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A Study of Variations of the Recti Muscles of the Eyeball in Cadavers

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ABSTRACT

The human beings are a highly visual species. Most of our information about the world comes to us through our eyes and most of our cultural and intellectual heritage is stored and transmitted as words and images to which our vision gives access and meaning. Knowing more about our eyes and vision is, therefore, one path to better understanding of ourselves. And, as it happens, the human eye is a fairly representative vertebrate eye; knowing more about it tell us much about the eyes of other animals and about how they view the world and us.

Any defect in the extraocular muscle results in a misalignment of the visual axes of the two eyes, the condition is called strabismus. In this condition patients suffers from double vision (diplopia) and also cosmetically it doesn't look good. Surgical treatment of this condition required the anatomical knowledge of extraocular muscles. Various studies are done on extraocular muscle but no literature showed such study in Indian population. This aroused an interest in doing a study on this subject. The aims and objectives of our study were,

1. *To measure the width of the recti muscles at the site of insertion*
2. *To measure the distance between the limbus and scleral attachments of the four recti muscles i.e. superior rectus, inferior rectus, medial recttus and lateral rectus.*
3. *To compare the measurements of right eye with with those of left eye*
4. *To study any variations in the recti muscles*
5. *To study variations in the nerve supply of these muscles.*

Keywords: *Extraocular muscle, Eye movement, Levator palpebrae suprioris, Muscle pulleys; Muscle sleeves, Orbital fascia.*

INTRODUCTION

The human beings are a highly visual species. Most of our information about the world comes to us through our eyes and most of our cultural and intellectual heritage is stored and transmitted as words and images to which our vision gives access and meaning. Knowing more about our eyes and vision is, therefore, one path to better understanding of ourselves. And, as it happens, the human eye is a fairly representative vertebrate eye; knowing more about it tell us much about the eyes of other animals and about how they view the world and us. We depend on sight more than any other of our senses excepting vestibular sense to maneuver through space around us. In a single glance lasting for a fraction of second, our eyes work with our brain to tell us about the external environment and also the size, color, shape and various aesthetic aspect of an object in visual field. Although the eyes are small compared to most of the bodies other organs, their structures is incredibly complex. Extraocular muscles are responsible for the movements of the eye. Binocular single vision is one of the hallmarks of the human race that has bestowed on it the supremacy in the hierarchy of the animal kingdom. It is not without reason that about 60% of the brain tissue and more than half of the twelve cranial nerves sub serve the eyes. Binocular single vision is accomplished by perfect sensorimotor coordination of the two eyes both at the rest and during movement.

Each eye lies within bony, roughly cone shaped cavity in the head called the orbit. The medial walls of the orbit are approximately parallel to the mid sagittal plane, and the lateral walls form an angle of approximately 90^0 with each other. Medial and lateral wall thus form an angle of 45^0 with each other. Each orbital axis therefore diverges from midline by about 22.5^0 and from the axis of other orbit by about 45^0.

Each orbit has roof, floor, medial and lateral walls, a base and apex. Roof of the orbit is formed chiefly by the thin orbital plate of frontal bone. Postriorly small part of the roof is formed by inferior aspect of the lesser wing of the sphenoid bone. Medial wall is the thinnest wall and extend from the anterior lacrimal crest on the frontal process of the maxilla to the optic foramen. It is formed by four bones: frontal process of maxilla, lacrimal, orbital plate of ethmoid and body of sphenoid. Floor is forrned by three bones, mostly by the orbital surface of the maxilla, anterolaterally by the zygomatic bone and posteromedially by the small triangular orbital surface of palatine bone. Lateral is the thickest wall of the orbit and is formed by the orbital surface of the greater wing of the sphenoid posteriorly and by the frontal process of the zygomatic bone anteriorly. The apex lies at the medial end of the superior orbital fissure and contain the optic canal.

There are seven extraocular muscles associated with the eye. Levator papebrae superioris is an elevator of the upper eyelid. Four recti (superior, inferior, medial, and lateral) and two oblique (superior and inferior) are capable of moving the eye in almost any direction. Four recti muscles arise from the common fibrous ring at the apex of the orbit called as annulus of the Zinn. The muscles are approximately 40 mm in length and course forword as flat strips in a cone shaped configuration attaching to sclera several millimeters posterior to limbus. The tendons are each a few millimeters long. The insertions vary somewhat in shape and location. The distance of insertion behind the limbus increases in the sequence from medial, inferior, lateral and superior rectus. This progression is known as spiral of Tillaux. Annulus of Zinn is oval in shape. The lower portion of ring is known as tendon of Zinn. The upper portion of the ring is called as tendon of lockwood.

