Anterior Segment Swept-source OCT in the Post-operatory Evaluation of Patients with Medial Rectus Surgery

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ABSTRACT

Purpose: Evaluate the Anterior Segment Swept-source Optical Coherence Tomography (AS-OCT) imaging features of medial rectus with previous surgery and to study the association of this features with the surgical plan.

Methods: Evaluation of 43 control eyes (Group A) and 25 eyes submitted to medial rectus surgery (Group B). AS-OCT scans were obtained on lateral gaze at a fixation light. Muscle insertion(MI) was detected using a graphical user interface(GUI) that identifies the corneo-scleral junction automatically and obtain a automatic muscle insertion to corneo-scleral(ML) distance. All algorithms and GUI were built as a unified tool in MATLAB.A receiver operating curve analysis (ROC) was used to identify cutt-off values from eye with previous muscle recession.

Results: In group B, 6 eyes were submitted to resection (23,1%), 5 eyes to faden operation (19,2%) and 6 eyes to recession (23,1%) and 8 eyes to a combination of recession and faden operation (34,6%). In group A, the mean ML distance was 5,12mm [+/-0,47mm]. On recession the mean ML distance was 7,50mm [+/- 1,01mm] and we found a strong correlation between the ML distance and the surgical plane ($r=0.77$; $p<0.01$). On faden operation the ML distance was not statistically different from Group A ($p=0.88$). In our resection cohort we verified that ML distance was statistically different from patients in control group ($p<0.01$) and non-different from eyes submitted to recession surgery.

Conclusion: AS-OCT evaluation of the ML distance have a strong correlation with the surgical plan and may identify with high sensitivity muscles submitted to surgery.

Keywords: Anterior segment optical coherence tomography, optical coherence tomography, muscle insertion, strabismus surgery, medial rectus

RESUMO

Objetivo: Avaliar as características imagiológicas de rectos medias submetidos a cirurgia e correlacioná-las com o plano cirúrgico.

Métodos: estudo de 43 olhos normais (grupo A) e 25 olhos submetidos a cirurgia de estrabismo (grupo B). Obtenção de scans longitudinais por tomografia de coerência óptica de segmento anterior swept-source (OCT-SA) durante fixação horizontal. Medição da distância limbo-músculo (ML) operatoriamente e em imagens de OCT-SA utilizando uma interface gráfica do utilizador programada em linguagem Matlab. A transição córneo-escleral e a distância ML foram obtidas automaticamente.

Resultados: No grupo B, 6 olhos foram submetidos a cirurgia de resseção (23,1%), 5 olhos a fio de Cüppers (19,2%), 5 olhos a retroinserção (23,1%) e 8 olhos a uma cirurgia combinada de retroinserção e fio de Cüppers (34,6%). No grupo A a média de distância ML foi 5,12mm[+/-0,47 mm]. Na retroinserção a média de distância ML foi 7,50mm[+/-1,01 mm] e foi possível estabelecer uma correlação estatisticamente significativa entre a distância ML e o plano cirúrgico. ($r=0.77$; $p<0.01$). Nos doentes submetidos a fio de Cüppers a média da distancia ML não foi diferente do grupo A ($P=0.88$). Mas nos doentes submetidos a encurtamento, a distância ML foi estatisticamente diferente do grupo de controlo. Foi possível estabelecer um cut-off de 5.90mm que distingue olhos submetidos a retroinserção (Sensibilidade=100%; Especificidade=85%).

