69	62	47	82
Rand, 1991	19	21	NR	48	41	73
Rand et al., 1998	51	54	62.3 (36-74)	57.6	52	81
Rosenberg et al., 1991	42	43	65	NR	36	74
	632	652	65.2 (22-90)	55.2 (47.4-63.0)*	51.5 (48.9-54.1)*	79.8 (76.4-83.1)*

* weighted values (95% CI)
NR = not reported in article

Table E-3. Studies reporting pre- and postoperative GKS and stratifying subjects categorically as excellent / good / satisfactory / poor

Paper	Adjusted Numberof subjects	Adjusted Number of Knees	Postoperative Number Excellent/Good	Postoperative Number Satisfactory/Poor	Postoperative Excellent/Good Proportion
Cameron et al., 1981	62	62	22	38	0.367
Chotivichit et al., 1991	18	18	14	4	0.778
Donaldson et al., 1988	14	14	7	2	0.778
Dorr et al., 1986	14	14	7	0	1
Elia et al., 1991	38	40	30	10	0.75
Engh et al., 1997	26	26	22	4	0.846
Fehring et al., 1998	20	20	14	6	0.7
Fehring et al., 1998	27	27	18	3	0.857
Goldman et al., 1996	60	64	46	18	0.719
Gustilo et al., 1996	51	56	50	6	0.893
Hartford et al., 1998	16	16	13	1	0.929
Hirakawa et al., 1998	54	55	31	10	0.756
Insall et al., 1982	72	72	64	8	0.889
Jacobs et al., 1989	9	9	5	4	0.556
Karpinski et al., 1987	51	52	12	40	0.231
Knight et al, 1997	10	10	9	1	0.9
Lachiewicz et al., 1996	21	21	20	1	0.952
Lai et al., 1993	45	48	39	9	0.813
Nicholls et al., 1990	12	13	5	8	0.385
Otte et al., 1997	28	29	20	9	0.69
Padgett et al., 1991	17	19	16	3	0.842
Pagnano et al., 1998	25	25	0	2	0
Pagnano et al., 1995	32	32	16	1	0.941
Peters et al., 1997	55	57	45	12	0.789
Rand et al., 1987	20	20	16	5	0.762
Rooser et al., 1987	55	69	29	11	0.725
Rosenberg et al., 1991	35	36	25	10	0.714
Wilde et al., 1988	13	13	7	4	0.636
Wilde et al., 1990	10	12	9	3	0.75
	910	949	611	233	77.7 (75.2-80.2)*

* weighted value (95% CI)

Table E-4. Complications

Description of Complication	Number of Studies Reporting Complication	Number of Knees in Reporting Studies	Number of Complications (%)
Prosthesis fracture, tibial	1	23	5 (21.7)
Failed patellar component	5	171	19 (11.1)
Deep vein thrombosis	5	154	16 (10.4)
Arterial injury	3	39	4 (10.3)
Wound, retained foreign body	7	321	30 (9.3)
Other complications	34	1182	97 (8.2)
Bone graft, nonunion	2	26	2 (7.7)
Unstable total knee	7	254	19 (7.5)
Unexplained pain	7	271	20 (7.4)
Fracture proximal tibia	1	14	1 (7.1)
Wound infection, deep	25	1258	84 (6.7)
Wound infection, superficial	12	504	24 (4.8)
Urinary tract infection	7	286	13 (4.5)
Wound hematoma	8	324	14 (4.3)
Gastrointestinal bleed	2	79	3 (3.8)
Cardiac arrhythmia	1	28	1 (3.6)
Implant loosening, F+T	3	140	5 (3.6)
Dislocation, patella	2	142	5 (3.5)
Septicemia	3	118	4 (3.4)
Wound dehiscence	3	145	5 (3.4)
Dislocation	5	213	7 (3.3)
Fracture, femur, undisplaced	5	192	6 (3.1)
Pulmonary embolus	4	161	5 (3.1)
Implant loosening, tibia	8	338	10 (3.0)
Patellar tendon rupture	10	400	12 (3.0)
Fracture, femur, displaced	4	210	6 (2.9)
Bone graft, resorption	1	40	1 (2.5)
Fracture, patella	7	417	10 (2.4)
Stroke	1	43	1 (2.3)
Implant loosening, femur	5	225	5 (2.2)
Pneumonia	2	92	2 (2.2)
Implant loosening, patella	1	48	1 (2.1)
Peroneal nerve injury	3	140	3 (2.1)
Ligament rupture	2	117	2 (1.7)
Modular component dissociation	1	78	1 (1.3)
			443 (26.3)

