Clinical ORTHOPTICS
Fiona J. Rowe
THIRD EDITION

Clinical Orthoptics has become established as a leading textbook providing fundamental information on anatomy, innervation and orthoptic investigation, in addition to diagnosis and management of strabismus, ocular motility and related disturbances. It is a valuable resource for trainee ophthalmologists as well as orthoptic and optometry students. Qualified orthoptists, general ophthalmologists and optometrists will also find helpful guidance in these pages.

In this third edition, the author has maintained the goal of producing a user-friendly, clinically relevant and succinct book, while revising it to reflect a variety of developments in the field.

KEY FEATURES
● Essential reading for students of orthoptics, optometry and ophthalmology
● Now fully revised and updated
● Generously illustrated with photographs and line drawings
● Includes diagnostic aids, case reports and helpful glossary

ABOUT THE AUTHOR
Fiona J. Rowe is a Senior Lecturer in Orthoptics at the University of Liverpool, and lectures extensively to undergraduate and postgraduate orthoptists, trainee and qualified ophthalmologists, ophthalmic nurses and other members of the multi-disciplinary eye care team.

RELATED TITLES
Normal Binocular Vision: Theory, Investigation and Practical Aspects
David Stidwill and Robert Fletcher
ISBN: 978-1-4051-9250-7

Diagnosis and Management of Ocular Motility Disorders
Alec M. Ansons and Helen Davis

www.wiley.com/wiley-blackwell
Clinical Orthoptics
Dedication

This book is dedicated to my family
Clinical Orthoptics

Third Edition

Fiona J. Rowe
PhD, DBO, CGLI CertEd
Senior Lecturer, Directorate of Orthoptics and Vision Science,
University of Liverpool, Liverpool, UK
## Contents

Preface xi  
Acknowledgements xii  
List of Figures xiii  
List of Tables xvii  

SECTION I 1  

1 **Extraocular Muscle Anatomy and Innervation** 3  
   Muscle pulleys 3  
   Ocular muscles 5  
   Innervation 10  
   Associated cranial nerves 12  
   References 15  
   Further reading 16  

2 **Binocular Single Vision** 17  
   Worth’s classification 17  
   Development 17  
   Retinal correspondence 19  
   Physiology of stereopsis 20  
   Fusion 23  
   Retinal rivalry 24  
   Suppression 24  
   Diplopia 25  
   References 27  
   Further reading 28  

3 **Ocular Motility** 29  
   Saccadic system 29  
   Smooth pursuit system 31  
   Vergence system 33  
   Vestibular-ocular response and optokinetic response 35  
   Brainstem control 37  
   Muscle sequelae 39  
   Past-pointing 40  
   Bell’s phenomenon 41  
   References 41  
   Further reading 43
4 Orthoptic Investigative Procedures

Visual acuity 45
Cover test 45
Ocular motility 60
Accommodation and convergence 68
Retinal correspondence 73
Fusion 77
Stereopsis 82
Suppression 89
Synoptophore 91
Aniseikonia 97
Fixation 98
Measurement of deviations 99
Hess charts 105
Field of binocular single vision 108
Unicocular field of vision 110
Measurement of torsion 111
Parks-Helveston three-step test 113
Diplopia charts 113
Bielchowsky phenomenon (dark wedge test) 115
Forced duction test 115
Forced generation test 115
Orthoptic exercises 115
References 119
Further reading 124

SECTION II

5 Heterophoria 131

Classification 131
Aetiology 131
Causes of decompensation 132
Esophoria 132
Exophoria 132
Hyperphoria/hypophoria 133
Alternating hyperphoria 133
Alternating hypophoria 133
Cyclophoria 133
Incomitant heterophoria 133
Hemifield slide 133
Investigation of heterophoria 134
Management 135
References 136
Further reading 137

6 Heterotropia 138

Esotropia 138
Factors necessary for development of binocular single vision 139
Constant esotropia with an accommodative element 140
Constant esotropia without an accommodative element 141
Accommodative esotropia 146
Contents vii

Relating to fixation distance 151
Exotropia 155
Hypertropia 168
Hypotropia 168
Cyclotropia 169
Dissociated vertical deviation 170
Dissociated horizontal deviation 172
Quality of life 173
Pseudostrabismus 174
References 175
Further reading 184