Conclusão: A medição limbo-inserção muscular em OCT-SA utilizando uma interface gráfica customizada tem uma excelente correlação com o plano cirúrgico. OCT-SA revelou uma excelente sensibilidade na identificação de músculos submetidos a retroinserção

Palavras-Chave: Tomografia de coerência optica, tomografia de coerência optica de segmento anterior, cirurgia de estrabismo, inserção muscular, músculo recto medial

INTRODUCTION

On strabismus surgery, detailed knowledge of extra ocular muscle (EOM) insertion is fundamental to perform a personalized surgical plane.[13] In eyes that had undergone previous strabismus surgery, locating the muscle insertion can be a challenging task. Most of the times it is performed during surgical exploration, with a high impact on the amount of time needed for each reoperation.[11] Accurately determining the muscle insertion prior to surgery would allow the surgeon to operate with less risk and greater chance of overall success.[11]

Previous works have tried to localize muscle insertions using computerized tomography, magnetic resonance imaging, B-scan ultrasound and ultrasound biomicroscopy (UBM).[12] Of these, only UBM proofed a good correspondence with intra-operative measurements. However, the accuracy declines with distance from the limbus and as a contact technique, UBM appliance in young children will mostly involve a general anesthesia.

With the advent of Anterior segment optical coherence tomography (AS-OCT), there is an emerging scientific interest on this imaging technology. AS-OCT is an increasingly available method to evaluate and analyze anterior segment structures, most commonly the cornea, anterior chamber and iridocorneal angle. Previous works[6,10,11,14] had used AS-OCT to measure EOM insertion and to study the agreement between preoperative

EOM insertion and limbus distance (ML) on AS-OCT scans and intraoperatively measurement with surgical caliper. Liu et al[10] and De-Pablo-Gomez-de-Liano et al[6] evaluated virgin muscle insertion in 37 and 67 muscles, respectively. Ngo et al[11] evaluated 65 muscles in which 9 were undergoing reoperation and Rossetto et al[14] measured 144 muscles, of whom 33 were reinterventions. These works suggested that AS-OCT detects muscle insertion and obtain ML measure with consistent and reproducible values and with a high level of correspondence with surgical caliper measurement. However, most of these studies were done on virgin muscle insertion. Regarding eyes with prior strabismus surgery the information is scarce.

Our group has recently demonstrated the usefulness of a semi-automatic software measurement of lateral rectus muscle insertion after hang-back recession, aided by a reflectivity map of normal extra-ocular muscle.[3,4]

The purpose of this study was to evaluate the imaging features of medial rectus previously submitted to recession, resection or faden operation and to study the association of AS-OCT features and the surgical plan.

METHODS

Study design & Setting

Prospective and cross-sectional observational study with evaluation of consecutive patients without strabismus (Group A) and patients previously submitted to medial rectus faden operation, recession and resection surgery (Group B). Patients were enrolled from the strabismus,consultation between October 2016 and December 2016.This study was conducted in accordance with the tenets of the Declaration of Helsinki (1964) and institutional review board approval (Comissão de Ética para a Saúde).

Participants

Eligible patients had to meet the following inclusion criteria: Group A: patients without any muscle phoria, tropia or previous muscle surgery; Group B: Patients with primary esotropia and exotropia and at least three medical evaluations (pre-surgery, 1 month after surgery and 1 one year after surgery) 3) complete clinical evaluation on medical files; 4) medial rectus surgery performed at least 1 year before AS-OCT data acquisition We excluded patients with: poor collaboration; restriction on medial gaze; more than one previous medial muscle surgery; poor quality images in AS-OCT (signal strength index [SSI] lower than 80; absence of corneo-scleral junction identification on the image).

Data Sources

All patients underwent structural AS-OCT scans (SS-OCT; DRI OCT Plus,® Topcon, Japan). Patient demographic characteristics evaluated included: age, gender and age at surgery.

Measurement & Bias

All AS-OCT images were evaluated by two readers (C.R. and D.C) to identify medial rectus muscle location. Disagreement between readers was solved by a blind senior evaluation (G.V). All images were evaluated independently in a separate sitting, two months after the first initial image evaluation, and the ML distance values were used to evaluate inter and intra-examiner reproducibility.

Image Analysis acquisition

Image acquisition and analysis followed the previous published protocol.[3,4]

Image acquisition was done with a high-speed (100 000 A-scans/seconds) 1050-nm wavelength swept-source (SS-OCT; DRI OCT Plus,® Topcon, Japan). A commercial lens was adapted to the OCT for anterior segment imaging. All patients underwent 3 longitudinal scans obtained on lateral gaze at a 40º fixation light.

