

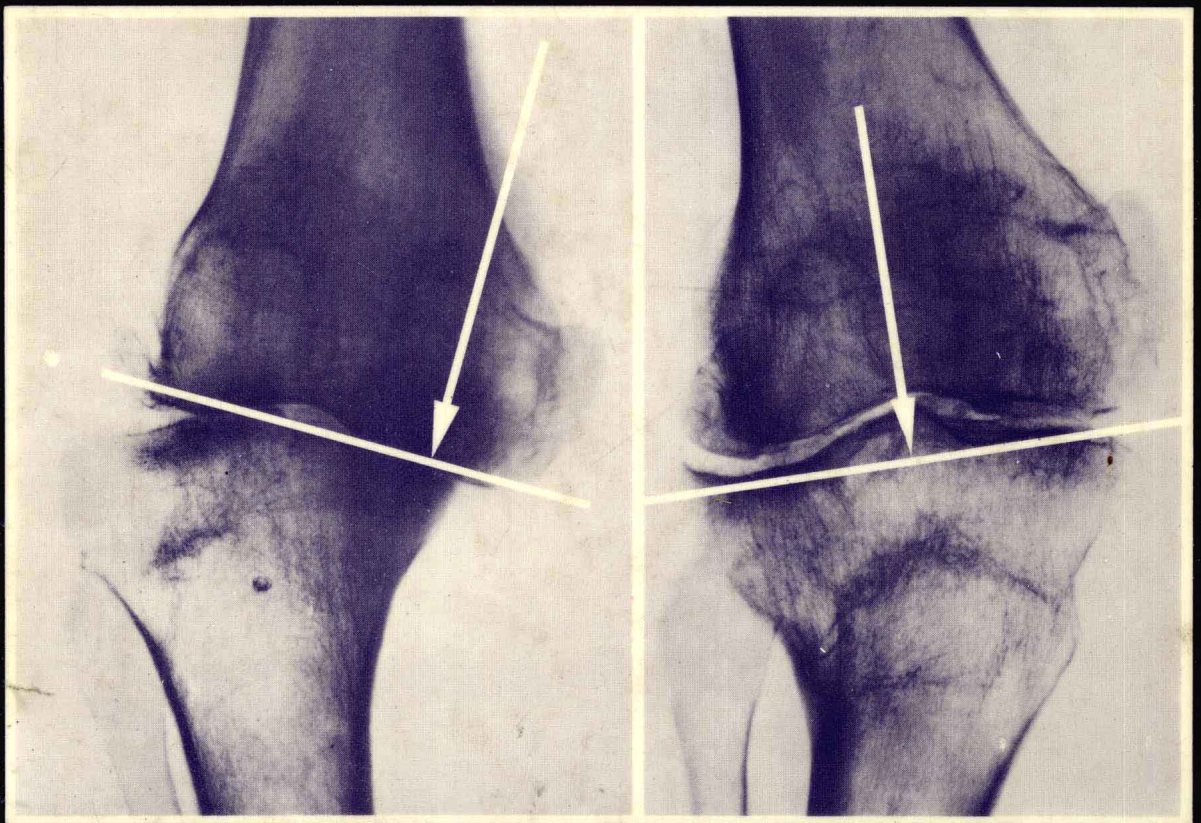
Paul G. J. Maquet

---

# Biomechanics of the Knee

With Application to the Pathogenesis  
and the Surgical Treatment of Osteoarthritis

Second Edition, Revised and Expanded



Springer-Verlag Berlin Heidelberg New York Tokyo

Paul G.J. Maquet

# Biomechanics of the Knee

*With Application to the Pathogenesis  
and the Surgical Treatment of Osteoarthritis*

2nd Edition, Expanded and Revised

With 243 Figures

Springer-Verlag  
Berlin Heidelberg NewYork Tokyo 1984

Docteur PAUL G.J. MAQUET  
25, Thier Bosset, B-4070 Aywaille

ISBN 3-540-12489-6 Springer-Verlag Berlin Heidelberg New York Tokyo  
ISBN 0-387-12489-6 Springer-Verlag New York Heidelberg Berlin Tokyo

ISBN 3-540-07882-7 1st edition Springer-Verlag Berlin Heidelberg New York  
ISBN 0-387-07882-7 1st edition Springer-Verlag New York Heidelberg Berlin

Library of Congress Cataloging in Publication Data

Maquet, Paul G.J., 1928 –  
Biomechanics of the knee.