7 Microtropia 189
Terminology 189
Classification 190
Investigation 191
Management 194
References 194
Further reading 195

8 Amblyopia and Visual Impairment 197
Classification 197
Aetiology 197
Investigation 198
Management 199
Eccentric fixation 205
Cerebral visual impairment 205
Delayed visual maturation 206
PHACE syndrome 207
References 207
Further reading 212

9 Aphakia 215
Methods of correction 215
Investigation 215
Problems with unilateral aphakia 216
Management 216
References 218
Further reading 219

SECTION III 221

10 Incomitant Strabismus 223
Aetiology 223
Aid to diagnosis 225
Diplopia 226
Abnormal head posture 227
References 230
Further reading 231

11 A and V Patterns 232
Classification 232
Aetiology 232
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation</td>
<td>236</td>
</tr>
<tr>
<td>Management</td>
<td>238</td>
</tr>
<tr>
<td>References</td>
<td>241</td>
</tr>
<tr>
<td>Further reading</td>
<td>243</td>
</tr>
<tr>
<td><strong>12</strong> Accommodation and Convergence Disorders</td>
<td>245</td>
</tr>
<tr>
<td>Accommodative disorders</td>
<td>245</td>
</tr>
<tr>
<td>Presbyopia – physiological</td>
<td>245</td>
</tr>
<tr>
<td>Presbyopia – premature (non-physiological)</td>
<td>246</td>
</tr>
<tr>
<td>Accommodative insufficiency</td>
<td>247</td>
</tr>
<tr>
<td>Accommodative fatigue</td>
<td>248</td>
</tr>
<tr>
<td>Accommodative paralysis</td>
<td>248</td>
</tr>
<tr>
<td>Accommodative spasm</td>
<td>249</td>
</tr>
<tr>
<td>Accommodative inertia</td>
<td>250</td>
</tr>
<tr>
<td>Micropsia</td>
<td>251</td>
</tr>
<tr>
<td>Macropsia</td>
<td>251</td>
</tr>
<tr>
<td>Convergence anomalies</td>
<td>251</td>
</tr>
<tr>
<td>Convergence insufficiency</td>
<td>252</td>
</tr>
<tr>
<td>Convergence paralysis</td>
<td>254</td>
</tr>
<tr>
<td>Convergence spasm</td>
<td>254</td>
</tr>
<tr>
<td>Specific learning difficulty</td>
<td>254</td>
</tr>
<tr>
<td>References</td>
<td>255</td>
</tr>
<tr>
<td>Further reading</td>
<td>257</td>
</tr>
<tr>
<td><strong>13</strong> Ptosis and Pupils</td>
<td>259</td>
</tr>
<tr>
<td>Ptosis</td>
<td>259</td>
</tr>
<tr>
<td>Marcus Gunn jaw-winking syndrome</td>
<td>263</td>
</tr>
<tr>
<td>Lid retraction</td>
<td>264</td>
</tr>
<tr>
<td>Pupils</td>
<td>264</td>
</tr>
<tr>
<td>References</td>
<td>269</td>
</tr>
<tr>
<td>Further reading</td>
<td>271</td>
</tr>
<tr>
<td><strong>14</strong> Neurogenic Disorders</td>
<td>272</td>
</tr>
<tr>
<td>III (third) cranial nerve</td>
<td>272</td>
</tr>
<tr>
<td>IV (fourth) cranial nerve</td>
<td>280</td>
</tr>
<tr>
<td>VI (sixth) cranial nerve</td>
<td>288</td>
</tr>
<tr>
<td>Multiple sclerosis</td>
<td>292</td>
</tr>
<tr>
<td>Acquired motor fusion deficiency</td>
<td>293</td>
</tr>
<tr>
<td>Non-accidental injury</td>
<td>294</td>
</tr>
<tr>
<td>Premature visual impairment</td>
<td>295</td>
</tr>
<tr>
<td>Ophthalmoplegia</td>
<td>296</td>
</tr>
<tr>
<td>References</td>
<td>300</td>
</tr>
<tr>
<td>Further reading</td>
<td>307</td>
</tr>
<tr>
<td><strong>15</strong> Mechanical Paralytic Strabismus</td>
<td>310</td>
</tr>
<tr>
<td>Congenital cranial dysinnervation disorders</td>
<td>312</td>
</tr>
<tr>
<td>Brown’s syndrome</td>
<td>319</td>
</tr>
<tr>
<td>Adherence syndrome</td>
<td>324</td>
</tr>
<tr>
<td>Moebius syndrome</td>
<td>325</td>
</tr>
<tr>
<td>Strabismus fixus syndrome</td>
<td>327</td>
</tr>
<tr>
<td>Thyroid eye disease</td>
<td>327</td>
</tr>
</tbody>
</table>
# Orbital Injuries