A thin facial membrane envelops the eyeball from the optic nerve to the corneoscleral junction called as Tenons capsule or facial bubi or vaginal bulbi. Intracapsular portion of rectus is about 7-10 mm. The superior rectus and medial rectus are closely attached to the dural sheath of the optic nerve at their origin. This attachments accounts for characteristic pain in case of retrobulbar neuritis, felt during upward and inward movements of globe [1].

Venous drainage of extraocular muscle is into the superior and inferior orbital veins.

Extraocular muscle have a rich nerve supply from the trunks of the third, fourth and sixth cranial nerve and equally rich connection in the central nervous system. Oculomotor nerve supplies the superior, inferior, medial ractus and inferior oblique muscle. Superior oblique is supplied by trochlear and lateral rectus by abducent nerve.

The nuclei of the ocular motor nerve contains more cells than the fibres presents in their efferent nerve, thus the number of cells in the fourth and sixth nuclei are 13% and 20% respectively greater than fibres in the corresponding trunks. Lateral rectus muscle paralysis is most common extraocular muscle palsy. The long intracranial course of sixth cranial nerve and its anatomic vulnerability are often cited as reason why it is involved in paralytic strabismus more often than the other two oculo motor nerves [2].

Microanatomy: The ocular muscles are composed of striated fibres similar to those of skeletal muscles. These muscles have unique feature; in this they hear a resemblance to the muscle of mastication which are also derived from the visceral arches. (Irvine 1936).

Extraocular muscles have a lower innervations ratio, greater vascularity and a loose connective tissue envelop, rich in elastic fibres that are found in skeletal muscle [3]. The normal feature seen in extraocular muscles resembles the features associated with myopathy in skeletal muscle [4]. Because of this, ordinary myopathy and neuropathy cannot be distinguished in extraocular muscles using conventional morphological criteria.

Lochard and Brandt (1938) believed that in human eyes fibres extend the entire length of the muscle as did by cooper and Daniel [5]. Merrilees and his colleagues (1950) and Peachy in 1971 concluded that, like skeletal muscles, fibres extend only part of the total length i.e. there have been reports of fibres terminating or arising along the course of the muscle.

Human extraocular muscle has been less exhaustively studied by electon microscopy. However electron microscopic studies have focused on the Fibrillenstruktur and Felderstruktur distinction[6]. In Fibrillenstruktur fibres sarcoplasmic reticulum and transverse tubular system are well developed and the motor end plate resembles those of the skeletal muscle [7].

Nerves: The motor nerves enter the extraocular muscles at the junction of middle and posterior third. Then, it breaks up into a great multitude of smaller fascicles, which passes between the muscle fibres and run both proximally and distally. Two basic types of neuromuscular junction are present in the extraocular muscle [8]. The classic end plate present in the singly innervated fibres. The second type has been fancied to resemble bunch of grapes and is called termination in grapes [9]. In human roughly 85% fibres are singly innervated. Mukuno has studied the neuromuscular junction in human extraocular muscle and has noted six different type of neuromuscular junction [10].

Development: Muscular system in our body develops from mesoderm, except for the muscle of the iris, which develops from neuroectoderm. Myoblast, embryonic muscle cells are developed from mesenchyme. Much of the mesenchyme in the head is derived from the neural crest cells particularly the tissues derived from pharyngeal arches, however the original mesenchyme in the arches gives rise to the musculature of the face and neck.

The pattern of human eye muscle development is similar to that in elasmobranches, reptiles, birds and cat [11]. In the presomite human embryo mesoderm of prochordal plate proliferate to form the premandibular condensation. Oculomotor eye muscle (superior, medial, inferior rectus and inferior oblique) develops from this condensation. The lateral rectus and superior oblique primordial arises from adjacent tissue masses in the maxilla-mandibular mesoderm. Orbital mesenchyme differentiate last [12]. By six months of intrauterine life the muscles are in their final position. The orbital connective tissue attains its adult configuration by sixth months.