Images were exported as *Tagged Image File Format* (TIFF) for analysis.

Muscle insertion mean gray values were assessed by two different observers (C.D and R.C.) in a limited area of 200-300 pixels (Fiji, ImageJ). Limbus identification was performed automatically using custom algorithms that disclosed a typical reflectivity modification of the sclero-corneal junction. This typical landmark is depicted in figure 1 (middle): corneal stroma has an increased reflectivity comparing to scleral tissue, which facilitates the automatic identification of this region. Muscle insertion was selected manually using a graphical user interface (GUI). Manual selection was aided by a color-coded image showing either the average and standard deviation or the k-means algorithm classes. All algorithms and GUI were built as a unified tool in Matlab coding language. Measurement values were obtained automatically. The reproducibility of anterior segment OCT to evaluate rectus muscles anterior insertion has been assessed previously by various authors[6,10,11,12,14] The usage of MATLAB to fine-tune this technique has also been previously validated.[3,4]

Fig.1 and Fig.2 illustrate GUI measurement in normal and post-surgery representative cases, respectively.

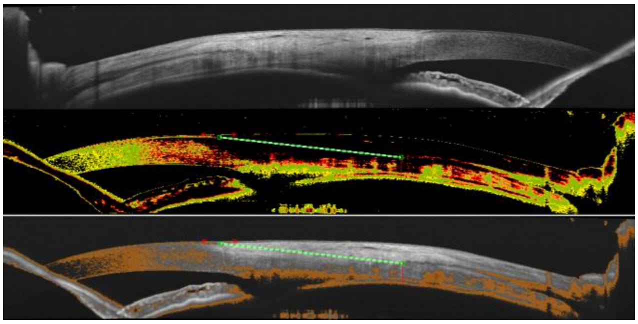

Figure 1 - Graphical user interface with application of algorithms and customized filters in a representative normal patient. Acquisition of preoperative image of the internal rectus muscle of the left eye with a 16mm cut centered on the pupillary axis. **(top)** Automatic detection of the surgical limb by the application of algorithms based on the radius of curvature and reflectivity of the tissues **(middle)** Application of color filter according to tissue reflectivity. Green identification of mean reflectivity +/- two standard deviations, yellow reflectivity > two standard deviations to the right and red reflectivity <two standard deviations to the left **(bottom)** Automatic measurement between the surgical limbo and the muscular insertion, obtaining a value of 4.58 millimeters, and of the scleral thickness, obtaining a value of 0.55 millimeters.

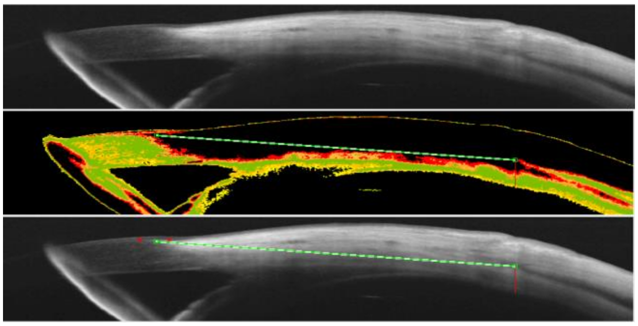

Figure 2 - Graphical user interface with application of algorithms and customized filters in a representative patient previously submitted to recession surgery. Image acquisition of the external rectus muscle of patient who performed internal rectus recession (4 mm) 3 years before. Right eye, 16mm cut centered on the pupillary axis. **(top)** Automatic detection of the surgical limb by the application of algorithms based on the radius of curvature and reflectivity of the tissues; **(middle)** Application of color filter according to tissue reflectivity. Green identification of mean reflectivity +/- two standard deviations, yellow reflectivity> two standard deviations to the right and red reflectivity <two standard deviations to the left; **(bottom)** Automatic measurement between the surgical limbo and the muscular insertion, obtaining the value of 7.68 millimeters and of the scleral thickness, obtaining a value of 0.58 millimeters.