- Blow-out fracture: 334
- Soft tissue injury: 339
- Supraorbital fracture: 341
- Naso-orbital fracture: 341
- Zygoma fracture: 341
- Conjunctival shortening syndrome: 342
- Retinal detachment: 342
- Cataract: 343
- Macular translocation surgery: 344
- References: 344
- Further reading: 350

## Myogenic Disorders

- Thyroid eye disease: 354
- Chronic progressive external ophthalmoplegia: 354
- Myasthenia gravis: 355
- Myotonic dystrophy: 358
- Ocular myositis: 358
- Kearns–Sayre ophthalmoplegia: 359
- References: 359
- Further reading: 361

## Craniofacial Synostoses

- Plagiocephaly: 362
- Brachycephaly: 362
- Scaphiocephaly/dolichocephaly: 362
- Occipital plagiocephaly: 362
- Apert’s syndrome: 363
- Craniofrontonasal dysplasia: 363
- Crouzon’s syndrome: 363
- Pfeiffer syndrome: 363
- Saethre–Chotzen syndrome: 364
- Unicoronal syndrome: 364
- General signs and symptoms: 365
- Ocular signs and symptoms: 365
- Management: 365
- References: 366
- Further reading: 367

## Nystagmus

- Aetiology: 368
- Classification: 368
- Investigation: 373
- Management: 375
- References: 378
- Further reading: 380

## Supranuclear and Internuclear Disorders

- Saccadic movement disorders: 382
- Smooth pursuit movement disorders: 384
<table>
<thead>
<tr>
<th>Section/Appendix</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vergence movement disorders</td>
<td>385</td>
</tr>
<tr>
<td>Gaze palsy</td>
<td>386</td>
</tr>
<tr>
<td>Optokinetic movement disorders</td>
<td>394</td>
</tr>
<tr>
<td>Vestibular movement disorders</td>
<td>395</td>
</tr>
<tr>
<td>Brainstem syndromes</td>
<td>395</td>
</tr>
<tr>
<td>Skew deviation</td>
<td>397</td>
</tr>
<tr>
<td>Ocular tilt reaction</td>
<td>398</td>
</tr>
<tr>
<td>Ocular investigation</td>
<td>398</td>
</tr>
<tr>
<td>Management options</td>
<td>400</td>
</tr>
<tr>
<td>References</td>
<td>401</td>
</tr>
<tr>
<td>Further reading</td>
<td>405</td>
</tr>
<tr>
<td>SECTION IV Appendices</td>
<td>407</td>
</tr>
<tr>
<td>Diagnostic Aids</td>
<td>409</td>
</tr>
<tr>
<td>Abbreviations of Orthoptic Terms</td>
<td>418</td>
</tr>
<tr>
<td>Diagrammatic Recording of Ocular Motility</td>
<td>424</td>
</tr>
<tr>
<td>Diagrammatic Recording of Nystagmus</td>
<td>426</td>
</tr>
<tr>
<td>Glossary</td>
<td>428</td>
</tr>
<tr>
<td>Case Reports</td>
<td>441</td>
</tr>
<tr>
<td>Index</td>
<td>459</td>
</tr>
</tbody>
</table>
Preface

*Clinical Orthoptics* has become established as a basic reference text providing fundamental information on anatomy, innervations and orthoptic investigation, plus diagnosis and management of strabismus, ocular motility and related visual disturbances. As with previous editions, the third edition is not designed to provide in-depth discussion of the content as it is recognised that this can be found in other excellent texts, in systematic reviews and in journal literature.

Following the revision of previous editions, this third edition, in addition to many of the original illustrations, contains new figures, tables and flowcharts designed to enhance the written text. Reference and further reading lists for each chapter have been extended and include up-to-date literature.

