



2nd ed. 2012, XXX, 1593 p. 1457 illus., 800 in color.

 **Printed book****Hardcover**

- ▶ 239,00 € | £215.50 | \$329.00
- ▶ \*255,73 € (D) | 262,90 € (A) | CHF 318.50

 **eBook**

**For individual purchases buy at a lower price on [springer.com](http://springer.com). A free preview is available. Also available from libraries offering Springer's eBook Collection.**

- ▶ [springer.com/ebooks](http://springer.com/ebooks)

 **MyCopy**

**Printed eBook exclusively available to patrons whose library offers Springer's eBook Collection.\*\*\***

- ▶ € | \$ 24.95
- ▶ [springer.com/mycopy](http://springer.com/mycopy)

L. Solomin, R.R. Vreden Russian Research Institute of Traumatology and Orthopaedics, St Petersburg, Russia (Ed.)

### **The Basic Principles of External Skeletal Fixation Using the Ilizarov and Other Devices**

- ▶ Provides detailed guidance on use of the Ilizarov and other external fixation devices
- ▶ Covers a wide range of fractures and pathologic settings
- ▶ Numerous high-quality illustrations and case reports
- ▶ New edition with contributions from leading world experts

When it was developed, the Ilizarov device represented a revolutionary advance that made it possible to correct previously untreatable conditions through the stimulation of bone growth based on the principle of distraction osteogenesis. The device subsequently gained popularity among surgeons throughout the world since it can be used for the treatment of fractures that have failed to heal satisfactorily and for deformity correction. The technique is, however, complex and requires specialist knowledge if it is to be applied optimally. This is the second edition of a well-received book that focuses primarily on external fixation using the Ilizarov device but also considers other devices employed for the purpose. The opening chapters include discussion of biomechanical principles, use of a system of coordinates to allow safer insertion of K-wires and half pins, preoperative preparation, and principles of frame construction. External fixation of a variety of fractures in different pathologic settings is then clearly explained in a series of detailed chapters with the aid of high-quality illustrations. Numerous case reports are included to illustrate the results of different treatment methods. In addition, principles of postoperative management are described and advice is provided on correction of errors and treatment of complications. Since the first edition the text has been thoroughly updated, with inclusion of contributions from leading world experts. This volume will serve as an indispensable manual both for trainee orthopedic surgeons embarking on a steep learning curve and for more experienced surgeons requiring advice and guidance in demanding cases.



Order online at [springer.com](http://springer.com) ▶ or for the Americas call (toll free) 1-800-SPRINGER ▶ or email us at: [orders-ny@springer.com](mailto:orders-ny@springer.com). ▶ For outside the Americas call +49 (0) 6221-345-4301 ▶ or email us at: [orders-hd-individuals@springer.com](mailto:orders-hd-individuals@springer.com).

The first € price and the £ and \$ price are net prices, subject to local VAT. Prices indicated with \* include VAT for books; the €(D) includes 7% for Germany, the €(A) includes 10% for Austria. Prices indicated with \*\* include VAT for electronic products; 19% for Germany, 20% for Austria. All prices exclusive of carriage charges. Prices and other details are subject to change without notice. All errors and omissions excepted.

\*\*\* Regional restrictions apply.

---

# Contents

After the title of each chapter, all Authors, who have contributed to that chapter, are listed. The specific authorship of the individual paragraphs is given after each section title.

## Part I General Aspects of External Fixation

<b>1 General and Special Aspects of External Fixation</b> . . . . .	3
Leonid Nikolaevich Solomin and Stuart Alan Green	
1.1 Historical Background and Classification. . . . .	3
1.2 Advantages and Disadvantages, Indications and Contraindications . . . . .	9
1.3 Equipment . . . . .	10
1.4 General Terms of External Fixation Constructs . . . . .	18
<b>2 Biomechanical Principles</b> . . . . .	23
Leonid Nikolaevich Solomin	
2.1 Relationship Between the Transosseous Elements and the Surrounding Tissues . . . . .	23
2.2 Control of Bone Fragment Position . . . . .	25
2.2.1 Moving the External Supports with the Transosseous Modules Fixing the Bone Fragments . . . . .	25
2.2.2 Moving the Transosseous Elements Relative to the External Supports; External Supports and Modules Remain Immobile . . . . .	25
2.3 Control of Bone Fragment Rigidity . . . . .	40
2.3.1 Number of Transosseous Elements . . . . .	41
2.3.2 Diameter and Type of Transosseous Elements . . . . .	41
2.3.3 Wire Tension . . . . .	41
2.3.4 Levels of Transosseous Element Insertion . . . . .	41
2.3.5 Plane of Orientation of the Transosseous Elements . . . . .	41
2.3.6 Distance from the Bone to the External Support . . . . .	43
2.3.7 External Support Geometry. . . . .	43
2.3.8 Number of Connecting Rods. . . . .	45
<b>3 Internal Contradictions of External Fixation. Combined External Fixation.</b> . . . . .	47
Leonid Nikolaevich Solomin	
3.1 Introduction . . . . .	47
3.2 Method of the Unified Designation of External Fixation (MUDEF) . . . . .	49
3.3 Reference Positions. . . . .	49
3.4 Use of Different Types of Transosseous Elements and External Support	49
3.5 Module Transformation. . . . .	49
3.6 Minimum Number of External Supports and Transosseous Elements . . . . .	49
3.7 Computer Navigation . . . . .	50
3.8 Converting to Internal Fixation. . . . .	50