Radiological anatomy: orbital imaging techniques are helpful in the preoperative evaluation of patient without available information regarding prior surgery provided that the corneoscleral limbus and muscle insertion can be clearly displayed. For this purpose, the use of

USG to detect surgical muscle recession by measurement of corneoscleral limbus to insertion site distance is useful [13]

Other imaging techniques include CT scan and high resolution MRI scan can demonstrate the origin and course of extraocular muscles with sufficient details. Cine MRI, which is perform in different gaze position to produce a video recording of ocular movement, has also been used to analyze restrictive motility disorders [14]. MRI is generally superior to CT scan in delineating soft tissues [15].

MATERIAL AND METHODS

Figure 1. Illustration showing instruments used for dissection of the extraocular muscle

Material which were used for the study are:

1) 50 embalmed cadavers i.e. study is done on 100 eyes.
2) Caliper – Castroviejo
3) Normal saline
4) Syringe

METHODS

This study has been carried out in the department of anatomy of a reputed medical institution. The unclaimed cadavers which the department received were used for present study. A total of 100 eyes were dissected and observation recorded after meticulous dissection of the orbits in a stepwise manner. After seeing the attachments of recti muscles and their nerve supply, incision was taken along the superior fornix and inferior fornix of conjunctiva. The oblique muscles were cut and eyeball was removed from the orbit by separating it from the orbit.

As the eyeball removed, it was in a shrunken state. It is first inflated by injecting normal saline with the help of 5 cc syringe. After injecting the fluid eyeball became rounded in shape. Then site of insertion of recti were seen.

With the help of Castroviejo caliper distance were measured from corneoscleral junction (Limbus) up to the midpoint of insertion of each rectus muscle. One end of caliper was kept at the limbus and other at the midpoint of insertion of recti muscles.

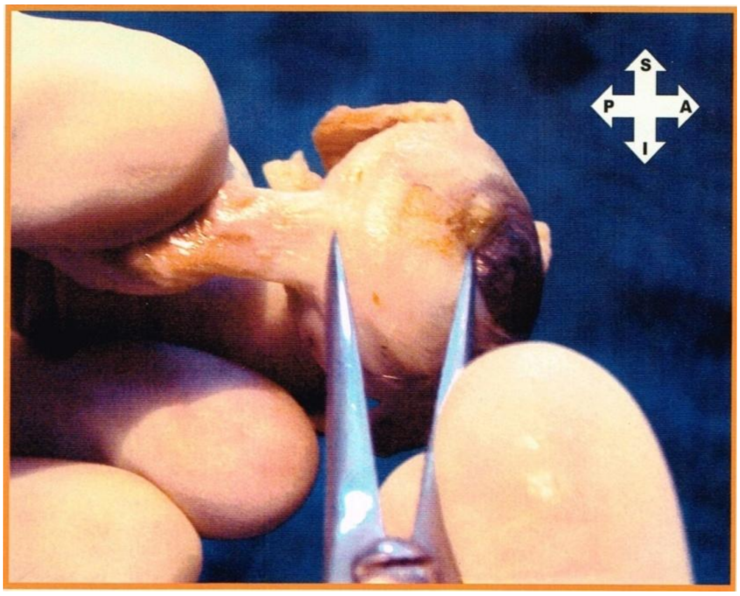

Figure 2: Illustration showing measurement of length (distance from limbus upto the midpoint of insertion.

The width was measured for each muscle at the insertion site with the help of caliper by putting its tips at the two ends of the insertion site.

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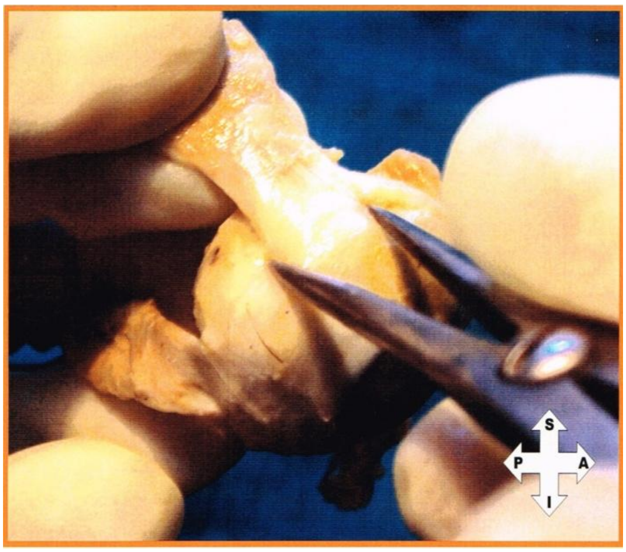

Figure 3: Illustration showing measurement of width at the insertion site.