The layout of the text remains similar to that of the previous edition. Section I concentrates on anatomy and innervations of extraocular muscles including muscle pulley systems and associated cranial nerves. Ocular motility and orthoptic investigative techniques have been updated to include new assessments and reference to normative data. Section II refers to concomitant strabismus and Section III to incomitant strabismus. There has been considerable revision to add new information on conditions not previously included. A new chapter on craniofacial synostosis syndromes has been added. Section IV includes an updated list of abbreviations and glossary of definitions with additions to the information provided on diagnostic aids, flowcharts and illustrative case reports.
Acknowledgements

Thanks are due to my colleagues and undergraduate students at the University of Liverpool, whose discussions provoke enquiry and understanding of orthoptics. Thanks are due to Addenbrooke’s Hospital, Cambridge, for permission to use patient photographs and to the patients and parents for their consent to use these images. The glossary incorporates terminology from the British and Irish Orthoptic Society, and thanks are due to the Society for permission to use the glossary terminology. Finally, a thank you to the team at Wiley-Blackwell, the publisher, for their input to this text.
List of Figures

1.1 Orbital apex 4
1.2 Extraocular muscles 4
1.3 Medial rectus action 5
1.4 Lateral rectus action 6
1.5 Superior rectus action 7
1.6 Inferior rectus action 7
1.7 Superior oblique action 8
1.8 Inferior oblique action 9
1.9 Extraocular muscle insertions 9
1.10 Cardinal positions of gaze – position of main action of extraocular muscles 9

2.1 Projection in normal retinal correspondence 20
2.2 Projection in abnormal retinal correspondence 20
2.3 Projection in heteronymous diplopia 21
2.4 Projection in homonymous diplopia 22
2.5 Horopter 23
2.6 Right convergent strabismus with suppression 25
2.7 Right convergent strabismus with pathological diplopia 26
2.8 Right convergent strabismus with paradoxical diplopia 26

3.1 Saccadic eye movement control pathways 32
3.2 Smooth pursuit eye movement control pathways 34
3.3 Vergence eye movement control pathways 35
3.4 Vestibulo-ocular and optokinetic response control pathways 36
3.5 Sagittal cross section of brainstem; schematic representation 37
3.6 Coronal cross section of brainstem; schematic representation 38
3.7 Sagittal view of cortical areas; schematic representation 39