<b>4 Method of Unified Designation of External Fixation (MUDEF)</b> . . . . .	53
Leonid Nikolaevich Solomin	
4.1 Introduction . . . . .	53
4.2 Symbols Used . . . . .	54
4.3 Coordinates . . . . .	54
4.3.1 Levels . . . . .	54
4.3.2 Positions . . . . .	54
4.4 Designation of Transosseous Elements . . . . .	54
4.4.1 Designation of K-wires . . . . .	54
4.4.2 Designation of Half-Pins . . . . .	58
4.5 Designation of the External Support Frame . . . . .	58
4.6 Designation of the Entire Device . . . . .	60
4.7 Additional Data . . . . .	61
<b>5 Atlas for the Insertion of Transosseous Element Reference Positions</b> . . . . .	63
Leonid Nikolaevich Solomin, Roman Nikolaevich Inyushin, Pavel Nikolaevich Kulesh, Maxim Vasil'evich Andrianov, Dmitry Alexandrovich Mykalo, Nikolay Fedorovich Fomin, Sergey Valerjevich Majkov, and Konstantin Andreevich Ukhanov	
5.1 Upper Arm (L.N. Solomin, R.N. Inyushin) . . . . .	65
5.2 Ulna (L.N. Solomin, P.N. Kulesh) . . . . .	74
5.2.1 Ulna, Mid-Position . . . . .	75
5.2.2 Ulna, Supination . . . . .	83
5.2.3 Ulna, Pronation . . . . .	91
5.3 Radius (L.N. Solomin, P.N. Kulesh) . . . . .	99
5.3.1 Radius, Mid-Position . . . . .	100
5.3.2 Radius, Supination . . . . .	108
5.3.3 Radius, Pronation . . . . .	116
5.4 Femur (L.N. Solomin, M.V. Andrianov) . . . . .	124
5.5 Tibia (L.N. Solomin, D.A. Mykalo) . . . . .	133
5.6 Foot (L.N. Solomin, N.F. Fomin, S.V. Majkov, K.A. Ukhanov) . . . . .	142
5.6.1 Cross-Sectional Cuts . . . . .	143
5.6.2 Oblique Cuts . . . . .	157
5.7 Pelvis (L.N. Solomin) . . . . .	160
<b>6 Preoperative Preparation</b> . . . . .	167
Leonid Nikolaevich Solomin	
6.1 Introduction . . . . .	167
6.2 X-Ray Examination . . . . .	168
6.2.1 Fractures . . . . .	168
6.2.2 Deformities . . . . .	168
6.2.3 Imaging of the Lower Limbs . . . . .	169
6.2.4 X-Ray Examination of the Upper Limbs . . . . .	174
<b>7 Principles of Frame Construction</b> . . . . .	181
Leonid Nikolaevich Solomin	
7.1 Identification of the Objectives . . . . .	181
7.2 Identification of the Optimal Levels for the Insertion of Transosseous Elements . . . . .	181
7.3 Identification of the Optimal Transosseous Elements on the Basis of Safe Positions and Reference Positions . . . . .	186
7.4 Identification of the Optimal Levels for Positioning the External Supports . . . . .	191

7.5	Identification of the Type and Size of the External Supports Corresponding to the Selected Transosseous Elements and Their Insertion Levels While Allowing for Module Transformation . . . . .	192
7.6	Marking the Selected Levels and Positions on the Segment for Transosseous Element Insertion and External Support Placement . . .	195
7.7	Transosseous Element Insertion, External Support Installation, and Frame Assembly . . . . .	195
7.8	Ilizarov Method of Corticotomy . . . . .	215
<b>8</b>	<b>Features of Reparative Osteogenesis and the Management of Distraction Osteogenesis in External Fixation . . . . .</b>	<b>219</b>
	Sergey Aleksandrovich Erofeev and Elena Andreevna Shchepkina	
8.1	Introduction (S.A. Erofeev) . . . . .	219
8.2	Distraction Osteogenesis (S.A. Erofeev) . . . . .	220
8.3	Features of Osteogenesis in External Fixation Depending on Various Mechanical and Biological Factors (S.A. Erofeev) . . . . .	223
8.3.1	Mechanical Factors (Stability of Bone Fragment Fixation) . . .	223
8.3.2	Biological Factors (Maintenance of Blood Supply, Bone Marrow and Periosteum) . . . . .	223
8.4	Osteogenesis Management (S.A. Erofeev) . . . . .	231
8.4.1	Optimal Regimens and Distraction Types . . . . .	231
8.4.2	Reparative Regeneration of the Bone After Rupture of the Distraction Regenerate . . . . .	234
8.5	Distraction Osteogenesis Stimulation (S.A. Erofeev) . . . . .	234
8.5.1	Dynamic (Compression) Loadings on the Osteogenesis Area . . . . .	234
8.5.2	Use of the Bone Marrow and Growth Factors . . . . .	238
8.5.3	Stimulation of Distraction Osteogenesis Using Intramedullary Curved Wires . . . . .	239
8.6	Special Features of Distraction Osteogenesis in Lengthening Over a Nail (S.A. Erofeev) . . . . .	241
8.7	Osteogenesis Stimulation by Different Types of Grafts (S.A. Erofeev) . .	242
8.8	Use of the Bone Marrow Cells, Morphogenetic Proteins, and Growth Factors (E.A. Shchepkina) . . . . .	245
<b>9</b>	<b>External Fixation at the Vreden Russian Research Institute of Traumatology and Orthopedics . . . . .</b>	<b>257</b>
	Leonid Nikolaevich Solomin	
9.1	Introduction . . . . .	257
9.2	The Early Experience in External Fixation (1961–1968) . . . . .	257
9.3	Consolidation of External Fixation (1968–2001) . . . . .	262
9.4	Present Stage . . . . .	281
<b>Part II Specific Aspects of External Fixation</b>		
<b>10</b>	<b>Fractures of the Humerus . . . . .</b>	<b>303</b>
	Leonid Nikolaevich Solomin	
10.1	Proximal Humerus (11-) . . . . .	306
10.2	Diaphyseal Fractures (12-) . . . . .	313
10.2.1	Proximal Third . . . . .	313
10.2.2	Middle Third . . . . .	314
10.2.3	Distal Third . . . . .	314
10.2.4	Radial Nerve Injury . . . . .	325
10.3	Distal Humerus (13-) . . . . .	332

