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

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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.

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Clinical Orthoptics
Dedication

This book is dedicated to my family
Clinical Orthoptics

Third Edition

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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.
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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 Medial rectus action.](image-url)
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Figure 1.4  Lateral 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.
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.

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**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