Translation of: Biomécanique du genou.

Bibliography: p.

Includes index.

1. Knee. 2. Knee-Surgery. 3. Osteoarthritis-Surgery. 4. Human mechanics. I. Title.  
RD561.M3613 1983 617'.582 83-14833

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically those of translation, reprinting, re-use of illustrations, broadcasting, reproduction by photocopying machine or similar means, and storage in data banks. Under § 54 of the German Copyright Law where copies are made for other than private use a fee is payable to "Verwertungsgesellschaft Wort", Munich.

© by Springer-Verlag Berlin Heidelberg 1984  
Printed in Germany.

The use of registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Product Liability: The publisher can give no guarantee for information about drug dosage and application thereof contained in this book. In every individual case the respective user must check its accuracy by consulting other pharmaceutical literature.

Typesetting, printing, and bookbinding: Universitätsdruckerei H. Stürtz AG, Würzburg.  
2124/3130-543210

Cen'est autre chose pratique  
Sinon l'effect de Theorique.

Siience sans experience  
N'apporte pas grande assurance.

*AMBROISE PARÉ, DE LAVAL CON-  
SEILLER ET PREMIER CHIRVRGIEN  
du Roy.*

*CANONS ET REIGLES  
Chirurgiques de l'Auteur.*

“Les Oeuvres d'Ambroise Paré, conseiller, et premier chirurgien du Roy, corrigées et augmentées par lui-même, peu avant son décès. A Paris, chez Barthelemy Macé, au mont St-Hilaire, à l'Ecu de Bretagne. 1607”.

# Foreword

Pathological conditions affecting the hip and knee joints occupy a particular place amongst the important orthopaedic entities affecting the extremities. On the one hand they are relatively frequent and on the other they mean for the patient limitation of his ability to walk, because of their considerable detrimental effects.

A purposeful basic treatment of these joint diseases (and here osteoarthritis takes pride of place) is only possible if it stems from a reliable biomechanical analysis of the normal and pathological stressing of the joint in question. Whilst the situation in the hip can be considered to be fundamentally clarified, a comprehensive representation of the knee is still lacking, particularly when taking into account the latest knowledge of biomechanics. Recently our concepts of the kinematics of the knee have been completely changed, but the clinically important question of articular stressing remains unanswered.

Dr. Maquet has carried out pioneer work in this field for some years in adapting, by analogy, to the knee joint principles already accepted for the hip joint. Since the knee is not a ball and socket joint, a complicated problem arises for which new thoughts are necessary. The results of the numerous operations carried out by Dr. Maquet according to the biomechanical considerations demonstrate that his thinking is fundamentally correct. Above all, it is here again proven (as earlier in the case of the hip) that healing of osteoarthritis depends decisively on reducing and evenly distributing joint pressure.

In the present book Dr. Maquet proceeds from the earlier static analyses for his evaluation of the kinetic stressing, by taking advantage mainly of the very accurate research of O. Fischer about human gait. The result is a survey of the stressing of the knee joint and until now nothing comparable has existed. Moreover, it is shown in an impressive way how judicious surgical procedures based on biomechanics can cause healing even in severe osteoarthritis of the knee. This happens, above all, without implanting endoprostheses which are certainly still more questionable for the knee than they already are for the hip.

May this book be widely disseminated and may much further discussion of this burning problem be stimulated!

Aachen, Summer 1976

F. PAUWELS

# Preface to the First Edition

Pauwels in 1950, relying on an experience of over 15 years, showed that the clinical and radiological signs of osteoarthritis of the hip could be made to disappear by a proper surgical approach which permitted astonishing regeneration of the diseased joint. His interventions were based on a profound knowledge of hip mechanics and biomechanics in general. The aim of these procedures was to diminish as much as possible the articular pressure to render this pressure supportable by the diseased tissues. These procedures decreased the pressure by reducing the load supported by the hip and increasing the weight-bearing surface of the joint.