Statistical Analysis:

We performed an exploratory analysis of the demographic, clinical, and AS-OCT (scleral thickness, ML distance) measurements. Continuous variables are presented as mean and standard deviation (SD) or median and interquartile range (25th percentile - 75th percentile), as appropriate.

For the analysis of repeated measures we used the calculation of the intraclass correlation coefficient (ICC) based on the variance. ICC values range from 0 to 1 and represent the correlation between the measurements. It was defined that the values of 0.8 to 0.9 would be good and above 0.9 excellent.

We analyzed the association between ML distance and the surgical procedure (recession, faden operation or resection surgery). Means comparison of ML values between the surgical groups and the control was issued using Mann-Whitney test. The discriminative ability to distinguish between operated and no-operated eyes was measured by the area under the receiver operating characteristic (ROC) curve (AUC), higher AUC values indicating better discriminative ability. A level of significance α=0.05 was considered. All statistical analyses were performed using SPSS (SPSS *statistics 22* for Windows; SPSS Inc., IBM, Somers, NY).

RESULTS

Demographic and clinical data

A total of 69 eyes of 62 consecutive patients were included in this study: 43 control patients (43 eyes, group A) and 19 patients (25 eyes, group B). In group B, 6 eyes were submitted to resection (23,1%), 5 eyes to faden operation (19,2%) 6 eyes to recession (23,1%) and 8 eyes to a combination of recession and faden operation (34,6%). The demographic, clinical, and AS-OCT characteristics of the study patients have been summarized in Table 1

Table 1 - Demographic and Clinical data of Patients

	Group A N=43	**Group B N=19**
Age at inclusion (years)	14.6 (3.8)	12.4 (4.7)
Age at surgery (years)	-	8.29 (4.2)
Female (%)	20 (46.5%)	7 (36.9%)

Normal patients and reproducibility evaluation

Scleromuscular juntion was evaluated in all normal patients. We found hyporreflective tissue similar to the muscular belly with small islands of hyperreflective tissue. The mean value of the reflectivity of the muscle insertion zone was 71.44 [+/- 10.35]. This value was further exported for MATLAB for the construction of a colour filter based on the distribution of reflectivity values Fig.1 (middle) and Fig.2 (middle).

Normal patients and reproducibility evaluation

In group A, the mean ML distance was 5,12mm [+/- 0,47mm] and the mean ST on the muscle insertion was 0,55mm [+/- 0,07mm]. Inter- and intra-observer ML distance reproducibility was assessed by the intraclass correlation coefficient (ICC) with excellent results (all ICC values > 0.9 (p <0.001)). In table 2 we detail conservatively and in detail the ICC values discriminated by AS-OCT parameters and observers.

Table 2 - Summary of the calculations of the intraclass correlation coefficient for a confidence interval of 95%

n=43	O_{1A}- O_2	O_{1A}- O_{1B}
MR ICC (p-value)	0,940 (<0,001)	0,945 (<0,001)
ST ICC (p-value)	0,960 (<0,001)	0,973 (<0.001)

O1A - first measurement performed by observer number one; O2 - measurement by observer number two; O1B - second measurement performed by observer number one, two months after initial observation; MR – medial rectus muscle; ST – scleral thickness; ICC – Intraclass correlation

Table 3 - Patients' characteristics and OCT-A parameters per surgical group

	Resection Surgery (n=6)	Isolated Faden Operation (n=5)	Recession Surgery
Surgical Dose (mm), median (IQR)	6.0 (5.75-6.6)	-	4.0 (3.5-4.5)
Muscle-limbus distance (mm), mean (SD)	7.58 (1.54)	4.92 (0.39)	7.50 (1.01)
Scleral thickness (mm), mean (SD)	0.49 (0.11)	0.48 (0.05)	0.44 (0.05)

Evaluation of eyes with previous medial rectus surgery

In group B, the muscle insertion was identified in all the cases. Concerning the eyes submitted to recession or recession + faden operation, the median surgical dose was 4,0mm [IQR 3,50 - 4,50mm]. For statistical purposes patients submitted to recession or recession and faden operation were considered as a single group. In patients submitted to resection surgery the ML distance was statistically different from patients in Group A (p <0.01) and non-different from eyes submitted to recession surgery. In patients submitted to isolated faden operation the ML distance was not statistically different from patients in Group A (p = 0.88). In patients submitted to muscle recession, the mean ML distance was 7,50mm [+/- 1,01mm]. This differed statistically from group A (p<0.001).

