Anatomical Variations of Insertion and Structure of transverse Rectus Muscles in Egyptian Strabismic Patients

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Abstract: Introduction: The possible anatomical variations of the EOM are of great importance because they must be adequately considered during surgical interventions. **(1).** Detailed understanding of length, width, point of insertion and the relationships between these muscles could be of significance for successful surgical outcomes **(2). Aim of the work:** The current study aims to evaluate the insertion distances of the horizontal rectus muscles in Egyptian strabismic patient as they differ in many races. This would help in refinement of the dose-response in strabismus surgery. This study also concerned with the structure of the horizontal rectus muscles in patients with strabismus, to evaluate either the structure may be a cause of strabismus or not. The previous aims would help in improvement of strabismus surgery prognosis in Egypt and decrease the rate of reoperations. **Subject and method**: *The statistical part*: A total number of 38 lateral rectus muscles of 19 patients with strabismus and 24 medial rectus muscles of 12 patient with strabismus included in this study to measure the distances between their insertions and the limbus (corneoscleral junction). *The histological part:* A total number of four lateral rectus muscles and two medial rectus muscles of patients with strabismus were included in this study to evaluate their histological structures under the light microscopy after staining with haematoxylin and eosin. One medial rectus muscles was obtained from a patient underwent enucleation to use it as a control. **Results:** the statistical part: the distances between the insertions of the horizontal rectus muscles and the limbus (the corneoscleral junction) in Egyptians were statistically different from other nationalities included in this study for comparison. The histological part: the muscle samples of both lateral and medial rectus muscles showed variations of their structures when compared by the control. **Conclusion:** the results of this study are specific to Egyptians, and provide an important knowledge about the insertion distances of the horizontal rectus muscles which are very important landmark in strabismus surgery. Also the study states that there is structural variations in the horizontal rectus muscles of the strabismus patients that may be a cause of the strabismus.

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Key words: lateral rectus muscles, medial rectus muscles, horizontal rectus muscles, insertion distance.

1. Introduction:

The term **strabismus**is derived from the Greek word *strabismus "to* squint, to look obliquely or askance" -and means ocular misalignment. This misalignment may be causedby abnormalities in binocular vision or by anomalies of neuromuscular control of ocularmotility **(3). Amblyopia** (Greek, “dull vision”) is a deficiency of corrected central visual acuity in the absence of a structural abnormality of the fovea. Amblyopia affects approximately 2.0–2.5% of the general population **(4).** In **Menoufia** 38 patients out of 510 (7.5%) had amblyopia and 31.58% of amblyopic patients in the study had amblyopia due to strabismus **(5).** Ocular diagnoses found in the **Alex** Eye vision screening program estimated strabismus as 2% **(6).** The prevalence of amblyopia worldwide is approximately 1%–5%. The World Health Organization (WHO) estimates 19 million children less than 15 years of age are visually impaired **(7).** Extraocular muscles (EOM) are important reference points in surgery and represent the most frequent site of surgical manipulation for the treatment of strabismus **(8).** The possible anatomical variations of the EOM are of great importance because they must be adequately considered during surgical interventions. Great variations in EOM are rare **(1).** Detailed understanding of length, width, point of insertion and the relationships between these muscles could be of significance for successful surgical outcomes **(2).** Strabismus surgery involves the resection, recession, tenectomy, or transposition of the EOM. These surgeries present risks of complications, amongst which the most common are: under- or over-correction, anterior segment ischemia, and other rare complications as perforation of the ocular globe and endophthalmitis **(9).** In order to minimize under- or