The laws of biomechanics enunciated by Pauwels (1950, 1951, 1958, 1959, 1960, 1964, 1965a, b, 1968, 1973a, b) and applied by him to the hip, elbow, and shoulder have general application. It seemed logical, therefore, in osteoarthritis of the knee to apply these rules which had permitted Pauwels to obtain spectacular results in patients suffering from osteoarthritis of the hip. This required a knowledge of the mechanics of the normal knee and of the arthritic knee which we have not been able to find in the literature. Certain movements of the knee have already been studied. However, the influence of the mechanical factors on osteoarthritis of the knee has never been clearly explained. Orthopaedic surgeons have empirically corrected varus deformities of the knee by a valgus osteotomy and valgus ones by a varus osteotomy in either the lower part of the femur or upper part of the tibia. They have obtained inconsistent results. From their experience they have concluded that one has to achieve overcorrection of the femoro-tibial angle in the coronal plane in varus deformities and reasonably precise correction for valgus deformities. These recommendations, deduced from empirical experience, are barely sufficient for one who wishes to base treatment on a sound theoretical foundation and obtain consistently good results. The essential aim of our labours is to furnish this theoretical foundation, rationally justifying the choice of one form of intervention over another, thereby improving the treatment of osteoarthritis of the knee.

Aywaille, Summer 1976

PAUL G.J. MAQUET

# Preface to the Second Edition

Since publication of the first edition further research has improved our knowledge of the mechanics of the knee, helping us especially to define more precisely the appropriate approaches to the different types of osteoarthritis. In this edition more emphasis has been put on surgical treatment. Tibial osteotomy remains the method of choice for treating medial osteoarthritis with a varus knee, whereas femoral osteotomy appears the best way of dealing with lateral osteoarthritis with a valgus deformity. Planning and surgical procedures are described more completely. The postoperative results are not only illustrated, but also more thoroughly analysed. These results support our views on biomechanics and osteoarthritis of the knee.

Aywaille, Summer 1983

Paul G.J. Maquet

# Acknowledgments

Professor F. Pauwels taught me the basic principles of biomechanics and spent innumerable hours discussing my clinical cases and shaping my way of thinking in orthopaedics. I am also deeply indebted to the many other individuals who made this work possible and first of all to my wife, Josette, for her patient understanding and for her many hours of work in preparing this manuscript.

My good friend, Dr. P. de Marchin, initially germinated the idea of this research. I would never have carried it out without the constant advice and encouragement of Professor J. Lecomte. Professor B. Kummer was most helpful in freely discussing and constructively criticizing the work.

Professor A. Pirard and his assistants, Mrs. G. Pelzer and Mr. F. de Lamotte, not only provided a solution to the difficult mathematical problems but also allowed me to use their laboratory with the help of their technician, Mr. C. Nihard, for the photoelastic studies. Professor E. Betz has kindly furnished me most of the anatomical specimens I needed. Mr. J. Simonet built the apparatus to measure the loads exerted on the specimens. Dr. A. Van de Berg X-rayed them in his private office. Dr. M. Vercauteren supplied the gait movie. After Dr. N. Matsumoto and Dr. T. Yamaguchi had each spent more than a year with me, they carried out arthroscopies of the knee before and after surgery, with Y. Fujisawa, K. Masuhara, N. Mii, H. Fuyihara and S. Shomi. They kindly granted me permission to reproduce some of their pictures in this book. Dr. F. Burny and Mrs. M. Donkerwolcke, using the computer terminal of the Hôpital Erasme at the Université Libre de Bruxelles and their knowledge of statistical analysis, enabled me to write the chapter dealing with the results. Associate Professor E.L. Radin helped me edit the first edition. Mr. R. Furlong F.R.C.S. offered his time, his patience and his accurate knowledge of the English language to prepare the final version of the text for both first and second editions.