We found a strong linear correlation between the distance to limbus and the surgical plane (r=0.77; p<0.01). ML distance proofed to be a very strong discriminative factor between eyes previously submitted to recession surgery vs surgery naïve eyes and eyes with an isolated faden operation (AUC = 1.0). A cut off point of 5.90 mm was established (Sensitivity = 100%; Specificity = 100%). Fig 3 summarizes ML distances in patients previously submitted to recession surgery or faden operation vs normal patients.

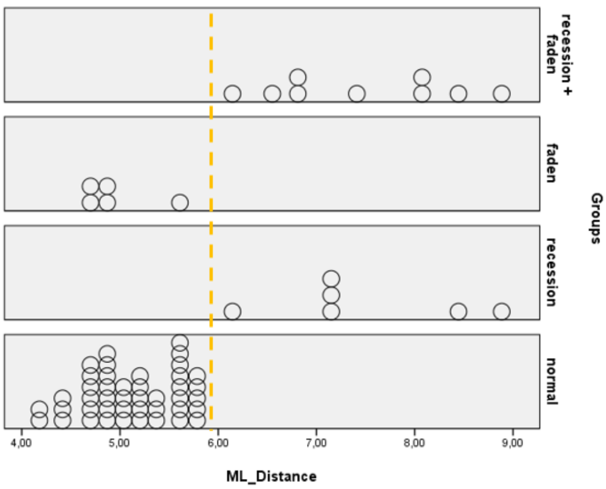

Figure 3 - **Muscle-limbus distance in patients with a previous recession or faden operation.** Distribution of muscle to limbus (ML) distances measured automatically depicts a well-defined boundary between eyes with a previous recession surgery vs surgery naïve eyes and eyes with a previous faden operation. A cut-off value is depicted using an orange dotted line.

DISCUSSION

Capitalizing on the higher axial resolution of MATLAB software, we identified corneo-scleral limbus automatically and applied specific filters based on a reflectivity of normal medial rectus muscle insertion to identify extra-ocular muscles in AS-OCT scans. We demonstrated an excellent inter-examiner reproducibility and repeatability of this approach, similar to our previous results reported with this software.[3,4] We found that in previously operated eyes AS-OCT evaluation of muscle-limbus distance have a strong correlation with the surgical plan. We propose a new cut off point with a high discriminative power to distinguish between eyes with a previous recession surgery from eyes without previous surgeries.

To the best of our knowledge, we provide the first evidence that specific algorithms can have advantages in the identification of eyes with prior strabismus surgery.

The first description of muscle-limbus distance (ML) reports to a study conducted by Fuchs[1,7] more than 100 years ago on a 31-autopsy sample, with a description a medial rectus ML of 5.5 mm. Later, Joseph Goldstein[8] performed an intraoperative study of in 72 medial rectus and found that ML distance range from 3,5mm to 6,0 mm. Stark et al[15] had also measured the ML distance during strabismus surgery in 675 medial rectus and found a mean ML distance of 4,5 mm. Recently, Liu et al[10] examined 18 medial rectus, using AS-OCT, and described a mean ML of 5.32 [± 0.44 mm].

The sclera decreases gradually in thickness as it approaches the equator of the globe (0.4 –0.6 mm), becoming thinnest under the rectus muscles just before its insertion sites (0.3 mm). It then gradually increases, measuring about 0.6 mm at the actual muscle insertion sites.[17]

Performing AS-OCT evaluation of ML distance on 43 patients without strabismus, we found a mean ML distance of 5,12mm [+/- 0,47mm] and a mean scleral thickness of 0,55mm [+/- 0,07mm] at the level of medial rectus insertion. Our results are in agreement with previous works conducted with AS-OCT.