over-correction, appropriate technique is necessary, as is a detailed understanding of the width and specific point of insertion of these muscles. In addition, the relationships that exist between the point of insertion of the EOM with respect to the fovea and optic nerve have been informative for the implantation of trans scleral drug delivery devices (TSDDD) **(10).** In patients with intermittent exotropia the medial recti showed pathological changes including varying fiber thickness, atrophy, abnormal alignment, internalized nuclei, excessive extracellular matrix, and even degenerated muscle fibers in a few patients. The pathological changes worsened with age and chronic strabismus (**11**). The histological changes are more pronounced in monocular strabism but they can also be found in alternating squint. They are observed in early occuring strabismus, but especially frequently in patients with a large angle of squint, in cases of severe amblyopia and defective binocular vision **(12)**. Light microscopic examination of EOMs of strabismic patients showed considerable variation in muscle fiber shape and size with sarcomere disruption, sharp increases in endomysial and perimysial collagen, numerous vacuoles and subsarcolemmal inclusions **(13).2-Subject and method: Statistical part of the study: Sample size:** The study included 38 lateral rectus muscles and 24 medial rectus muscles for measuring the distance between the muscle insertions and the limbus (corneo-scleral junction). **Method of measurement:** The insertion distances collected in a retrospective manner, then statistically analyzed. The measurements done after fornix incision in conjunctiva, tenon´s capsule separation and muscle hooking. The measurements were taken from limbus (corneoscleral junction) to muscle insertion using Helveston Scleral Ruler (4-5/8"). The measurements were approximated by 0.5mm**. Helveston Scleral Ruler:** Scleral Ruler 15mm long, with notches in 5mm increments single marking tooth at tip**).**

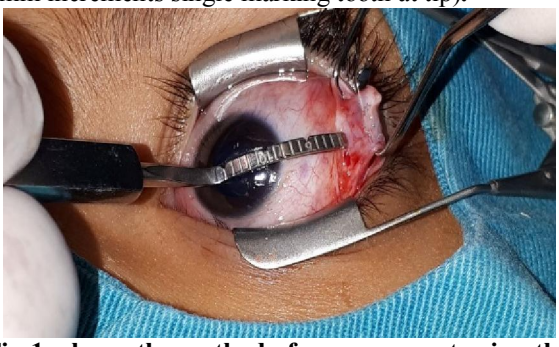

Fig 1: shows the method of measurement using the scleral ruler.

Histological part of the surgery: Sample size:

The study included four samples of the lateral rectus muscles and two samples of the medial rectusmuscles of strabismic patient and one sample of normal individual with no strabismus who underwent enucleation surgery. **Histological method:** The muscle samples were taken immediately and fixed in 10 % neutral formaldehyde for 24 hours. The specimens were cut then dehydrated in ascending grades of alcohol and xylol was used as a clearing agent. Impregnation was used in pure soft paraffin for two hours at 55C° followed by embedding in hard paraffin. Paraffin blocks were cut in to 3-5 µm sections that were stained by Haematoxylin and Eosin then examined under light microscope.

3. Results:

Table (1): The Statistical study

Measure	Eye	N	Mean	SD	Minimum	Maximum	Median	IQR
LR insertion to limbus distance (mm)	Right eye	19	7.26	0.86	6.00	9.00	7.00	6.63 to 8.00
	Left eye	19	7.29	0.92	5.50	9.00	7.00	7.00 to 8.00
	Average of both eyes	19	7.28	0.88	5.75	9.00	7.00	6.81 to 8.00
	All eyes	38	7.28	0.88	5.50	9.00	7.00	7.00 to 8.00
MR insertion to limbus distance (mm)	Right eye	12	5.79	0.58	4.50	7.00	6.00	5.50 to 6.00
	Left eye	12	5.79	0.50	5.00	7.00	5.75	5.50 to 6.00
	Average of both eyes	12	5.792	0.5312	4.750	7.000	5.875	5.50 to 6.00
	All eyes	24	5.79	0.53	4.50	7.00	6.00	5.50 to 6.00

N = number, SD = standard deviation, IQR = interquartile range.

Statistical results of the lateral rectus insertion distances:

A total number of38 lateral rectus muscles, 19 right sided and 19 left sided, of 11 males (57.9%) and 8 females (42.1%) included in this study. The minimum distance of the right and left lateral rectus muscle insertions from limbus were **6** mm and **5.5** mm respectively. The maximum insertion distance is **9** mm and **9** mm respectively. (Approximated by **0.5** mm). The average was taken for both right and left lateral rectus muscles and showed that the minimum insertion distance was **5.75** mm and the maximum insertion distance was **9** mm. The minimum insertion distance of all lateral rectus muscles regardless the side is **5.50** mm and the maximum insertion distance was **9** mm.