<b>11 Fractures of the Forearm</b> .....	339
Leonid Nikolaevich Solomin and Pavel Nikolaevich Kulesh	
11.1 Proximal Forearm (21-) (L.N. Solomin) .....	343
11.2 Diaphyseal Fractures (22-) (L.N. Solomin, P.N. Kulesh) .....	346
11.2.1 Ulnar Diaphysis .....	346
11.2.2 Radial Diaphysis .....	351
11.2.3 Diaphysis of the Radius and Ulna .....	359
11.3 Distal Forearm (23-) (L.N. Solomin, P.N. Kulesh) .....	369
<b>12 Fractures of the Femur</b> .....	375
Leonid Nikolaevich Solomin and Viktor Alexandrovich Vilensky	
12.1 Proximal Femur (31-) (L.N. Solomin) .....	378
12.2 Diaphyseal Fractures (32-) (L.N. Solomin) .....	385
12.2.1 Proximal Third .....	385
12.2.2 Middle Third .....	386
12.2.3 Distal Third .....	390
12.3 Distal Femur (33-) (L.N. Solomin) .....	405
12.4 Patella (91.1-) (L.N. Solomin) .....	417
12.5 External Fixation for the Treatment of Periprosthetic Fractures of the Femur (L.N. Solomin, V.A. Vilensky) .....	418
12.5.1 ECD Design .....	422
12.5.2 ECD Placement Technique .....	422
12.5.3 Other Indications .....	428
<b>13 Fractures of the Tibia and Fibula</b> .....	433
Leonid Nikolaevich Solomin and Tracy J. Watson	
13.1 Proximal Tibia and Fibula (41-) (L.N. Solomin, T.J. Watson) .....	437
13.1.1 Surgical Technique for Limited Internal Fixation with Spanning External Fixation of Tibial Plateau Fractures .....	442
13.1.2 Arthroscopy and Fracture Management .....	457
13.2 Diaphyseal Fractures (42-) (L.N. Solomin) .....	459
13.2.1 Proximal Third .....	459
13.2.2 Middle Third .....	459
13.2.3 Distal Third .....	474
13.3 Distal Tibia and Fibula (43-) (L.N. Solomin) .....	484
13.4 Ankle Injuries (44-) (L.N. Solomin) .....	494
13.5 Chronic Ankle Injuries (L.N. Solomin) .....	502
<b>14 Open Fractures</b> .....	507
Alexander A. Lerner and Leonid Nikolaevich Solomin	
14.1 Fixation Methods in the Treatment of Open Limb Fractures .....	507
14.2 Debridement and Primary Bone Fixation Using Unilateral External Fixation Frames .....	508
14.3 Final Bone Reconstruction Using Circular and Hybrid External Fixation Frames .....	517
14.3.1 Conversion from Primary Unilateral External Fixation Devices with Half-Pin Preservation .....	519
14.3.2 Hybrid External Fixation Devices .....	520
14.4 The Ilizarov Device as a Basic Frame .....	520
14.4.1 Special Features of the Ilizarov Circular Device in the Treatment of Open Peri-articular Fractures .....	525
14.5 Universal Reduction Units .....	530