Permission to reproduce

Figures 13, 14, 18, 20, 21, 22, 23, 24, 26, 67, 75, 76, 81, 106, 139 (Maquet, Simonet, and de Marchin, 1967) has been granted by courtesy of the *Revue de Chirurgie Orthopédique et réparatrice de l'Appareil Moteur*;

Figures 11, 15, 65, 74, 82, 107, 109, 116, 236, 242 (Maquet, 1969) by the *Société Internationale de chirurgie Orthopédique et Traumatologique*;

Figures 16, 17, 29, 30, 143, 152, 183a and 184b (Maquet, 1972) and 51, 66, 113, 114, 117 (Maquet, Pelzer, and de Lamotte, 1975) by the *Acta Orthopaedica Belgica*;

Figures 59, 62, 63 (Maquet, Van de Berg, and Simonet, 1975) by the *Journal of Bone and Joint Surgery*;

Figure 54 (Maquet, 1976) by the *Clinical Orthopaedics and Related Research*;

Figures 245, 246 by Fujisawa et al. and by *Igaku Shoin Ltd*;

Figures 155, 156 by Shiomi et al. and by the *Japanese Arthroscopy Association*.

---

## **Arthritis of the Knee**

### **Clinical Features and Surgical Management**

Editor: **M. A. R. Freeman**

With contributions by numerous experts

1980. 206 figures, 50 tables. XIII, 282 pages. ISBN 3-540-09699-X

**M. K. Dalinka**

## **Arthrography**

1980. 324 figures, 4 tables. XIV, 209 pages

(Comprehensive Manuals in Radiology). ISBN 3-540-90466-2

**H. R. Henche**

## **Arthroscopy of the Knee Joint**

With a Foreword by E. Morscher.

Translated from the German by P. A. Casey.

1980. 163 figures, most in colour, diagrams by F. Freuler, 1 table.  
XII, 85 pages. ISBN 3-540-09314-1

## **Late Reconstructions of Injured Ligaments of the Knee**

Editors: **K.-P. Schulitz, H. Krahl, W. H. Stein**

With contributions by M. E. Blazina, D. H. Donoghue, S. L. James,  
J. C. Kennedy, A. Trillat

1978. 42 figures, 21 tables. V, 120 pages. ISBN 3-540-08720-6

**W. Müller**

## **The Knee**

### **Form, Function, and Ligament Reconstruction**

Translated from the German by T. C. Telger

Preface by J. C. Hughston. Illustrations by R. Muspach

1983. 299 figures in 462 partially coloured separate illustrations.  
XVIII, 314 pages. ISBN 3-540-11716-4

Distribution rights for Japan: Igaku Shoin Ltd., Tokyo

**C. J. P. Thijn**

## **Arthrography of the Knee Joint**

Foreword by J. R. Blickman

1979. 173 figures in 209 separate illustrations, 11 tables.

IX, 155 pages. ISBN 3-540-09129-7

**M. Watanabe, S. Takeda, H. Ikeuchi**

## **Atlas of Arthroscopy**

3rd edition. 1979. 226 figures, 11 tables. X, 156 pages

ISBN 3-540-07674-3

Distributions rights for Japan: Igaku Shoin Ltd., Tokyo



Springer-Verlag  
Berlin  
Heidelberg  
New York  
Tokyo

**P. Beighton, R. Grahame, H. Bird**

### **Hypermobility of Joints**

Foreword by E. Bywaters  
1983. 101 figures. XIII, 178 pages. ISBN 3-540-12113-7

**R. Bombelli**

### **Osteoarthritis of the Hip**

Classification and Pathogenesis  
The Role of Osteotomy as a Consequent Therapy  
With a Foreword by M. E. Müller  
2nd revised and enlarged edition. 1983.  
374 figures (partly in colour). XVII, 386 pages  
ISBN 3-540-11422-X

**C. F. Brunner, B. G. Weber**

### **Special Techniques in Internal Fixation**

Translated from the German by T. C. Telger  
1982. 91 figures. X, 198 pages. ISBN 3-540-11056-9

### **Current Concepts of External Fixation of Fractures**

Editor: **H. K. Uthoff**  
Associate Editor: **E. Stahl**  
1982. 227 figures. X, 442 pages. ISBN 3-540-11314-2

### **Current Concepts of Internal Fixation of Fractures**

Editor: **H. K. Uthoff**  
Associate Editor: **E. Stahl**  
1980. 287 figures, 51 tables. IX, 452 pages  
ISBN 3-540-09846-1