The mean insertion distances of the right and left lateral rectus muscles were **7.26 ± 0.86** mm and **7.29 ± 0.92** respectively. The average of the mean of both sides is **7.28 ± 0.88** mm. The mean of all lateral rectus muscles insertion distances is **7.28 ± 0.88** mm. The comparison of the mean of both sides lateral rectus insertion distances revealed p value of **0.5** that indicate insignificant difference between both sides, so the study reveal that the mean insertion distance of the Egyptian lateral rectus muscles is **7.28 ± 0.88** mm regardless the laterality. The mean insertion distance of the right lateral rectus muscles in males is **7.45 ± 0.76** mm and in females is **7.00 ± 0.96** mm. The comparison of the previous two values reveals p value of **0.26** which means that there is no significant difference in right lateral rectus insertion distance between Egyptian male and female. The mean insertion distance of the left lateral rectus muscles in males was **7.55 ± 0.76** mm and in females was **6.94 ± 1.05** mm. The comparison of the previous two values reveals p value of **0.16** which means that there is no significant difference in left lateral rectus insertion distance between Egyptian male and female. The mean of the average insertion distance of both eyes in males is **7.50 ± 0.75** mm and in females **6.97 ± 1.00**mm. The comparison of the previous values reveals p value of **0.2** and this indicates no significant difference in the insertion distance of the lateral rectus muscles between Egyptian males and females regardless laterality.

Statistical results of the medial rectus insertion distances:

A total number of 24 medialrectus muscles, 12 right sided and 12 left sided, of 8 males (66.7%) and 4 females (33.3%) included in this study. The minimum insertion distances of the right and left medial rectus muscles were 4.5 mm and 5.00 mm and the maximum were 7.00 mm and 7.00 mm respectively. The average of the minimum insertion distance of both sides was 4.75 mm and maximum was 7.00 mm. The minimum of insertion distances of all medial rectus muscles regardless laterality is 4.50 mm and maximum was 7.00 mm. The mean insertion distance of the right medial rectus muscles was 5.79 ± 0.58 mm and of the left medial rectus was 5.79 ± 0.50 mm, the average of both sides was 5.79 ± 0.53 mm. The mean of all medial rectus muscles regardless laterality was 5.79 ± 0.53 mm. Comparison between the mean insertion distances of the right and left sides revealed p value of 1.0 which mean that **there is no significant difference in between both sides.** Regarding the right medial rectus insertion distances, the mean values in males and females were 5.63± 0.52 mm and 6.13 ± 0.63 mm respectively. P value of both was 0.17 that indicates no significant difference in between genders in the right medial rectus insertion distance. Regarding the left medial rectus insertion distances, the mean values in males and females were 5.63± 0.35 mm and 6.13 ± 0.63 mm respectively. P value of both was 0.102 that indicates no significant difference in between genders in the left medial rectus insertion distance. Regarding the average of both sides medial rectus insertion distances, the mean values in males and females were 5.63± 0.42 mm and 6.13 ± 0.63 mm respectively. P value of both was 0.129 that indicates no significant difference in between genders.

B. Histological study:

Table 2: Histological report:

Number (N)	Lateral rectus muscle				Medial rectus muscle		control
	1	2	3	4	1	2	1
Fascicles	Few	Average	Few	Average	Few	Average	Average
Connective tissue	Excess	Excess	Excess	Excess	Excess	Excess	Average
Nuclei	Pyknotic	Multiple Central Pyknotic	Multiple Central Pyknotic	Pyknotic	Pyknotic	Pyknotic	Average
Vacuoles	-	Mild	-	Mild	Mild	Marked	-
Striations	-	+	-	-	+	-	++
Blood vessels	Congested	Congested	Congested	-	Thick-walled	-	-
Inflammatory cells	-	-	-	-	-	+	-

Table (3): Comparison of the Egyptians patient insertion distances with other nationalities:

Nationality	Egyptians	Taiwanese (14)	Western populations (15)	South Korea (16)
Measurement type	**Intraoperative**	**Intraoperative**	**Dissection**	**Intraoperative**
LR mean	**7.28± 0.88**	**6.4 ± 0.8**	**6.9 ± 0.7**	**5.8 ± 0.7**
LR N.	**38**	**130**	**100**	**60**
P value (LR)		**0.0001**	**0.0091**	**0.0001**
MR mean	**5.79± 0.53**	**5.3 ± 0.7**	**5.3 ± 0.7**	
MR N.	**24**	**133**	**100**	
P.value (MR)		**0.0014**	**0.0017**	

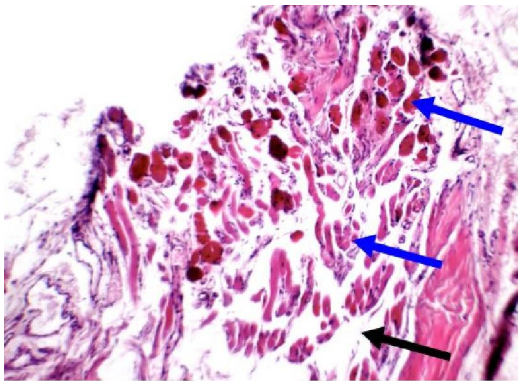

Fig 2: Lateral rectus muscle N.1: few fascicles of muscle fibers (blue arrows) embedded in excess loose connective tissue (black arrow) (Hand E X235).

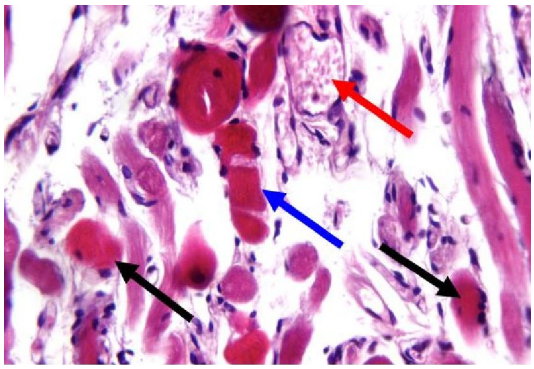

Fig 3: Lateral rectus muscle N: high power view of previous slide showing average muscle fiber with peripheral nuclei (blue arrow) and another fibers with small pyknotic nuclei (black arrows) in excess loose connective tissue showing congested blood vessel (red arrow) (HandE X 360)**.**

4. Discussion:

Table 3: (LR: Lateral rectus- LRN: Lateral rectus number-MR: Medial rectus- MRN: Medial rectus number- P value by unpaired *t* test).

The previous comparison shows statistically significant differences in the insertion distances between the Egyptians and mentioned nationalities in both lateral and medial rectus muscles.

Table 4: (LR: Lateral rectus- LRN: Lateral rectus number-MR: Medial rectus- MRN: Medial rectus number- P value by unpaired *t* test).

Nationality	**Egyptians**	Thai (2)	Mexican (8)	Indian (17)
Measurement type	**Intraoperative**	**Dissection**	**Dissection**	**Dissection**
LR mean	**7.28± 0.88**	**6.94 ± 0.49**	**7.76 ± 1.40**	**8.71 ± 2.54**
LR N	**38**	**46**	**20**	**40**
P value (LR)		**0.0281**	**0.1148**	**0.0015**
MR mean	**5.79± 0.53**	**5.70 ± 0.41**	**6.77 ± 0.61**	**7.34 ± 1.56**
MR N.	**24**	**46**	**20**	**40**
P.value (MR)		**0.4340**	**0.0001**	**0.0001**

The previous comparison shows statistically significant differences in the insertion distances between the Egyptians and mentioned nationalities in both lateral and medial rectusmuscles but there are no significant difference with Mexicans (in case of lateral rectus insertion distances) and Thai populations (in case of medial rectus insertion distances.

Table 5: (LR: Lateral rectus- LRN: Lateral rectus number-MR: Medial rectus- MRN: Medial rectus number – US: ultrasonography- P value by unpaired *t* test).