<b>15</b>	<b>Malunited Fractures</b> . . . . .	535
	Leonid Nikolaevich Solomin	
<b>16</b>	<b>Basic Principles of External Fixation in the Correction of Long-Bone Deformities</b> . . . . .	541
	Leonid Nikolaevich Solomin, Konstantin Igorevich Novikov, Anna Majorovna Aranovich, Mark Eidelman, and Pavel Nikolaevich Kulesh	
16.1	Terminology and Classification (L.N. Solomin) . . . . .	541
16.2	Planning the Correction of a Deformity (L.N. Solomin) . . . . .	544
16.3	The General Principles of Deformity Correction (L.N. Solomin) . . . . .	547
16.3.1	Correction of Axial Translation: Shortening or Lengthening . . . . .	547
16.3.2	Peripheral Translation Correction . . . . .	547
16.3.3	Correction of Angular Deformities . . . . .	548
16.3.4	Torsion Deformity Correction . . . . .	558
16.4	Order of Deformity Components Correction (L.N. Solomin) . . . . .	561
16.5	Basic Principles of Long-Bone Deformity Correction in the Lower Limbs (L.N. Solomin) . . . . .	562
16.5.1	Referent Lines of the Lower Limbs and Their Mutual Relations . . . . .	562
16.5.2	Length Discrepancies of the Lower Limbs . . . . .	568
16.5.3	Peripheral Translation . . . . .	572
16.5.4	Angular Deformities . . . . .	573
16.5.5	Torsion Deformities . . . . .	575
16.5.6	Examples of Deformity Correction Planning in the Femur: The Basic Frames Assemblies . . . . .	576
16.5.7	Examples of Deformity Correction Planning for the Lower Legs: The Basic Frame Assemblies . . . . .	593
16.6	Technical Tips and Tricks for the Correction of Deformities of the Humerus and Forearm . . . . .	615
16.6.1	Referent Lines of the Upper Limbs and Their Mutual Relations (L.N. Solomin, P.N. Kulesh) . . . . .	615
16.6.2	Upper-Limb Length Discrepancies . . . . .	617
16.6.3	Peripheral Translation . . . . .	619
16.6.4	Angular Deformities . . . . .	619
16.6.5	Torsion Deformities . . . . .	619
16.6.6	Examples of Deformity Correction Planning in the Humerus: The Basic Frames Assemblies . . . . .	619
16.6.7	Examples of Deformity Correction Planning in the Forearm Bones (L.N. Solomin, P.N. Kulesh) . . . . .	632
16.7	Special Features of Deformity Correction in Achondroplasia (K.I. Novikov, A.M. Aranovich) . . . . .	641
16.7.1	Introduction . . . . .	641
16.7.2	Special Features of Long Bone Formation in the Lower Limb . . . . .	642
16.7.3	Special Features of Humerus Formation . . . . .	648
16.7.4	Special Features in the Formation of the Forearm Bones . . . . .	651
16.7.5	General Principles of Operative Treatment . . . . .	651
16.7.6	Special Features of Lengthening and Deformity Correction of the Lower Limbs . . . . .	656
16.7.7	Lengthening and Correction of Upper Limb Deformities . . . . .	661
16.7.8	Postoperative Care . . . . .	663
16.7.9	Complications . . . . .	664

16.8	Principles of Limb Lengthening and Deformity Correction in Children and Adolescents (M. Eidelman) . . . . .	666
16.8.1	Prediction of Leg Length Discrepancy . . . . .	668
16.8.2	Basic Principles of Treatment of Leg Length Discrepancy . . .	670
16.8.3	Limb Lengthening . . . . .	670
16.8.4	Osteosynthesis by Circular External Fixation . . . . .	675
16.8.5	Supramalleolar Osteotomy . . . . .	679
16.8.6	Correction of Deformities in Children by Partial Epiphysiodesis (Hemiepiphysiodesis) . . . . .	682
16.8.7	Principles of Deformity Correction of the Upper Extremities .	684
<b>17</b>	<b>Deformity Correction and Fracture Treatment Using the Software-Based Ortho-SUV Frame . . . . .</b>	<b>705</b>
	Leonid Nikolaevich Solomin, Alexander Igorevich Utekhin, and Viktor Alexandrovich Vilensky	
17.1	Introduction . . . . .	705
17.2	Design of the Ortho-SUV Frame . . . . .	709
17.2.1	Strut Design of an Ortho-SUV Frame . . . . .	709
17.2.2	External Supports . . . . .	709
17.3	Ortho-SUV Frame Assembly . . . . .	719
17.3.1	Assembling the Universal Reduction Unit . . . . .	719
17.4	Modes of Ortho-SUV Frame Operation . . . . .	725
17.4.1	Fast Struts Mode . . . . .	725
17.4.2	Deformity Correction Mode . . . . .	725
17.5	Software for the Ortho-SUV Frame . . . . .	732
17.5.1	Parameters Measured on the Frame . . . . .	732
17.5.2	Parameters Measured on X-Ray . . . . .	732
17.5.3	Working with the Program . . . . .	732
17.6	Application of the Ortho-SUV Frame: Clinical Cases . . . . .	775
17.6.1	Fracture Treatment . . . . .	775
17.6.2	Diaphyseal Deformities . . . . .	775
17.6.3	Metaphyseal Deformities . . . . .	787
17.6.4	Deformity Correction of the Foot . . . . .	793
17.6.5	Knee Joint Stiffness . . . . .	793
17.7	Tips and Tricks for Using the Ortho-SUV Frame . . . . .	794
<b>18</b>	<b>Basics of Aesthetic Correction of the Lower Extremities . . . . .</b>	<b>805</b>
	Leonid Nikolaevich Solomin, Oleg Anatoljevich Kaplunov, Pavel Nikolaevich Kulesh, and Alexander Aleksandrovich Artemev	
18.1	Introduction (L.N. Solomin, O.A. Kaplunov, P.N. Kulesh) . . . . .	805
18.2	Correction of the Shape of the Legs (L.N. Solomin, O.A. Kaplunov, P.N. Kulesh) . . . . .	809
18.2.1	Special Features of the Examination . . . . .	809
18.2.2	X-Ray Examination Features . . . . .	809
18.2.3	Preoperative Planning . . . . .	810
18.2.4	Preoperative Planning Software: “Leg Shape Correction” (O.A. Kaplunov) . . . . .	813
18.2.5	Correction of Leg Shape Using Circular Fixators (L.N. Solomin, O.A. Kaplunov, P.N. Kulesh) . . . . .	816
18.2.6	Correction of Leg Shape Using Semicircular Fixators (L.N. Solomin, P.N. Kulesh) . . . . .	818