OBSERVATIONS AND RESULTS:

Table No. 1. The Following table shows the minimum, maximum and mean of the length (distance from limbus up to midpoint of insertion) and width at the site of insertion of **Superior rectus muscle.**

EYE	LENGTH (mm) (Distance from limbus up to midpoint of insertion)			WIDTH (mm)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Right	7.0	10	8.36	6	9.5	7.73
Left	6.5	10	8.34	7	10	7.76

Table No. 2. The Following table shows the minimum, maximum and mean of the length (distance from limbus up to midpoint of insertion) and width at the site of insertion of **Medial rectus muscle.**

EYE	LENGTH (mm) (Distance from limbus up to midpoint of insertion)			WIDTH (mm)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Right	6.0	8.0	6.49	6.0	10	8.09
Left	5.5	10	6.72	6.0	10	8.33

Table No. 3. The Following table shows the minimum, maximum and mean of the length (distance from limbus up to midpoint of insertion) and width at the site of insertion of **Lateral rectus muscle.**

EYE	LENGTH (mm) (Distance from limbus up to midpoint of insertion)			WIDTH (mm)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Right	6.0	11.5	9.17	6.0	11	8.29
Left	7.0	12	8.87	5.0	10	8.05

Table No. 4. The Following table shows the minimum, maximum and mean of the length (distance from limbus up to midpoint of insertion) and width at the site of insertion of **Inferior rectus muscle.**

EYE	LENGTH (mm) (Distance from limbus up to midpoint of insertion)			WIDTH (mm)		
	Minimum	Maximum	Mean	Minimum	maximum	Mean
Right	6.0	10	7.27	6.0	9.0	6.90
Left	6.0	10	7.36	5.0	10	7.09

In two cadavers, variation in the extraocular muscle was seen. In one cadaver, it was in the left eye while in other it was in the right eye.

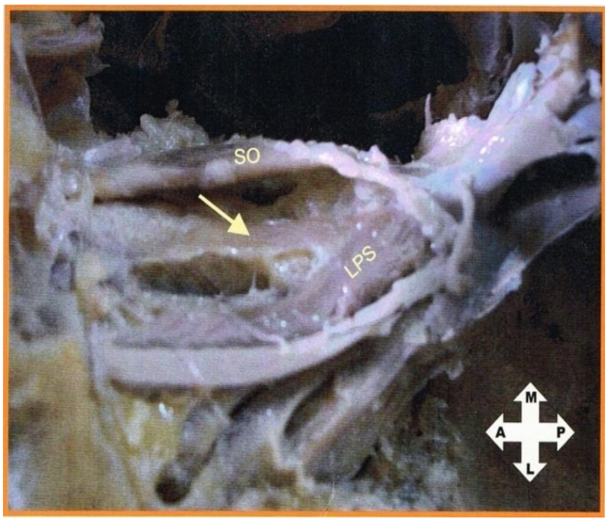

Figure 4. Illustration showing the muscular slip (arrow) between the Levator palpebrae superioris (LPS) and Superior oblique (SO).

In both these cadaver, there was a muscular slip 3 mm width, arising from the apex of the orbit close to the origin of the levator palpebrae superioris and superior rectus muscle. It was running anteriorly and slightly medially parallel to the superior oblique muscle. Anteriorly it was inserted into the fibrous tissue of the orbit. This muscular slip was supplied by superior division of the oculomotor nerve in both cadavers.