From histological studies in humans, we know that tissue at the scleromuscular junction contains striated muscle with minimal connective (tendinous) tissue connecting to the sclera.[9] Evaluating the scleromuscular junction in AS-OCT, we found hyporreflective tissue similar to the muscular belly with small islands of hyperreflective tissue, that may correspond to tendinous tissue. Thereby, our results agree with histological studies that scleromuscular junction contains striated muscle with minimal connective (tendinous) tissue connecting to the sclera.

Medial rectus recession is the standard weakening procedure for rectus muscle. In this surgery a removal and reattachment of muscle insertion is performed, so that the muscle insertion is closer to its origin.[2] We evaluated 15 eyes submitted to recession, with a median surgical dose of 4mm. With our software it was possible to clearly detect muscle insertion from as far as 9,80mm. Employing ultrasound biomicroscopy it is possible to evaluate medial rectus insertions from as far as 11,2 mm - 12 mm[5,16] from the limbus. However, this technique is more user dependent than AS-OCT, which renders our approach more feasible for routine practice. We found a strong linear association between AS-OCT measurement of the ML distance and the surgical plane. We were also able to found a cut-off value with a very high discriminative power (AUC = 0.93) to distinguish between recessed muscles and muscles with a virgin attachment. This value may proof to be useful for the evaluation of patients in whom there is no information regarding previous medial rectus surgeries. Further works may explore this correlation on a larger cohort to determine if it is possible to establish cut-off points according to the surgical plan, which was not possible in this study due to the small number of patients.

Faden operation is a surgery commonly performed to weak the rotational force of the eye by suturing the muscle belly to the sclera, 12-14mm posterior to the muscle insertion. This surgery is performed without moving the virgin muscle insertion.[2] On AS-OCT scans we demonstrated that there was no difference in ML comparing to the control group. We could not recognize any specific feature in the eyes with a faden operation of our cohort, highlighting the limitation of AS-OCT to evaluate medial rectus modifications beyond 10 mm from the limbus.

Resection is considered the standard surgery to strengthen the rectus muscle. In this procedure, the muscle is shortened by removing the anterior part and reattaching the remaining muscle to the original insertion site. In our cohort we found that ML distance was statistically different between patients who had undergone resection procedures and the control group ($p < 0.01$). In contrast, no statistically significant difference was found between the patients that had undergone resection procedures and the ones submitted to recession surgery. This result may seem counter-intuitive, as one would expect to find an equal ML distance in resected medial rectus muscles and in the non-operated eyes.[2] In our opinion, the absence of tendinous tissue and a disarray of the normal tendinous anatomy may limit the evaluation of the scleromuscular junction by AS-OCT. Our results might be explained by the presence of a stretched muscle belly and not the scleromuscular junction. Further works might explore these modifications in a larger cohort and es3lish different patterns of the scleromuscular junction, which unfortunaty was not possible in this study due to the small number of patients.

Strengths of our study include a designed semi-automated software for AS-OCT scans. Employing Matlab coding language it was possible to include algorithms and filters not able on commercial AS-OCT. These enable to identify automatically the surgical limbo and semi-automatically the muscular insertion, avoiding the bias of subjectivity inherent to manual measurement in grayscale and obtaining a very low variability between ML measures.

Other advantage is the use of a high wavelength from the swept source OCT imaging modality that allows us to obtain higher resolution image on the muscle insertion zone.

Our study has inherent limitations to the cross sectional design and image acquisition. The reduced recruiting time (3 months) implied a limited number of patients suitable for inclusion. There were also patients excluded because of the poor image quality, which can induce a selection bias chargeable to the exclusion of patients with ocular movements restriction and with nystagmus.