18.2.7	Postoperative Period (L.N. Solomin, O.A. Kaplunov, P.N. Kulesh) . . . . .	819
18.2.8	Volume and Contour of the Lower Legs (L.N. Solomin, O.A. Kaplunov) . . . . .	827
18.3	Growth and Length of the Lower Extremities Under Aesthetic Indications (A.A. Artemjev, O.A. Kaplunov, L.N. Solomin) . .	830
18.4	Complications (L.N. Solomin) . . . . .	840
<b>19</b>	<b>Non-unions, Pseudoarthroses, and Long-Bone Defects</b> . . . . .	<b>841</b>
	Leonid Nikolaevich Solomin, Dmitry Jur'evich Borzunov, Redento Mora, Vladimir Ivanovich Shevtsov, and Luisella Pedrotti	
19.1	Introduction (L.N. Solomin, D.J. Borzunov, R. Mora) . . . . .	841
19.2	Non-unions . . . . .	842
19.3	Parafocal Osteotomy (L. Pedrotti) . . . . .	853
19.4	Long-Bone Defects (L.N. Solomin, D.J. Borzunov, R. Mora) . . . . .	854
19.4.1	Polylocal Osteosynthesis . . . . .	861
19.4.2	Tibiofibular Synostosis . . . . .	872
19.5	Treatment of Congenital Tibial Pseudoarthrosis Using the Ilizarov Method of Transosseous Osteosynthesis (V.I. Shevtsov) . . .	879
19.5.1	Introduction . . . . .	879
19.5.2	Etiology of Congenital Pseudoarthrosis . . . . .	880
19.5.3	Signs and Symptoms of Tibial Congenital Pseudoarthroses . . .	880
19.5.4	Morphology and Biochemistry . . . . .	881
19.5.5	Treatment of Congenital Pseudoarthrosis . . . . .	881
19.5.6	Complications . . . . .	888
19.5.7	Results of Treatment . . . . .	892
<b>20</b>	<b>Combined Strained Fixation of the Long Bones</b> . . . . .	<b>895</b>
	Leonid Nikolaevich Solomin	
20.1	Equipment for CSF and Principles of Its Application . . . . .	896
20.2	Humerus . . . . .	899
20.3	Femur . . . . .	902
20.4	Forearm . . . . .	905
20.4.1	Ulna . . . . .	906
20.4.2	Radius . . . . .	907
20.4.3	CSF of Both Forearm Bones: Combined Fixation . . . . .	909
20.5	Clavicle . . . . .	920
20.5.1	External Fixation of the Clavicle . . . . .	923
20.6	Postoperative Protocol . . . . .	929
<b>21</b>	<b>Pelvic Injuries</b> . . . . .	<b>933</b>
	Aleksey Vladimirovich Runkov and Leonid Nikolaevich Solomin	
21.1	Equipment . . . . .	934
21.2	Principles of External Device Assembly for the Fixation of Pelvic Injuries . . . . .	935
21.2.1	Surgical Technique . . . . .	935
21.2.2	Osteosynthesis in Stable and Partially Stable Pelvic Injuries (61-A, 61-B) . . . . .	936
21.2.3	Osteosynthesis in Vertically Unstable Pelvic Injuries (61-C) . .	936
21.2.4	External Fixation of Acetabular Fractures . . . . .	943
21.3	External Fixation of Malunited Pelvic Fractures and Pelvic Deformations . . . . .	960
21.4	Postoperative Recommendations . . . . .	967



<b>22</b>	<b>Foot and Hand</b> . . . . .	969
	Alexander Kirienko, Leonid Nikolaevich Solomin, Natalya Grigorjevna Shikhaleva, Vladimir Ivanovich Shevtsov, Mikhail Jur'evich Danilkin, and Konstantin Andreevich Ukhanov	
22.1	Reference Lines and Angles of the Foot (L.N. Solomin, K.A. Ukhanov) . . . . .	969
22.2	Foot Injuries (L.N. Solomin) . . . . .	978
22.2.1	Forefoot Injuries . . . . .	978
22.2.2	Midfoot Injuries . . . . .	979
22.2.3	Hindfoot Injuries . . . . .	981
22.3	Closed Correction of Foot Deformities (L.N. Solomin) . . . . .	984
22.4	Foot Osteotomies (A. Kirienko) . . . . .	988
22.4.1	Introduction . . . . .	988
22.4.2	Osteotomy of the Heel . . . . .	988
22.4.3	Astragalocalcaneal Osteotomies . . . . .	989
22.4.4	Osteotomies of the Middle Part of the Foot . . . . .	995
22.4.5	Osteotomy of the Anterior Part of the Foot . . . . .	1000
22.5	Fusion of the Joints of the Foot (A. Kirienko, L.N. Solomin) . . . . .	1010
22.5.1	Fusion of the Ankle Joint . . . . .	1010
22.5.2	Subtalar Joint Fusion . . . . .	1011
22.5.3	Fusion of Ankle and Subtalar Joints . . . . .	1013
22.5.4	Triple Joint Fusion . . . . .	1013
22.5.5	Panarthrodesis of the Foot . . . . .	1017
22.5.6	Fusion of the Lisfranc Joint . . . . .	1018
22.6	Basics of External Fixation in Hand Surgery (N.G. Shikhaleva, V.I. Shevtsov, M.J. Danilkin) . . . . .	1023
22.6.1	Introduction . . . . .	1023
22.6.2	Indications and Contraindications for Transosseous Osteosynthesis of the Hand . . . . .	1023
22.6.3	Equipment . . . . .	1023
22.6.4	Osteosynthesis of Fractures of the Hand Bones with the Mini-fixator . . . . .	1024
22.6.5	Deformity Correction of the Bones of the Hand Using External Fixation . . . . .	1027
22.6.6	Transosseous Osteosynthesis in the treatment of Post-traumatic Stumps of the Hand . . . . .	1035
22.6.7	Congenital Anomalies of the Hand . . . . .	1035
22.6.8	Syndactyly . . . . .	1036
22.6.9	Contractures of the Joints of the Hand . . . . .	1039
22.6.10	Complications . . . . .	1046
22.6.11	Result of Treatment . . . . .	1046
<b>23</b>	<b>Large-Joint Pathology</b> . . . . .	1047
	Leonid Nikolaevich Solomin, Elena Aleksandrovna Volokitina, Jury Petrovich Soldatov, and William Dean Terrell	
23.1	Shoulder (L.N. Solomin) . . . . .	1047
23.2	Elbow (L.N. Solomin, J.P. Soldatov) . . . . .	1051
23.3	Wrist (L.N. Solomin) . . . . .	1059
23.4	External Fixation of the Hip Joint . . . . .	1062
23.4.1	Support Osteotomies Using the Ilizarov Technique (E.A. Volokitina, L.N. Solomin) . . . . .	1062
23.4.2	Femur Lowering Before Hip Replacement (E.A. Volokitina, L.N. Solomin) . . . . .	1081