4.1 Optics of visual acuity 46
4.2 Forced choice preferential looking 47
4.3 Teller cards 48
4.4 LogMAR test 48
4.5 LEA symbols 49
4.6 Snellen test 50
4.7 Sheridan Gardiner test 51
4.8 Kay’s pictures 51
4.9 Cardiff acuity cards 52
## List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.10</td>
<td>Vistech chart</td>
<td>55</td>
</tr>
<tr>
<td>4.11</td>
<td>LEA contrast numbers</td>
<td>55</td>
</tr>
<tr>
<td>4.12</td>
<td>Heidi contrast faces</td>
<td>56</td>
</tr>
<tr>
<td>4.13</td>
<td>Hypermetropia</td>
<td>57</td>
</tr>
<tr>
<td>4.14</td>
<td>Myopia</td>
<td>57</td>
</tr>
<tr>
<td>4.15</td>
<td>Astigmatism</td>
<td>58</td>
</tr>
<tr>
<td>4.16</td>
<td>Occluders</td>
<td>60</td>
</tr>
<tr>
<td>4.17</td>
<td>Fixation targets</td>
<td>61</td>
</tr>
<tr>
<td>4.18</td>
<td>Cover/uncover test in manifest strabismus</td>
<td>62</td>
</tr>
<tr>
<td>4.19</td>
<td>Cover/uncover test in latent strabismus</td>
<td>63</td>
</tr>
<tr>
<td>4.20</td>
<td>Alternate cover test</td>
<td>63</td>
</tr>
<tr>
<td>4.21</td>
<td>Rotation of the eye</td>
<td>65</td>
</tr>
<tr>
<td>4.22</td>
<td>Optokinetic nystagmus Drum</td>
<td>67</td>
</tr>
<tr>
<td>4.23</td>
<td>RAF rule</td>
<td>69</td>
</tr>
<tr>
<td>4.24</td>
<td>Flipper lenses</td>
<td>70</td>
</tr>
<tr>
<td>4.25</td>
<td>Bagolini glasses</td>
<td>74</td>
</tr>
<tr>
<td>4.26</td>
<td>Results with Bagolini glasses</td>
<td>74</td>
</tr>
<tr>
<td>4.27</td>
<td>Worth’s four lights test</td>
<td>75</td>
</tr>
<tr>
<td>4.28</td>
<td>Risley prism (a); Prism bars and loose prisms (b)</td>
<td>79</td>
</tr>
<tr>
<td>4.29</td>
<td>Response to overcome a base out prism</td>
<td>79</td>
</tr>
<tr>
<td>4.30</td>
<td>Lang two pencil test</td>
<td>84</td>
</tr>
<tr>
<td>4.31</td>
<td>Frisby stereotest</td>
<td>84</td>
</tr>
<tr>
<td>4.32</td>
<td>FD2 stereotest</td>
<td>85</td>
</tr>
<tr>
<td>4.33</td>
<td>Lang stereotest</td>
<td>86</td>
</tr>
<tr>
<td>4.34</td>
<td>TNO stereotest</td>
<td>87</td>
</tr>
<tr>
<td>4.35</td>
<td>Titmus/Wirt stereotest</td>
<td>88</td>
</tr>
<tr>
<td>4.36</td>
<td>Randot stereotest</td>
<td>88</td>
</tr>
<tr>
<td>4.37</td>
<td>Sbisa bar</td>
<td>89</td>
</tr>
<tr>
<td>4.38</td>
<td>Amsler chart</td>
<td>91</td>
</tr>
<tr>
<td>4.39</td>
<td>Synoptophore</td>
<td>92</td>
</tr>
<tr>
<td>4.40</td>
<td>Optics of the synoptophore</td>
<td>92</td>
</tr>
<tr>
<td>4.41</td>
<td>Maddox slides</td>
<td>93</td>
</tr>
<tr>
<td>4.42</td>
<td>Simultaneous perception slides</td>
<td>94</td>
</tr>
<tr>
<td>4.43</td>
<td>Fusion slides</td>
<td>95</td>
</tr>
<tr>
<td>4.44</td>
<td>Stereopsis slides: (a) gross stereopsis; (b) detailed stereopsis</td>
<td>96</td>
</tr>
<tr>
<td>4.45</td>
<td>Angle kappa</td>
<td>96</td>
</tr>
<tr>
<td>4.46</td>
<td>Angle kappa slide assessment</td>
<td>97</td>
</tr>
<tr>
<td>4.47</td>
<td>Fixation</td>
<td>98</td>
</tr>
<tr>
<td>4.48</td>
<td>Fusion response with 4 dioptre prism test</td>
<td>99</td>
</tr>
<tr>
<td>4.49</td>
<td>Suppression scotoma response with 4 dioptre prism test</td>
<td>99</td>
</tr>
<tr>
<td>4.50</td>
<td>Prism position</td>
<td>101</td>
</tr>
<tr>
<td>4.51</td>
<td>Hirschberg’s corneal reflections</td>
<td>103</td>
</tr>
<tr>
<td>4.52</td>
<td>Maddox rod</td>
<td>103</td>
</tr>
<tr>
<td>4.53</td>
<td>Maddox wing</td>
<td>105</td>
</tr>
</tbody>
</table>
List of Figures

4.54 Hess screen 106
4.55 Lees screen 106
4.56 Arc perimeter 109
4.57 Goldmann perimeter 109
4.58 Octopus perimeter 110
4.59 Six vectors for uniocular rotations 111
4.60 Objective assessment of torsion 112
4.61 Diplopia chart of IV nerve palsy 114
4.62 Diplopia chart of VI nerve palsy 114
4.63 Bar reading 116
4.64 Stereograms 117
5.1 Post-fixational blindness 134
6.1 Classification of esotropia 139
6.2 Infantile esotropia 142
6.3 Intermittent fully accommodative esotropia 147
6.4 Intermittent convergence excess esotropia 149
6.5 Classification of exotropia 156
6.6 Constant exotropia 157
6.7 Intermittent distance exotropia 160
6.8 Hypertropia 172
6.9 Pseudostrabismus 174
8.1 Neutral density filter bar 200
11.1 A pattern 233
11.2 V pattern 234
14.1 Right III nerve palsy 274
14.2 Hess chart of right III nerve palsy 275
14.3 Hess chart of left inferior rectus palsy 276
14.4 Hess chart of right inferior oblique palsy 277
14.5 Left IV nerve palsy 282
14.6 Hess chart of left IV nerve palsy 283
14.7 Field of binocular single vision of left IV nerve palsy 284
14.8 Right VI nerve palsy 290
14.9 Hess chart of right VI nerve palsy 290
14.10 Field of binocular single vision of right VI nerve palsy 291
15.1 Duane’s retraction syndrome 314
15.2 Hess chart of Duane’s retraction syndrome 315
15.3 Field of binocular single vision of Duane’s retraction syndrome 315
15.4 Right Brown’s syndrome 321
15.5 Hess chart of right Brown’s syndrome 322
15.6 Field of binocular single vision of right Brown’s syndrome 323
15.7 Thyroid eye disease 329
15.8 Hess chart of thyroid eye disease 330
15.9 Hess chart of unilateral thyroid eye disease 331
xvi List of Figures