Nationality	**Egyptians**	**Italian (18)**	
Measurement type	**Intraoperative**	**intraoperative**	**US**
LR mean	**7.28± 0.88**	**6.25 ± 0.51**	**5.76 ± 0.60**
LR N	**38**	**19**	**19**
P value (LR)		**0.0001**	**0.0001**
MR mean	**5.79± 0.53**	**5.46 ± 0.76**	**5.61 ± 0.62**
MR N.	**24**	**19**	**19**
P.value (MR)		**0.1014**	**0.3109**

The previous comparison shows statistically significant differences in the insertion distances between the Egyptians and Italians in case of lateral rectus muscles regardless the measurement type.

There are no significant differences with Italians incase of medial rectus muscle insertion distances regardless the measurement type. The previous results show the accepted accuracy of using US in measuring the insertion distance.

Table 6: (LR: Lateral rectus- LRN: Lateral rectus number-MR: Medial rectus- MRN: Medial rectus number – AS-OCT: anterior segment optical coherence tomography - P value by unpaired *t* test).

Nationality	**Egyptians**	Chinese (19)	
Measurement type	**Intraoperative**	**intraoperative**	**AS-OCT**
LR mean	**7.28 ± 0.88**	**6.58 ± 0.53**	**6.80 ± 0.61**
LR N	**38**	**19**	**19**
P value (LR)		**0.0024**	**0.0376**
MR mean	**5.79± 0.53**	**5.32 ± 0.44**	**5.72 ± 0.60**
MR N.	**24**	**18**	**18**
P.value (MR)		**0.0040**	**0.6911**

The previous comparison shows statistically significant differences in the insertion distances between the Egyptians and Chinese populations in lateral rectus insertion distances regardless the measurement type. This indicates the accepted accuracy of AS-OCT in measuring the insertion distances. There is significant difference in medial rectus insertion distances as the measurement type was direct intraoperative while the difference is insignificant in case of using AS-OCT.

Histological result Discussion:

Our results coincide with the results obtained by **Yao J, et al.,** who worked 20 patients with intermittent exotropia and 5 patients without strabismus (were undergoing enucleation) and found that the muscle fibers of the medial recti in the normal controls were closely aligned in one direction with very little extracellular matrix. However, in patients with intermittent exotropia the medial recti showed pathological changes including varying fiber thickness, atrophy, abnormal alignment, internalized nuclei, excessive extracellular matrix, and even degenerated muscle fibers in a few patients. The pathological changes worsened with age and chronic strabismus (**11**). Our study also agreed with **Gralek M** and **Krawczyk T** in their study in which Light microscopy analysis included 131 fragments of rectus muscles, with the majority of lateral, collected from patients with concomitant squint of different angles and disease durations and concluded that Pathomorphological changes were observed with the majority of the extraocular muscles in the microscopic picture. The observed changes in the cellular structure of the extraocular muscles influenced the extent of the squint angle, affecting the result of surgery **(20)**. Alsoour results agreed with **Martínez AJ, Biglan AW** and **Hiles DA** in their study that had been done on Ninety extraocular muscle (EOM) biopsy specimens from 80 children with strabismus and normal ocular alignment and Light microscopy showed considerable variation inmuscle fiber shape and size with sarcomere disruption, sharp increases in endomysial and perimysial collagen, numerous vacuoles and subsarcolemmal inclusions (**13).** Also our results agreed with **Ferić-Seiwerth F, et al** who found that The changes of muscle tissue are found as well in convergent as in divergent squint, especially in insufficiency of convergence. The histological changes are more pronounced in monocular strabism but they can also be found in alternating squint. They are observed in early occuring strabismus, but especially frequently in patients with a large angle of squint, in cases of severe amblyopia and defective binocular vision **(12)**. In the other hand the histological results of this study disagree with **V. Forrester J.** who stated that in normal extraocular muscle there often appear to be histopathological or ultrastructural changes normally associated with myopathy, i.e. mild mononuclear cellular infiltrate, centrally placed nuclei, disorganization of the sarcolemma, disruption of the Z lines, and mitochondrial clumping **(21).** But it can be said that there were histological changes in the muscle samples due to traumatic manipulation during surgery. **Conclusion:** the previous results shows significant differences in the insertion distances between Egyptians and other nationalities that recommend the Egyptian ophthalmologists to consider these variations in their dose therapy of strabismus.

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