23.4.3	Deformity Correction of the Proximal Femur Before Total Hip Replacement (E.A. Volokitina) . . . . .	1092
23.4.4	Arthrodiastasis (W.D. Terrell) . . . . .	1107
23.4.5	Hip-Joint Fusion (L.N. Solomin) . . . . .	1119
23.5	Knee (L.N. Solomin) . . . . .	1121
23.6	Ankle (L.N. Solomin) . . . . .	1150
<b>24</b>	<b>Infectious Complications of Long-Bone Fractures</b> . . . . .	<b>1157</b>
	Maurizio A. Catagni and Leonid Nikolaevich Solomin	
24.1	General Data (L.N. Solomin) . . . . .	1157
24.2	General Strategy of Pseudoarthrosis Treatment (M.A. Catagni) . . . . .	1159
24.2.1	Non-unions Without Bone Loss . . . . .	1160
24.2.2	Non-union with Bone Loss . . . . .	1170
24.3	Infected Non-union . . . . .	1196
24.4	Skin Problems in Infected Non-unions . . . . .	1219
24.5	Massive Segmental Tibial Bone Loss . . . . .	1239
24.6	Frame Removal . . . . .	1247
<b>25</b>	<b>Features of External Fixation in Children, the Elderly, and the Senile</b> . . . . .	<b>1249</b>
	Jury Evgen'evich Garkavenko, Elena Andreevna Shchepkina, and Leonid Nikolaevich Solomin	
25.1	Indications and Features of External Fixation in Children . . . . .	1249
25.1.1	External Fixation in Children with Acquired Limb Deformities . . . . .	1258
25.2	Features of External Fixation in the Elderly and the Senile (E.A. Shchepkina, L.N. Solomin) . . . . .	1279
<b>26</b>	<b>Combined and Consecutive Use of External and Internal Fixation</b> . . . . .	<b>1309</b>
	Mehmet Kocaoğlu, Leonid Nikolaevich Solomin, Erkal F. Bilen, Alexandr Nikolaevich Chelnokov, John E. Herzenberg, and Florian Maria Kovar	
26.1	Lengthening Over a Nail (LON) (M. Kocaoğlu, L.N. Solomin, E.F. Bilen) . . . . .	1309
26.1.1	Introduction . . . . .	1309
26.1.2	Indications and Contraindications . . . . .	1310
26.1.3	Special Features of the Equipment . . . . .	1310
26.1.4	Femoral LON: Surgical Technique . . . . .	1310
26.1.5	Tibial LON: Surgical Technique . . . . .	1312
26.1.6	Distraction Period . . . . .	1323
26.1.7	Removal of the External Fixator . . . . .	1323
26.1.8	Complications . . . . .	1324
26.2	Bone Transport Over Nail (BTON) (M. Kocaoğlu, E.F. Bilen, L.N. Solomin) . . . . .	1329
26.2.1	Introduction . . . . .	1329
26.2.2	Indications and Contraindications . . . . .	1330
26.2.3	Special Features of the Equipment . . . . .	1330
26.2.4	General Principles of the BTON Surgical Technique . . . . .	1330
26.2.5	Femoral BTON Surgical Technique . . . . .	1331
26.2.6	Tibial BTON Surgical Technique . . . . .	1332
26.2.7	Postoperative Care . . . . .	1340
26.2.8	Complications . . . . .	1340