**E. Letournel, R. Judet**

### **Fractures of the Acetabulum**

Translated and edited from the French by R. A. Elson  
1981. 289 figures in 980 separate illustrations.  
XXI, 428 pages. ISBN 3-540-09875-5

**R. Louis**

### **Surgery of the Spine**

Surgical Anatomy and Operative Approaches  
Translated from the French by E. Goldstein  
Foreword by L. L. Wiltse  
Original Illustrations by R. Louis with the Technical  
Assistance of W. Ghafar  
1983. 140 figures in 655 separate illustrations.  
XVII, 328 pages. ISBN 3-540-11412-2

**A. Sarmiento, L. L. Latta**

### **Closed Functional Treatment of Fractures**

1981. 545 figures, 85 tables. XII, 608 pages  
ISBN 3-540-10384-8

## **Progress in Orthopaedic Surgery**

Editorial Board: **N. Gschwend, D. Hohmann,  
J. L. Hughes, D. S. Hungerford, G. D. MacEwen, E. Mor-  
scher, J. Schatzker, H. Wagner, U. H. Weil**

Volume 1

### **Leg Length Discrepancy - The Injured Knee**

Editor: **D. S. Hungerford**  
With contributions by numerous experts  
1977. 100 figures. X, 160 pages  
ISBN 3-540-08037-6

Volume 2

### **Acetabular Dysplasia - Skeletal Dysplasia in Childhood**

Editor: **U. H. Weil**  
With contributions by numerous experts  
1978. 133 figures, 20 tables. IX, 200 pages  
ISBN 3-540-08400-2

Volume 3

### **The Knee: Ligament and Articular Cartilage Injuries**

Guesteditor: **D. E. Hastings**  
With contributions by numerous experts  
1978. 139 figures, 20 tables. X, 191 pages  
ISBN 3-540-08679-X

Volume 4

### **Joint Preserving Procedures of the Lower Extremity**

Editor: **U. H. Weil**  
With contributions by numerous experts  
1980. 87 figures, 9 tables. VIII, 121 pages  
ISBN 3-540-09856-9

Volume 5

### **Segmental Idiopathic Necrosis of the Femoral Head**

Editor: **U. H. Weil**  
With contributions by numerous experts  
1981. 68 figures, 30 tables. VII, 121 pages  
ISBN 3-540-10718-5

**Springer-Verlag**  
Berlin  
Heidelberg  
New York  
Tokyo



# Contents

<i>Chapter I. Aims and Limitations of the Work</i> . . . . .	1
<i>Chapter II. Review of the Literature</i> . . . . .	3
<i>Chapter III. Methods</i> . . . . .	9
I. Mathematical Analysis . . . . .	9
II. Experiments on Anatomical Specimens . . . . .	9
III. Photoelastic Models . . . . .	10
A. Theoretical Basis . . . . .	11
B. Historical . . . . .	11
C. Application and Limitation of the Photoelastic Technique . . . . .	12
IV. Clinical and Radiological Material . . . . .	12
<i>Chapter IV. Mechanics of the Knee</i> . . . . .	15
I. Load and Mechanical Stresses . . . . .	15
A. Concept of Load and Stresses. Rigid Models . . . . .	15
B. Articulated Models . . . . .	18
1. Forces . . . . .	18
2. Contact Stresses . . . . .	20
II. Mechanical Stress in the Knee . . . . .	22
A. Forces Exerted on the Knee . . . . .	22
1. Force Exerted on the Knee During Symmetrical Stance on Both Legs . . . . .	22
2. Forces Exerted on the Knee in Standing on One Leg . . . . .	24
a) Coronal Plane . . . . .	24
b) Sagittal Plane . . . . .	26
3. Forces Exerted on the Knee During Gait . . . . .	28
a) Displacement of the Centre of Gravity $S_7$ . . . . .	29
b) Forces of Inertia Due to the Accelerations of $S_7$ . . . . .	33
c) Force P Exerted on the Knee by the Partial Mass $S_7$ of the Body . . . . .	36
d) Position in Space of Point G Which Lies Centrally on the Axis of Flexion of the Knee . . . . .	37
e) Position of the Knee in Relation to the Partial Centre of Gravity $S_7$ . . . . .	43
f) Distance a Between the Line of Action of Force P and Point G . . . . .	46