F = Femoral component
T = Tibial component

Figure E-1. Mean increase In Knee Society scores (postoperative less preopertive Scores) as a function of postoperative followup (months)

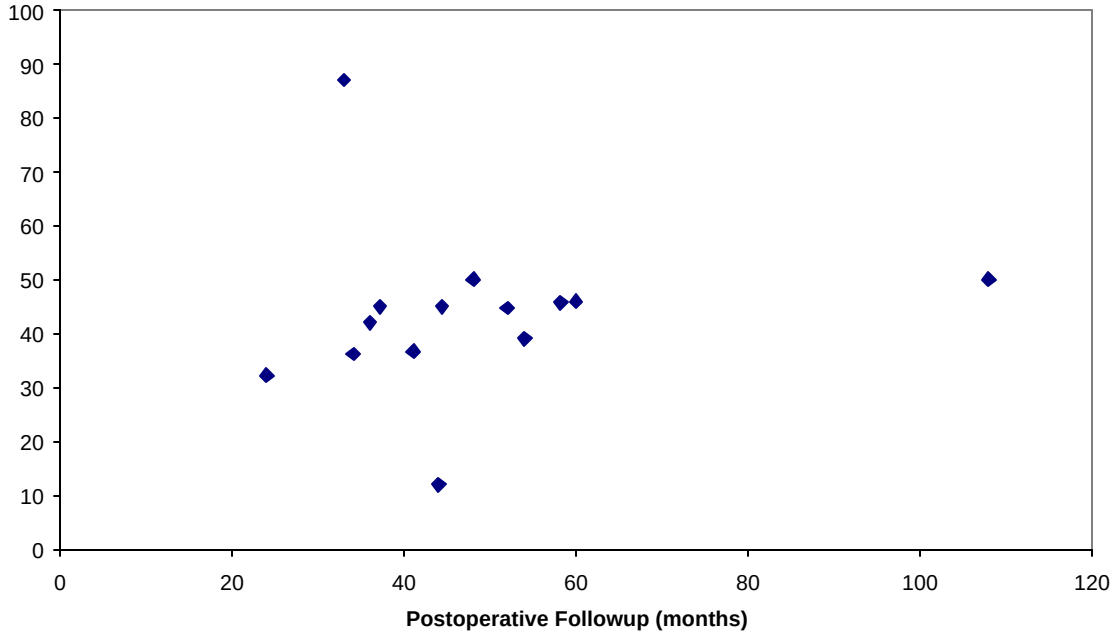

Figure E-2. Mean increase In Hospital Special Surgery scores (postoperative less preopertive scores) as a function of postoperative followup (months)