26.3	Sequential External Fixation and Nailing (SEFaN) (A.N. Chelnokov, L.N. Solomin) . . . . .	1344
26.3.1	Introduction . . . . .	1344
26.3.2	Indications and Contraindications . . . . .	1344
26.3.3	Special Features of the Equipment . . . . .	1344
26.3.4	General Principles of the SEFaN Surgical Technique . . . . .	1345
26.3.5	Femoral SEFaN Surgical Technique . . . . .	1347
26.3.6	Tibial SEFaN Surgical Technique . . . . .	1347
26.3.7	Upper Arm and Forearm SEFaN Surgical Technique . . . . .	1355
26.3.8	Postoperative Period . . . . .	1362
26.3.9	Complications . . . . .	1362
26.4	External Fixation Assisted Nailing (EFAN) and External Fixation Assisted Plating (EFAP) for Deformity Correction (J.E. Herzenberg, F.M. Kovar) . . . . .	1363
26.4.1	Introduction . . . . .	1363
26.4.2	Goals of Deformity Correction . . . . .	1363
26.4.3	Special Features of the Equipment . . . . .	1365
26.4.4	Indications and Contraindications . . . . .	1365
26.4.5	External Fixator Assisted Retrograde Nailing for Acute Distal Femur Valgus Deformity Correction: Surgical Technique . . . . .	1365
26.4.6	External Fixator Assisted Plating (EFAP) for Distal Femur Valgus Deformity Correction: Surgical Technique . . . . .	1370
26.4.7	Postoperative Care. Additional Concepts . . . . .	1370
<b>27</b>	<b>Applications of External Fixation in Long Bone Tumor</b> . . . . .	<b>1379</b>
	Hiroyuki Tsuchiya and Katsuhiko Hayashi	
27.1	Introduction . . . . .	1379
27.2	Indications . . . . .	1379
27.3	Classification of Reconstruction with Distraction Osteogenesis . . . . .	1380
27.4	Type 1: Diaphyseal Reconstruction . . . . .	1383
27.5	Type 2: Metaphyseal Reconstruction . . . . .	1383
27.6	Type 3: Epiphyseal Reconstruction . . . . .	1383
27.7	Type 4: Subarticular Reconstruction . . . . .	1383
27.8	Type 5: Arthrodesis . . . . .	1384
27.9	Postoperative Care . . . . .	1384
<b>28</b>	<b>Application of Transosseous Osteosynthesis in Vertebrology</b> . . . . .	<b>1391</b>
	Alexander Nikolaevich Djachkov, Alexander Timofeevich Khudiaev, Oksana Germanovna Prudnikova, and Oleg Sergeevich Rossik	
28.1	Introduction . . . . .	1391
28.2	Equipment Properties . . . . .	1391
28.3	Special Principles in the Application of Transosseous Osteosynthesis in Vertebrology . . . . .	1392
28.4	Transosseous Osteosynthesis in the Management of Patients with “Uncomplicated” Fractures of the Thoracic and Lumbar Spine . . . . .	1393
28.5	Transosseous Osteosynthesis in the Management of Patients with Complicated Fractures of the Thoracic and Lumbar Spine . . . . .	1397
28.6	Transosseous Osteosynthesis in the Management of Patients with Neglected Lesions of the Thoracic and Lumbar Spine . . . . .	1400
28.7	Transosseous Osteosynthesis in the Management of Patients with Spondylolisthesis . . . . .	1405

28.8	Transosseous Osteosynthesis in the Management of Patients with Scoliosis . . . . .	1409
28.9	Complications . . . . .	1413
28.9.1	Complications During Surgery . . . . .	1413
28.9.2	Postoperative Complications . . . . .	1413
28.10	Efficacy of Transosseous Osteosynthesis Application in Vertebrology . . . . .	1414
<b>29</b>	<b>Correction of the Sizes and Forms of the Jaws</b> . . . . .	<b>1417</b>
	Metin Orhan	
29.1	Introduction . . . . .	1417
29.2	Indications and Contraindications . . . . .	1417
29.3	Special Features of the Equipment . . . . .	1418
29.3.1	Extraoral Distractors . . . . .	1418
29.3.2	Intraoral Distractors . . . . .	1418
29.4	General Principles of the Surgical Techniques in Maxillary and Mandibular Distraction . . . . .	1420
29.4.1	RED Surgical Procedure . . . . .	1420
29.4.2	Segmental DO Surgical Procedure . . . . .	1420
29.5	Postoperative Protocol . . . . .	1420
29.5.1	RED . . . . .	1420
29.5.2	Intraoral Distractor . . . . .	1420
29.6	Complications . . . . .	1423
<b>30</b>	<b>Application of External Fixation in Skull Surgery</b> . . . . .	<b>1425</b>
	Alexander Nikolaevich Djachkov, Alexander Timofeevich Khudiaev, and Oksana Germanovna Prudnikova	
30.1	Introduction . . . . .	1425
30.2	Theoretical Basis Underlying the Use of Transosseous Osteosynthesis in Craniotomy . . . . .	1425
30.3	Etiology and Pathogenesis of Brain Ischemia . . . . .	1428
30.4	Clinical Manifestations and the Diagnosis of Cerebral Ischemic Lesions . . . . .	1428
30.5	Transosseous Osteosynthesis for the Treatment of Patients with Cranial Vault Defects . . . . .	1429
30.6	Transosseous Osteosynthesis for the Treatment of Patients with Disturbed Cerebral Circulation . . . . .	1431
30.7	Efficacy of Transosseous Osteosynthesis in Craniotomy . . . . .	1431
30.8	Complications . . . . .	1435
<b>31</b>	<b>External Fixation in the Treatment of Chronic Limb Ischemia</b> . . . . .	<b>1437</b>
	Vladimir Dmitrievich Shatokhin	
31.1	Introduction . . . . .	1437
31.2	Indications and Contraindications . . . . .	1440
31.3	Preoperative Protocol . . . . .	1440
31.4	Stimulation of the Blood Supply and Microcirculation by Forming a Bone Splinter Followed by Its Consequent Transversal Transport . . . . .	1440
31.5	Stimulation of the Peripheral Circulation Using Wires Implanted into the Medullary Cavity of a Long Bone . . . . .	1442
31.6	Revascularizing Bone Trepanation (RBT) in the Stimulation of the Blood Supply and Microcirculation . . . . .	1443
31.7	Stimulation of the Blood Supply and Microcirculation by Creating Tunnels in the Bone Metaphysis . . . . .	1444
31.8	Stimulation of the Blood Supply and Microcirculation Using a “Scooping Out” Osteotomy . . . . .	1445