g) Muscular and Ligamentous Forces Balancing Force $P$ . . . . .	48
$\alpha$ ) Formularization . . . . .	48
$\beta$ ) Calculation . . . . .	51
$\gamma$ ) Critical Analysis of the Chosen Solution . . . . .	52
h) Curves Illustrating the Forces Transmitted Across the Femoro-Tibial Joint . . . . .	56
i) Patello-Femoral Compressive Force . . . . .	58
B. Weight-Bearing Surfaces of the Joint . . . . .	62
1. Femoro-Tibial Joint . . . . .	62
a) Technique . . . . .	62
b) Results . . . . .	65
2. Patello-Femoral Joint . . . . .	70
C. Contact Articular Stresses . . . . .	71
1. Femoro-Tibial Joint . . . . .	71
2. Patello-Femoral Joint . . . . .	73
III. Conclusion . . . . .	73
<i>Chapter V. The Pathomechanics of Osteoarthritis of the Knee</i> . . . . .	75
I. Theoretical Analysis of the Causes of Knee Osteoarthritis . . . . .	75
A. Medial Displacement of Force $R$ . . . . .	76
B. Lateral Displacement of Force $R$ . . . . .	81
C. Unstable Knees . . . . .	86
D. Evolution of the Maximum Stress in Relation to Several Parameters . . . . .	88
1. Varus or Valgus Deformity . . . . .	89
a) Magnitude and Line of Action of $R$ . . . . .	89
b) Articular Compressive Stresses . . . . .	91
2. Strengthening or Weakening of the Muscular Force $L$ . . . . .	94
3. Cumulative Effect of a Change of the Force $L$ and a Deformity of the Leg . . . . .	96
4. Modification of Force $P$ . . . . .	100
5. Horizontal Displacement of $S_7$ in the Coronal Plane . . . . .	102
6. Conclusion . . . . .	103
E. Posterior Displacement of Force $R$ . . . . .	104
F. Anterior Displacement of Force $R$ . . . . .	106
G. Increase of the Patello-Femoral Compressive Force . . . . .	107
H. Lateral Displacement of the Patello-Femoral Compressive Force . . . . .	108
II. Radiographic Examination of the Osteoarthritic Knee with Demonstration of the Effect of Changes in the Compressive Force on the Stress Distribution . . . . .	110
A. Demonstration of Joint Stresses . . . . .	110
1. A.-P. View . . . . .	110
2. Lateral View . . . . .	113
3. Tangential View . . . . .	116
B. Utility of X-Rays in the Standing Position . . . . .	117
C. Arthrography . . . . .	118
D. Computerized Axial Tomography . . . . .	119

III. The Use of Photoelastic Models to Illustrate How the Position of Compressive Femoro-Tibial and Patello-Femoral Forces Affects the Distribution of Articular Stresses . . .	121
A. Femoro-Tibial Joint . . . . .	121
1. Normal Load, Centred . . . . .	122
2. Normal Load, Off Centre . . . . .	123
3. Inclined Load, Centred . . . . .	126
4. Inclined Load, Off Centre . . . . .	127
B. Patello-Femoral Joint . . . . .	128
1. Directional Distribution of the Stresses . . . . .	128
2. Quantitative Distribution of the Stresses . . . . .	130
IV. Osteoarthritis of the Knee of Mechanical Origin . . . . .	131

<i>Chapter VI. Instinctive Mechanisms Which Reduce Stress in the Knee</i> . . . . .	133
I. Effects of Limping . . . . .	133
II. Use of a Walking Stick . . . . .	136
III. Comment and Conclusion . . . . .	137