15.10 Field of binocular single vision of thyroid eye disease 331
15.11 Left orbital floor fracture 335
15.12 Hess chart of left orbital floor fracture 336
15.13 Hess chart of right medial wall fracture 337
15.14 Field of binocular single vision of left orbital floor fracture 337
18.1 Nystagmus; early onset 369
18.2 Nystagmus; late onset 371
18.3 Nystagmus velocity 374
19.1 Hess chart of right internuclear ophthalmoplegia 388
19.2 Field of binocular single vision of right internuclear ophthalmoplegia 389
19.3 Internuclear ophthalmoplegia and one and a half syndrome – site of lesions 390
Chart 1 Eso-deviations 415
Chart 2 Exo-deviations 416
Chart 3 Microtropia 416
## List of Tables

1.1 Primary, secondary and tertiary muscle actions 10  
4.1 Age-related visual acuity norms 50  
10.1 Differences between congenital and acquired defects 225  
10.2 Differences between neurogenic and mechanical defects 225  
10.3 Torticollis differential diagnosis 229  
14.1 Differences of superior oblique and superior rectus palsy 285  
14.2 Differences of unilateral and bilateral superior oblique palsy 285
SECTION I
This chapter outlines the anatomy of the extraocular muscles and their innervation and associated cranial nerves (II, V, VII and VIII).

There are four rectus and two oblique muscles attached to each eye. The rectus muscles originate from the Annulus of Zinn, which encircles the optic foramen and medial portion of the superior orbital fissure (Fig. 1.1). These muscles pass forward in the orbit and gradually diverge to form the orbital muscle cone. By means of a tendon, the muscles insert into the sclera anterior to the rotation centre of the globe (Fig. 1.2).

The extraocular muscles are striated muscles. They contain slow fibres, which produce a graded contracture on the exterior surface, and fast fibres, which produce rapid movements on the interior surface adjacent to the globe. The slow fibres contain a high content of mitochondria and oxidative enzymes. The fast fibres contain high amounts of glycogen and glycolytic enzymes and less oxidative enzymes than the slow fibres. The global layer of the extraocular muscles contains palisade endings in the myotendonous junctions, which are believed to act as sensory receptors. Signals from the palisade endings passing to the central nervous system may serve to maintain muscle tension (Ruskell 1999, Donaldson 2000).

Muscle pulleys

There is stereotypic occurrence of connective tissue septa within the orbit and stereotypic organisation of connective tissue around the extraocular muscles (Koornneef 1977, 1979). There is also stability of rectus extraocular muscle belly paths throughout the range of eye movement, and there is evidence for extraocular muscle path constraint by pulley attachment within the orbit (Miller 1989, Miller et al. 1993, Clark et al. 1999). High-resolution MRI has confirmed the presence of these attachments via connections that constrain the muscle paths during rotations of the globe (Demer 1995, Clark et al. 1997). CT and MRI scans have shown that the paths of the rectus muscles remain fixed relative to the orbital wall during excursions of the globe and even after large surgical transpositions (Demer et al.)
1996, Clark et al. 1999). It is only the anterior aspect of the muscle that moves with the globe relative to the orbit. Histological studies have demonstrated that each rectus pulley consists of an encircling ring of collagen located near the globe equator in Tenon fascia attached to the orbital wall, adjacent extraocular muscles and equatorial Tenon fascia by sling-like bands, which consist of densely woven collagen, elastin and smooth muscle (Demer et al. 1995, Porter et al. 1996). The global layer of each rectus extraocular muscle, containing about half of all extraocular muscle fibres, passes through the pulley and becomes continuous with the tendon to insert on the globe. The orbital layer containing the remaining half of the extraocular muscle fibres inserts on the pulley and not on the globe (Demer et al. 2000, Oh et al. 2001, Hwan et al. 2007).
The orbital layer translates pulleys while the global layer rotates the globe through its insertion on the sclera. The inferior oblique muscle also has a pulley that is mechanically attached to the inferior rectus pulley (Demer et al. 1999).