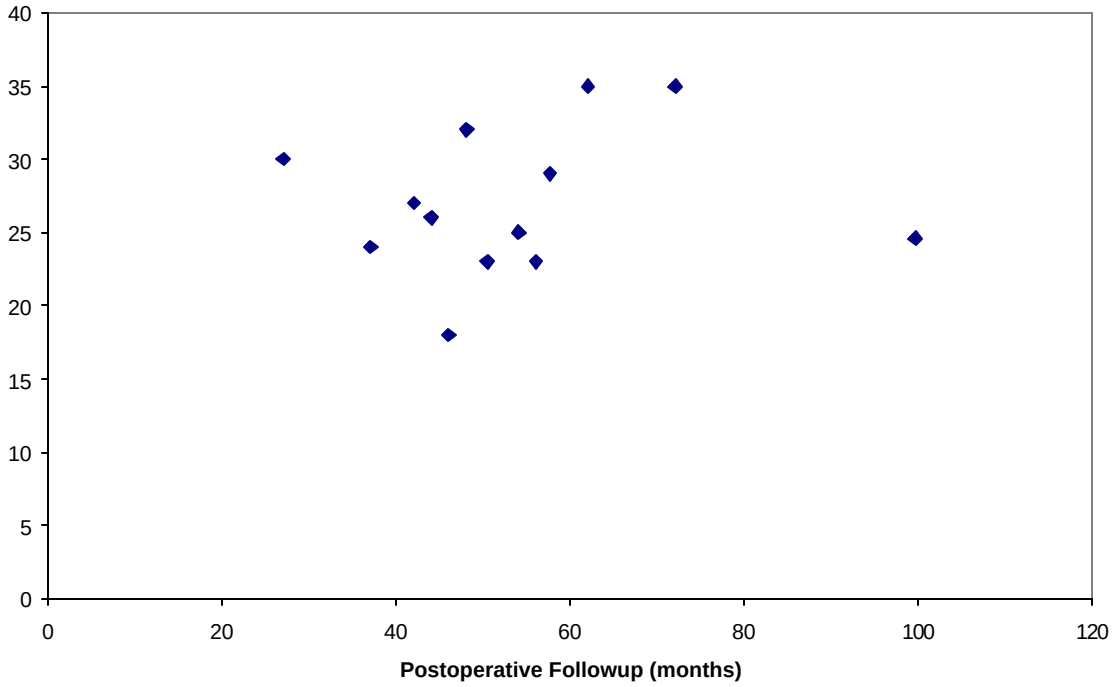
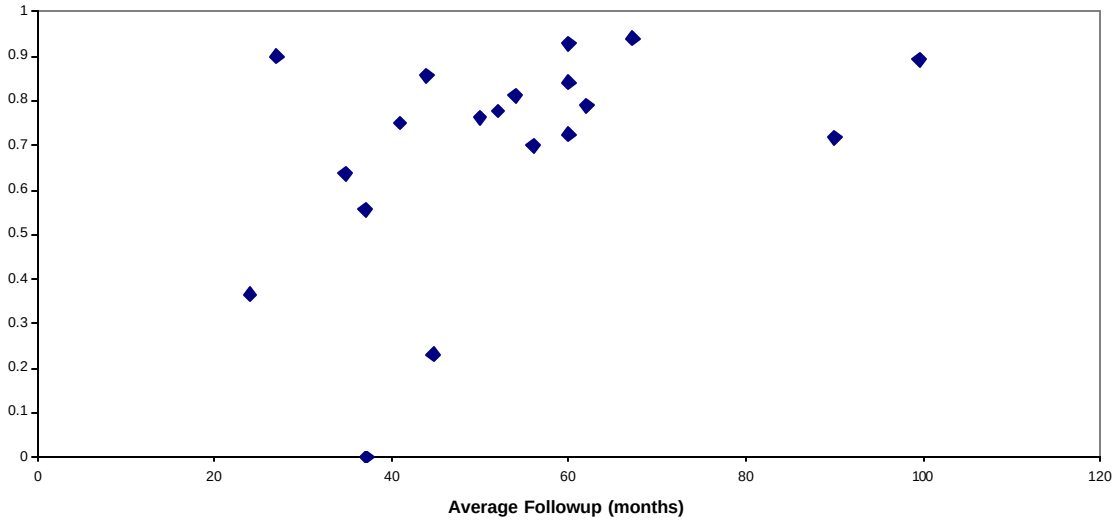
Figure E-3. Proportion of subjects rated as excellent or good as a function of postoperative followup (months)