Another limitation of this work is the inclusion of patients ranging 9-20 years old. The applicability of this protocol to younger patients need to be established by further studies. Some authors claim that muscle to limbus distance may be directly proportional to the axial length. However, as all the patients had more than 3 years old (when the globe reaches 95% of the axial length)[1], we didn't include this co-variate in the analysis.

Anterior segment swept-source can identify with a high discriminative power muscles previously submitted to surgery using a cut-off of 5.90 mm. This method may be a feasible imaging modality for the study of extra-ocular muscle anatomy in routine clinical practice. Semi-automatic AS-OCT software provides excellent reproducibility results, is time and labour sparing and is a new potencial tool for the preoperative assessment in cases of strabismus reoperation.

REFERENCES

1. Apt L, Call NB. An anatomical reevaluation of rectus muscle insertions. Ophthalmic Surg. 1982
2. Bérard, P. V. ., Quére, M.A.; Roth, A., Spielmann, A. & Woillez, M. . Chirurgie Des Strabismes. Masson, 1984.
3. Cabral D, Pereira T, Rodrigues P, Franca M, Camacho P, Rodrigues C, Seldon R, Braz F, Varandas G. Anterior Segment swept-source Optical Coherence Tomography evaluation of patients submitted to lateral recti hang-back recession surgery. Acta Ophthalmologica. 2018
4. Cabral D, Pereira T, Rodrigues P, Franca M, Camacho P, Rodrigues C, Seldon R, Braz F, Varandas G. Tomografia de Coerência Óptica do Segmento Anterior swept-source na avaliação pós-operatória de doentes com exotropia. Oftalmologia. 2019
5. Dai S, Kraft SP, Smith DR, Buncic JR. Ultrasound Biomicroscopy in Strabismus Reoperations. J AAPOS. 2006.
6. de-Liaño L, Fernández-Vigo JI, Ventura-Abreu N, Morales-Fernández L, García-Feijóo J, Gómez-de-Liaño R. Concordancia de la distancia desde la inserción hasta el limbo de los músculos rectos entre la medida intraoperatoria y con tomografía de coherencia óptica. Arch Soc Esp Oftalmol. 2016
7. Fuchs E. Beitrage zur normalen Anatomie des Augapfels. Albrecht von Graefes Archiv für Ophthalmologie 1884;
8. Goldstein J. Strabismus and Insertion of Horizontal Rectus Muscles. Am J Ophthalmol. 1969.
9. Jaggi GP, Laeng HR, Müntener M, Killer HE. The anatomy of the muscle insertion (scleromuscular junction) of the lateral and medial rectus muscle in humans. Investig Ophthalmol Vis Sci. 2005
10. Liu, X., Wang, F., Xiao Y. Anterior segment optical coherence tomography for identifying muscle status in strabismus surgery. Int J Ophthalmol; 2016
11. Ngo CS, Smith D, Kraft SP. The accuracy of anterior segment optical coherence tomography (AS-OCT) in localizing extraocular rectus muscles insertions. American Association for Pediatric Ophthalmology and Strabismus; 2015.
12. Patel JR, Gunton KB. The role of imaging in strabismus. Curr Opin Ophthalmol. 2017

13. Rosenbaum, A. L. & Santiago AP. Clinical Strabismus Management: Principles and Surgical Techniques. 1999
14. Rossetto JD, Cavuoto KM, Allemann N, McKeown CA, Capó H. Accuracy of Optical Coherence Tomography Measurements of Rectus Muscle Insertions in Adult Patients Undergoing Strabismus Surgery. Am J Ophthalmol. 2017.
15. Stärk N KH. Distance of muscle insertions in the corneal limbus. Klin Monbl Augenheilkd. 1986
16. Thakur N, Singh R, Kaur S, Kumar A, Phuljhele S, Sukhija J. Ultrasound biomicroscopy in strabismus surgery: Efficacy in postoperative assessment of horizontal muscle insertions. Strabismus. 2015
17. Watson PG, Young RD. Scleral structure, organisation and disease. A review. Exp Eye Res. 2004.

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