The general arrangement of orbital connective tissues is uniform throughout the range of human age from foetal life to the tenth decade. Such uniformity supports the concept that pulleys and orbital connective tissues are important for the mechanical generation and maintenance of ocular movements (Kono et al. 2002).

### Ocular muscles

#### Medial rectus muscle

This muscle originates at the orbital apex from the medial portion of the Annulus of Zinn in close contact with the optic nerve. It courses forward for approximately 40 mm along the medial aspect of the globe and penetrates Tenon’s capsule roughly 12 mm from the insertion. The last 5 mm of the muscle are in contact with the eye and the insertion is at 5.5 mm from the limbus with a width of 10.5 mm. The muscle is innervated by the inferior division of the III nerve, which enters the muscle on its bulbar side. Its function is adduction of the eye (Fig. 1.3).

#### Lateral rectus muscle

This muscle arises by two heads from the upper and lower portions of the Annulus of Zinn where it bridges the superior orbital fissure. It courses forward for approximately 40 mm along the lateral aspect of the globe and crosses the inferior oblique insertion. It penetrates Tenon’s capsule at roughly 15 mm from the insertion and the last 7–8 mm of the muscle is in contact with the eye. The insertion is at

![Figure 1.3](image.jpg)  
**Figure 1.3** Medial rectus action.
7 mm from the limbus with a width of 9.5 mm. The muscle is innervated by the VI nerve, which enters the muscle on its bulbar side. Its function is abduction of the eye (Fig. 1.4).

Superior rectus muscle

This muscle arises from the superior portion of the Annulus of Zinn and courses forward for approximately 42 mm along the dorsal aspect of the globe forming an angle of 23° with the sagittal axis of the globe. Superiorly, it is in close contact with the levator muscle. It penetrates Tenon’s capsule at roughly 15 mm from the insertion and the last few millimetres of the muscle are in contact with the eye. The insertion is at 7.7 mm from the limbus with a width of 11 mm. The muscle is innervated by the superior division of the III nerve, which enters the muscle on its bulbar side. Its functions are elevation, intorsion and adduction of the eye (Fig. 1.5).

Inferior rectus muscle

This muscle arises from the inferior portion of the Annulus of Zinn and courses forward for approximately 42 mm along the ventral aspect of the globe forming an angle of 23° with the sagittal axis. It penetrates Tenon’s capsule roughly 15 mm from the insertion and the last few millimetres of the muscle are in contact with the eye as it arcs to insert at 6.5 mm from the limbus. The width of insertion is 10 mm. The muscle is innervated by the inferior division of the III nerve, which enters the muscle on its bulbar side. Its functions are depression, extorsion and adduction of the eye (Fig. 1.6).
Figure 1.5  Superior rectus action. The course of the superior rectus is at an angle of 23° to the medial wall of the orbit. Actions in adduction are principally intorsion and adduction; in the primary position, actions are elevation, intorsion and adduction; action in abduction is principally elevation.

Superior oblique muscle

This muscle originates from the orbital apex from the periosteum of the body of the sphenoid bone, medial and superior to the optic foramen. It courses forward for approximately 40 mm along the medial wall of the orbit to the trochlea.

Figure 1.6  Inferior rectus action. The course of the inferior rectus is at an angle of 23° to the medial wall of the orbit. In adduction, the actions are principally extorsion and adduction; in the primary position, actions are depression, extorsion and adduction; action in abduction is principally depression.
Clinical Orthoptics

Figure 1.7  Superior oblique action. The course of the superior oblique tendon is at an angle of 51° to the medial wall of the orbit. Action in adduction is depression; in the primary position, actions are depression, intorsion and abduction; in abduction, action is intorsion.

(a V-shaped fibrocartilage that is attached to the frontal bone). The trochlear region is described by Helveston et al. (1982).

