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ORIGINAL PAPER

# Measurement of extraocular horizontal muscle insertion distance via anterior segment optical coherence tomography of healthy children and comparison with healthy adults

**Osman Bulut Ocak · Asli İnal · İhsan Yilmaz · Ebru Demet Aygit · Serap Yurttaser Ocak · Selcen Celik · Muhittin Taskapili · Birsen Gokyigit**

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**Abstract**
*Purpose* The aim of the study was to determine the corneal limbus–extraocular muscle insertion distance (LID), via anterior segment optical coherence tomography, in healthy children and healthy adults and to compare the results of the measurements of the two groups.
*Methods* Muscle limbus distances were measured using AS-OCT in 60 healthy cases in two groups. Children aged 8–13 years were evaluated as group 1, and healthy adults aged 25–30 years were evaluated as group 2. Measurements of 120 horizontal muscles were taken by one doctor (OBO). The values were compared according to age and gender groups, and correlation between LID measurements and spherical equivalent. Statistical evaluation was performed using SPSS 16® for Windows with the Student's *t* test and Pearson correlation coefficient test.
*Results* LID measurements for MR and for lateral rectus (LR) were 5.74 ± 0.75 and 6.74 ± 1.11 mm, in the pediatric age-group, and 5.73 ± 0.75 and 6.84 ± 1.15 mm, in the adult age-group, respectively. There was no statistically significant difference between the two groups in terms of MR distances. There was a slight increase in the adult values, for the LR distance. There was no significant difference in terms of gender. Correlation was found 0.62 for MR and 0.46 for LR between LID measurements and spherical equivalent in the pediatric age-group.
*Conclusions* In healthy individuals, different imaging modalities can be used to measure LID, but AS-OCT can be used in pediatric age-groups as a preferred imaging method because it is easy and noninvasive.

**Keywords** Anterior segment optical coherence tomography · Children · Horizontal muscles · Limbus–insertion distance

O. B. Ocak (✉) · A. İnal · İ. Yilmaz · E. D. Aygit · S. Celik · M. Taskapili · B. Gokyigit
Beyoglu Eye Education and Research Hospital, University of Health Sciences, Bereketzade Mah, Meşrutiyet Cad No:73, 34421 Istanbul, Turkey
e-mail: bulutocak@gmail.com

S. Y. Ocak
Department of Ophtalmology, Okmeydanı Education and Research Hospital, University of Health Sciences, Kaptan Paşa Mah, Darülaceze Cad. No:25, 34384 Okmeydani, Istanbul, Turkey

## Introduction

Localization of insertions of extraocular muscles (EOMs) and corneal limbus–insertion distance (LID) measurements are important in preoperative planning for strabismus surgery [1]. Several methods of imaging have been used to identify EOM insertions and their distances from the limbus [2–6]. Computerized tomography (CT) and magnetic resonance imaging

(MRI) are successful methods for imaging the EOM localizations; however, they are insufficient to assess LID [2, 3]. LID can be measured successfully by ultrasound bio-microscopy (UBM); however, measurements can be taken only under general anesthesia in pediatric cases due to the difficulties in the procedure [4, 5]. LID measurements have not been taken in healthy children using UBM.

Anterior segment optic coherence tomography (AS-OCT) allows LID measurements without the need for general anesthesia due to its high resolution and easy performance [6–11]. AS-OCT studies show that LID measurements were compatible with intra-operative measurements with calipers and had similar results with repetitive measurement [6, 7, 9–11].

The study by Ngo et al. [9] in patients with strabismus in childhood is the only study in which pediatric cases are included. No study has been published about the comparison measurements of the LID with AS-OCT between healthy children and healthy adults.

The aim of this study was to determine the LID of horizontal rectus muscles via AS-OCT in a healthy pediatric age cohort and to compare this with healthy adult individuals.

## Patients and methods

This study is a retrospective, comparative, and cross-sectional study of 60 healthy adult cases (aged 20–25 years) and 60 healthy pediatric cases (aged 8–13 years) who were referred to our hospital between December 2015 and December 2016. This study was compatible with the Declaration of Helsinki, and the approval from our hospitals ethics committee was obtained. Consent forms were signed by the parents of all the pediatric cases and by all cases in the adult group for measurement and evaluations.

The inclusion criteria were: being between 8 and 13 years old and having 20/20 visual acuity in both eyes as assessed with Snellen charts.

The exclusion criteria were: history of any ocular disease or any systemic disease that may affect the eyes, history of previous intraocular surgery, or spherical or cylindrical refractive error greater than 1 diopter. Patients under the age of 8 were excluded due to possible cooperation difficulties in LID measurements.

The sample size was estimated using the free-software G*Power 3.1.9.2 (Franz Faul, University of Kiel, Kiel, Germany) [12]. With a power of 80%, a 0.05 statistical level of significance, and an effect size of 0.80, the sample size for each group was calculated to be 51 patients in each group.

We recruited 60 adult controls from subjects who visited our clinic and had no ocular or systemic disease, no refractive spherical or cylindrical error greater than 1 diopter, and 20/20 visual acuity in both eyes. The right eye was designated as the study eye for the study and control subjects. Eligible patients were included consecutively until both the patient and control groups reached 60 participants. Healthy children and adults were grouped as group 1 and group 2, respectively.