<i>Chapter VII. Biomechanical Treatment of Osteoarthritis of the Knee</i> . . . . .	139
I. Rationale of Biomechanical Treatment . . . . .	140
II. Biomechanical Treatment of Osteoarthritis of the Knee . .	141
A. Correction of Flexion Contracture . . . . .	142
1. Rationale . . . . .	142
2. Operative Procedure . . . . .	143
a) Capsulotomy Alone . . . . .	143
b) Capsulotomy Associated with Other Procedures	143
3. Results . . . . .	143
B. Anterior Displacement of the Tibial Tuberosity . . .	144
1. Rationale . . . . .	144
2. Operative Procedures . . . . .	146
a) Anterior Displacement of the Tibial Tuberosity by Elevating the Tibial Crest . . . . .	146
b) Anterior and Medial Displacement of the Tibial Tuberosity . . . . .	151
c) Anterior Displacement of the Tibial Tuberosity Combined with Upper Tibial Osteotomy . . . . .	154
d) Anterior Displacement of the Tibial Tuberosity Combined with Osteotomy of the Lower End of the Femur . . . . .	154
3. Anterior Displacement of the Tibial Tuberosity After Patellectomy . . . . .	155
4. Changes at Arthroscopy . . . . .	156
C. Recentring the Load . . . . .	158
1. Osteoarthritis of the Knee with a Varus Deformity	158
a) Necessity of Overcorrecting the Varus Deformity	158
b) Accurate Estimation of Overcorrection . . . . .	159
c) Choice of Procedure: Tibial or Femoral Osteotomy? . . . . .	162

d) Previous Operative Procedures . . . . .	164
e) The Barrel-Vault-Osteotomy for Varus Deformity	165
$\alpha$ ) Planning . . . . .	165
$\beta$ ) Instruments . . . . .	168
$\gamma$ ) Surgical Procedure . . . . .	169
$\delta$ ) Postoperative Care . . . . .	171
$\epsilon$ ) Comments and Examples . . . . .	171
f) Cases Requiring a Derotation of the Leg . . . . .	193
g) Revisions . . . . .	197
$\alpha$ ) Revision After Undercorrection . . . . .	197
$\beta$ ) Revision After Exaggerated Overcorrection	202
h) The Exceptions. Femoral Osteotomy for a Varus	
Deformity of the Knee . . . . .	209
$\alpha$ ) Planning . . . . .	209
$\beta$ ) Surgical Procedure . . . . .	210
$\gamma$ ) Postoperative Care . . . . .	211
$\delta$ ) Second Example . . . . .	212
2. Osteoarthritis of the Knee with Varus and Flexion	
Deformity . . . . .	214
3. Osteoarthritis with a Valgus Deformity . . . . .	218
a) Necessity of Overcorrection . . . . .	218
b) Choice of Procedure: Femoral or Tibial Osteo-	
tomy? . . . . .	218
c) Previous Techniques . . . . .	226
d) Distal Femoral Osteotomy with Fixation by Four	
Steinmann Pins and Two Compression Clamps	227
$\alpha$ ) Planning . . . . .	227
$\beta$ ) Surgical Procedure . . . . .	230
$\gamma$ ) Postoperative Care . . . . .	231
$\delta$ ) Comments and Examples . . . . .	231
e) Distal Femoral Osteotomy Combined with Ante-	
rior Displacement of the Tibial Tuberosity . . . . .	237
f) Revisions . . . . .	240
$\alpha$ ) Revision After Exaggerated Overcorrection	240
$\beta$ ) Revision After Miscorrection . . . . .	242
4. Bilateral Osteoarthritis with a Valgus Deformity	
on One Side and a Varus Deformity on the Other	
Side . . . . .	244
5. Osteoarthritis with Genu Recurvatum . . . . .	246
6. Osteoarthritis of the Knee Due to a Distant Deformity	248
7. Rheumatoid Arthritis . . . . .	254
8. Osteoarthritis of the Knee in Haemophiliacs . . . . .	256
9. Osteonecrosis of the Medial Condyle of the Femur	258
10. Widespread Osteoarthritis without Deformity . . . . .	260
11. Histological Confirmation of the Regenerative Process	260
D. Critical Analysis of Patellectomy and Other Procedures	
on the Patella . . . . .	262
1. Standard Patellectomy . . . . .	262
2. Coronal Patellectomy . . . . .	264
3. Sagittal Osteotomy of the Patella . . . . .	266
E. Operative Indications . . . . .	266