The muscle becomes tendonous roughly 10 mm posterior to the trochlea and is encased in a synovial sheath through the trochlea. From the trochlea, it courses posteriorly, laterally and downwards forming an angle of 51° with the visual axis of the eye in the primary position. It passes beneath the superior rectus and inserts on the upper temporal quadrant of the globe ventral to the superior rectus. Its insertion is fanned out in a curved line 10–12 mm in length. The muscle is innervated by the IV nerve that enters the muscle on its upper surface roughly 12 mm from its origin. Its functions are intorsion, depression and abduction of the eye (Fig. 1.7).

Inferior oblique muscle

This muscle arises from the floor of the orbit from the periosteum covering the anteromedial portion of the maxilla bone. It courses laterally and posteriorly for approximately 37 mm, forming an angle of 51° with the visual axis. It penetrates Tenon’s capsule near the posterior ventral surface of the inferior rectus, crosses the inferior rectus and curves upwards around the globe to insert under the lateral rectus just anterior to the macular area. The muscle is innervated by the inferior division of the III nerve that enters the muscle on its bulbar surface. Its functions are extorsion, elevation and abduction of the eye (Fig. 1.8).

Figure 1.9 illustrates the muscle insertions in relation to the anterior segment of the eye. Figure 1.10 illustrates the positions of main action of each extraocular muscle and Table 1.1 illustrates all primary, secondary and tertiary muscle actions.
Figure 1.8 Inferior oblique action. The course of the inferior oblique is at an angle of 51° to the medial wall of the orbit. Action in adduction is elevation; actions in the primary position are elevation, extorsion and abduction; in abduction, action is extorsion.

Figure 1.9 Extraocular muscle insertions. SR, superior rectus; MR, medial rectus; LR, lateral rectus; IR, inferior rectus.

Figure 1.10 Cardinal positions of gaze – position of main action of extraocular muscles.
Table 1.1  Primary, secondary and tertiary extraocular muscle actions.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Primary action</th>
<th>Secondary action</th>
<th>Tertiary action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial rectus</td>
<td>Adduction</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Lateral rectus</td>
<td>Abduction</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Superior rectus</td>
<td>Elevation, maximum in abduction</td>
<td>Intorsion, maximum in adduction</td>
<td>Adduction, maximum in adduction</td>
</tr>
<tr>
<td>Inferior rectus</td>
<td>Depression, maximum in abduction</td>
<td>Extorsion, maximum in adduction</td>
<td>Adduction, maximum in adduction</td>
</tr>
<tr>
<td>Superior oblique</td>
<td>Intorsion, maximum in adduction</td>
<td>Depression, maximum in abduction</td>
<td>Abduction, maximum in abduction</td>
</tr>
<tr>
<td>Inferior oblique</td>
<td>Extorsion, maximum in abduction</td>
<td>Elevation, maximum in adduction</td>
<td>Abduction, maximum in abduction</td>
</tr>
</tbody>
</table>

**Levator palpebral superioris**

This muscle originates from the under surface of the lesser wing of sphenoid bone above and in front of the optic foramen by a short tendon that blends with the origin of the superior rectus. It runs forward and changes directly from horizontal to vertical at the level of the equator of the globe. At approximately 10 mm above the superior margin of the tarsus, it divides into anterior and posterior lamellae. The anterior lamellae form the levator aponeurosis that is inserted into the lower third of the entire length of the anterior surface of the tarsus. Its fibres extend to the pre-tarsal portion of the orbit and skin. The posterior lamellae form Muller’s muscle that is attached inferiorly to the superior margin of the tarsus.

**Innervation**

The extraocular muscles are innervated by the III, IV and VI nerves.

**III nerve**

The III nerve (third/oculomotor) supplies the superior rectus, inferior rectus, medial rectus, inferior oblique and levator muscles. Its visceral fibres innervate the ciliary muscle and sphincter pupillary muscle that synapse in the ciliary ganglion.

The nuclei are in the mesencephalon at the level of the superior colliculus. There is an elongated mass of cells that form the nuclei. Peripheral motor neurones innervate multiply innervated extraocular muscle fibres and central motor neurones innervate single innervated muscle fibres. Dorsal nucleus fibres pass to the ipsilateral inferior rectus, intermediate nucleus fibres pass to the ipsilateral inferior oblique, ventral nucleus fibres pass to the ipsilateral medial rectus, paramedian nucleus fibres pass to the contralateral superior rectus, central caudal nucleus fibres pass to both levator muscles, and the anterior median/Edinger-Westphal nucleus