31.9	Stimulation of the Blood Circulation and Microcirculation by Fenestration and Dosed Damage of the Bone Marrow . . . . .	1446
31.10	Postoperative Care. . . . .	1446
31.11	Complications . . . . .	1446
<b>32</b>	<b>General Principles of Patient Management in the Postoperative Period . . . . .</b>	<b>1449</b>
	Leonid Nikolaevich Solomin	
32.1	Position in Bed . . . . .	1449
32.2	Anesthesia . . . . .	1449
32.3	Dressings. . . . .	1449
32.4	Exercise Therapy. . . . .	1451
32.5	Physio- and Pharmacotherapy. . . . .	1454
32.6	Biomechanical Device State . . . . .	1454
32.7	Outpatient Treatment. . . . .	1458
32.8	Device Removal . . . . .	1471
<b>33</b>	<b>Complications and Solutions. . . . .</b>	<b>1475</b>
	Leonid Nikolaevich Solomin and Stuart Alan Green	
 <b>Part III Supplementary Materials</b>		
<b>34</b>	<b>External Fixation: a Brochure Containing Useful Information for Patients . . . . .</b>	<b>1495</b>
	Leonid Nikolaevich Solomin, Tatyana Nikolaevna Vorontsova, and Victor Viktorovich Ershov	
34.1	General Information . . . . .	1495
34.1.1	What Is External Fixation? . . . . .	1495
34.1.2	Design of External Fixation Devices . . . . .	1497
34.1.3	How Is New Bone Formed? . . . . .	1497
34.1.4	Your Core Team . . . . .	1499
34.2	Treatment Planning . . . . .	1499
34.3	The Postoperative Period . . . . .	1501
34.3.1	Nutrition . . . . .	1503
34.3.2	Weight. . . . .	1503
34.3.3	Personal Hygiene . . . . .	1503
34.3.4	Sex. . . . .	1503
34.3.5	Quit Smoking!. . . . .	1503
34.3.6	Physiotherapy Exercises . . . . .	1503
34.3.7	Removal of the External Fixation Device . . . . .	1504
34.4	Possible Complications. . . . .	1504
A	Appendixes . . . . .	1504
A.1	Appendix A: Dressings. . . . .	1504
A.2	Appendix B: Frame Manipulation . . . . .	1505
A.3	Appendix C: Your Orthopedic Status Diary . . . . .	1509
A.4	Appendix D: Walking with the Aid of Crutches or a Cane . . . . .	1509
A.5	Appendix E: Clothing Adjustments . . . . .	1511
A.6	Appendix F: Isometric Exercises . . . . .	1512
A.7	Appendix G: Rehabilitatory Gymnastics . . . . .	1515

<b>35 Method for the Definition of “Reference Positions” for the Insertion of Transosseous Elements</b> . . . . .	1519
Leonid Nikolaevich Solomin, Maxim Vasil’evich Andrianov, Roman Nikolaevich Inyushin, Dmitry Alexandrovich Mykalo, and Pavel Nikolaevich Kulesh	
35.1 Introduction . . . . .	1519
35.2 Main Principles in the Determination of Positions with Minimum Soft-Tissue Displacement . . . . .	1519
35.2.1 Skin Displacement Evaluation . . . . .	1520
35.2.2 Fascia Displacement Evaluation . . . . .	1520
35.2.3 Muscle Displacement Evaluation . . . . .	1520
35.3 Determination of Positions with Minimum Soft-Tissue Displacement . .	1523
35.3.1 Femur . . . . .	1523
35.3.2 Upper Arm . . . . .	1523
35.3.3 Lower Leg . . . . .	1523
35.3.4 Forearm . . . . .	1524
<b>36 Method for Rigidity Testing of External Fixation Assemblies</b> . . . . .	1531
Leonid Nikolaevich Solomin, Petr Iosiphovich Begun, and Vladimir Anatol’evich Nazarov	
36.1 Introduction . . . . .	1531
36.2 Indications and Contraindications . . . . .	1531
36.3 General Theoretical Principles . . . . .	1532
36.3.1 Transosseous Module Classification . . . . .	1532
36.3.2 Method for the Unified Designation of External Fixation . . . .	1536
36.3.3 Modeling the Displacing Forces . . . . .	1536
36.3.4 Primary Standard for the Rigidity of Transosseous Modules . .	1537
36.4 Experimental Procedures . . . . .	1539
36.4.1 Investigating the Rigidity of Transosseous Modules of the First (M1) and Second (M2) Orders . . . . .	1539
36.4.2 Investigating the Rigidity of Third-Order Modules (M3) . . . .	1541
<b>Appendixes</b> . . . . .	1545
<b>Instead of the Conclusion</b> . . . . .	1569
<b>References</b> . . . . .	1571
<b>Index</b> . . . . .	1587