DISCUSSION

Extraocular muscles are very important as they are responsible for movements of the eyes in all direction of gaze. Binocular single vision requires a perfect sensorimotor coordination of the two eyes both at rest and during movement. The knowledge of the exact distance between the corneoscleral junction and midpoint of insertion of the rectus muscle is important in calculation of the amount of recession to be done in strabismus surgery. Various studies are done on extraocular muscle measurements, but in all studies a considerable difference in the measurements was found. In case of the medial rectus muscle, it has been classically reported to insert 5.5 mm from corneoscleral junction (Limbus), recent studies of healthy human and of patients with infantile esotropia have shown considerable variation in the distance.

Fuchs in 1884 carried out the study on morphometry of extraocular muscle. Similar study was conducted by Weiss in 1894. Whitnall et al in another study calculated the average of 12 authors. Motais is another person who also studied the morphometry of extraocular muscle. Observations by all these authors are shown in the following table (Table No.5).

Table No. 5: The following table shows the result of previous studies.

Muscle	Distance from midpoint of insertion up to the limbus					
	Fuchs study		**Weiss study**		**Whitnall**	**Motais**
	Aver-age (mm)	Range (mm)	Aver-age (mm)	Range (mm)	Average (mm)	Range (mm)
Medial rectus	5.5	4.3-6.7	5.85	5.0-7.5	5.84	5.5-7.0
Inferior rectus	6.5	5.3-8.2	6.85	6.0-7.5	6.65	5.5-8
Lateral rectus	6.9	5.3-8.2	6.75	6.25-7.75	7.18	6.7-7.0
Superior rectus	7.7	6.8-9.0	8.01	6.75-9.0	7.88	6.5-11

Table No. 6: The following table shows the results of length (Distance from midpoint of insertion up to the limbus) **in present study.**

Muscle	Average (mm)		Range (mm)	
	Right eye	Left eye	Right eye	Left eye
Medial rectus	6.49	6.72	6.0-8.0	5.5-10
Inferior rectus	7.27	7.36	6.0-10	6.0-10
Lateral rectus	9.17	8.87	6.0-11.5	7.0-12
Superior rectus	8.36	8.34	7.0-10	6.5-10

Table No. 7: The following table shows the results **of width of muscle** at the site of insertion in **previous and present study**.

Muscle	**Fuchs study**		**Weiss study**		**Present study**			
	Average (mm)	Range (mm)	Average (mm)	Range (mm)	Average (mm)		Range (mm)	
					Right	Left	Right	Left
Medial rectus	10.3	8.8-12	10.76	10-12.5	8.09	8.33	6-10	6-10
Inferior rectus	9.8	7.8-13.2	10.35	10-11.1	6.90	7.09	6-9	5-10
Lateral rectus	9.2	8.5-10.2	9.67	8.3-12.0	8.29	8.05	6-11	5-10
Superior rectus	10.6	8.5-13.2	10.75	10-11.25	7.73	7.76	6-9.5	7-10

In two cadavers, variation in the extraocular muscle was seen. In one cadaver it was in the left eye while in the other it was in the right eye. In both these cadaver, there was a muscular slip 3 mm width, arising from the apex of the orbit close to the origin of the levator palpebrae superioris and superior rectus muscle. After going through the literature it was found that the congenital anomalies in the extraocular muscles are rare, but the muscular slip from the margins of the levator papebrae superioris occur quite frequently i.e. in 8 – 15 % of cases[16]. These muscle slips splits off from the medial or lateral margin of levator muscle and acquire own muscular identity. When developed medially, such a muscular slip may insert either into the trochlea itself, into the fibrous sheath of the trochlea or inferior to the trochlea in its vicinity. Such a muscle is also called as the levator or tensor trochleae or gracillimus muscle. Such an anomaly of laevator papebrae superioris was first described by Vesalius. Any anomaly of extraocular muscle may be due to an early disturbance in the development of the superior and inferior mesenchymal / mesectodermal complexes [17].

SUMMARY AND CONCLUSSION:

This was a cadveric study conducted on 50 cadavers (100 eyes). After analyzing the data the following results were seen:1) the normal range and mean of the length (distance of midpoint of insertion of each muscle from the limbus were determined. 2) The normal range and mean of width of each muscle at the site of insertion were determined. 3) There was no bilateral asymmetry seen in this study. 4) The width of medial rectus at the site of insertion was found to be greater than the distance of insertion midpoint from limbus. 5) No variation found in the nerve supply of recti muscles.

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