<i>Chapter VIII. Results</i> . . . . .	267
A. Femoro-Tibial Osteoarthritis . . . . .	269
1. Osteoarthritis with a Varus Deformity . . . . .	271
a) Valgus Tibial Osteotomy . . . . .	271
b) Valgus Femoral Osteotomy . . . . .	273
2. Osteoarthritis with a Valgus Deformity . . . . .	274
3. Correction of a Deformity at a Distance from the Af- fected Knee . . . . .	276
4. Complications and Unsatisfactory Results . . . . .	278
5. Conclusions . . . . .	279
B. Patello-Femoral Osteoarthritis . . . . .	279
1. Division of the Lateral Retinaculum . . . . .	279
2. Anterior Displacement of the Tibial Tuberosity . . . . .	280
3. Complications of the Anterior Displacement of the Tibial Tuberosity . . . . .	282
4. Conclusions . . . . .	283
 <i>Chapter IX. Conclusions</i> . . . . .	 285
 <i>Appendix. Remarks About the Accuracy of the Calculation of             Forces and Stresses in the Knee Joint</i> . . . . .	  291
A. Introduction . . . . .	291
1. The Weights . . . . .	291
2. Formularization . . . . .	292
3. The Laws . . . . .	292
4. Direct Personal Measurements . . . . .	292
B. Analysis of the Influence of the Variation of Time Be- tween Two Successive Phases . . . . .	293
C. Influence of a Systematic Error of 10% in All the Mea- surements of Braune and Fischer . . . . .	293
D. Theory of Cumulated Errors, a Variation of 0.2 mm Be- ing Assumed for All the Measurements . . . . .	294
E. Influence of a Variation of the Weight-Bearing Surfaces . . . . .	296
F. Influence of an Error in Estimating $r$ . . . . .	297
G. Direct Measurements . . . . .	298
H. Conclusion . . . . .	298
 References . . . . .	 299
 Subject Index . . . . .	 305



# Chapter I. Aims and Limitations of the Work

Biomechanics encompasses a study of:

1. the mechanical stresses to which living tissues are subjected under physiological and pathological conditions;

2. the biological response of the tissues to these mechanical stresses and to their modifications;

3. the possibility of surgically changing the stresses in the living tissues to achieve a therapeutic effect.

This monograph will apply the discipline of biomechanics to the knee.

The forces supported by the normal knee will be analysed successively in standing symmetrically on both feet, in standing on one foot and during gait. These forces are transmitted from the femur to the tibia across joint surfaces the size of which will be measured. They provoke compressive stresses in the joint which will be defined.

There normally exists a physiological balance between the mechanical stress and the resistance of the articular tissues. This equilibrium can be disturbed by several factors: either the resistance of the articular tissues can be lowered by metabolic causes with the mechanical stress remaining normal or the mechanical stress can become abnormally great due to a mechanical disturbance while the integrity of the tissue remains normal. Disturbance of the physiological equilibrium produces reactions in the tissues, leading to osteoarthritis (Müller, 1929; Pauwels, 1973).

If the origin of the imbalance is metabolic and diminishes the tissue resistance, osteoarthritis will initially affect the whole knee. If it is mechanical, the osteoarthritis can primarily affect the medial or lateral part of the femoro-tibial joint. Degeneration can also be localized to the patello-femoral joint.

The causes of mechanically induced degeneration of the knee must be understood. We shall study what can modify the forces exerted on the knee and the mechanical consequences of these changes. The biological phenomena which lower the resistance of the tissues to mechanical stress will not be considered as this is more in the province of metabolic pathology.

After having determined the forces acting on the normal and abnormal knee, as well as the articular joint stresses in both the physiological and pathological states, we shall discuss how to influence the latter by surgery in order to achieve a therapeutic effect. We shall propose several operative procedures which reduce the mechanical stress in the knee. Original techniques will be described. The results of this surgery will be presented to illustrate and substantiate the theoretical analysis and biomechanical principles which are the basis of the treatment.

Methods which replace the whole or parts of the joint by metallic or plastic implants have certain indications but do not use the potential for regeneration possessed by living tissue. By strict definition they are not a biomechanical treatment and will not be considered in this presentation.