### Examination

Full ophthalmological examination, including refraction (cycloplegic refraction via retinoscopy), visual acuity, slit-lamp bio-microscopy, and dilated fundoscopy, was performed in all cases. The visual acuity was measured via Snellen chart from 5 m. Cycloplegic refractions were measured by dropping three times cyclopentolate hydrochloride (1%) for 5 min and then waiting 45 min. Cases', ages, genders, and cycloplegic values as spherical equivalent were recorded. The LID of the extraocular horizontal muscles of the right eyes of the cases were measured by VISANTE®—OCT (Carl Zeiss, Meditec, Germany) after ophthalmological examination. All measurements were taken by a single physician (OBO) with 20× magnification. Cases were required to make a 15° temporal gaze for MR measurement and to make a 30° nasal gaze for LR measurement, guided by a fixation light during the measurement by VISANTE®—OCT. During the measurement, the starting point of the space between the muscle and sclera was accepted as the insertion point of the muscle. The distance between the localized insertion of the muscle and anterior camera angle/iris root was measured using a caliper, which was included in the program (Figs. 1, 2). LIDs were defined by adding 1 mm, i.e., the mean distance from the anterior camera angle and limbus based on previous studies, to the measured distances [6, 7, 9]. Subgroupings by age in group 1, and gender were defined in both groups. Axial length (AL) was

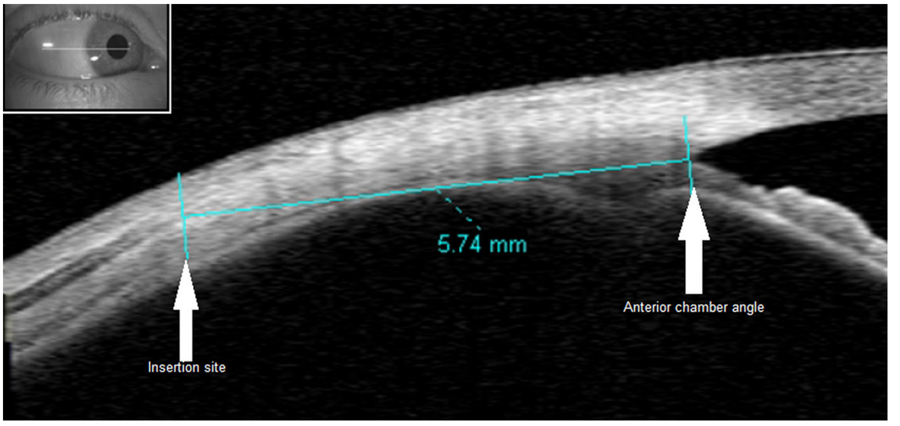


**Fig. 1** AS-OCT image of a lateral rectus muscle and anterior chamber–muscle insertion distance measurements with the program's caliper

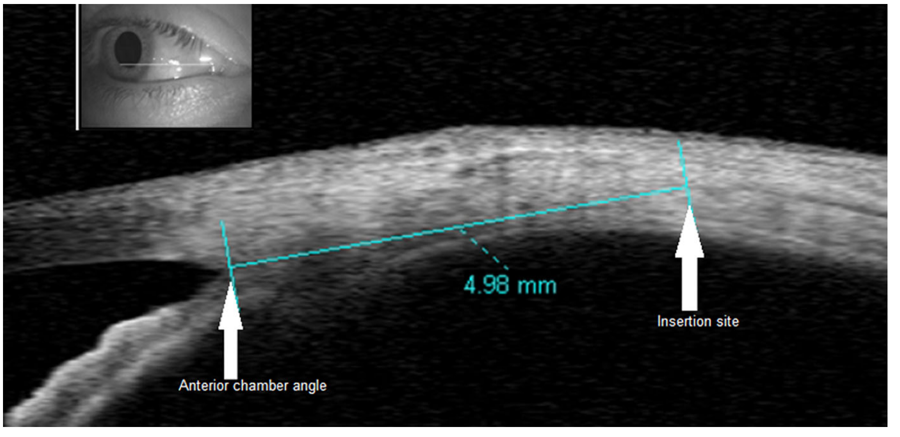


**Fig. 2** AS-OCT image of a medial rectus muscle and anterior chamber–muscle insertion distance measurements with the program's caliper

measured using the IOL Master 500 (Carl Zeiss, Meditec, Germany) at pediatric age-group.

All measurements were evaluated retrospectively, and the LIDs in the pediatric and adult groups were recorded and statistically compared after the evaluation of the measurement. In addition, the gender distribution in the groups was defined, and any differences between the genders within the groups were evaluated. Statistical analysis was performed using an independent-sample *t* test (Student's *t* test) as a parametric test with SPSS® 16 for Windows. $p < 0.05$ was considered statistically significant.

In pediatric age-group, the linear relationships between LID measurements and spherical equivalent and age and AL were evaluated with Pearson correlation coefficient.

## Results

### Group 1

Thirty-six cases (60.00%) were males and 24 (40.00%) were females among the pediatric cases. The mean age was 10.80 ± 1.77 years (range 8–13 years). Eight patients to age 8 (13.34%), 9 patients to age 9 (15.00%), 13 patients to age 10 (21.66%), 8 patients to age 11 (13.34%), 9 patients to age 12 (15.00%), and 13 patients to age 13 (21.66%) included this study. Mean spherical equivalent was + 1.50 ± 1.25 diopters (D) (range − 0.50 to + 2.25 D). Mean AL was 22.86 ± 2.01 mm (range 20.71–24.90). MR and LR LIDs in total and in the subgroups according to gender in group 1 are listed in Table 1. LID measurements in the subgroups according to age in group 1 are shown in Fig. 3.

**Table 1** Mean LIDs in groups 1 and 2 with subgroups

| | Group 1 | | | Group 2 | | |
|---|---|---|---|---|---|---|
| | Male ($n$ = 36) | Female ($n$ = 24) | Total ($n$ = 60) | Male ($n$ = 20) | Female ($n$ = 40) | Total ($n$ = 60) |
| LID for MR (mm) [range (mm)] | 5.73 ± 0.78 [4.31–7.72] | 5.75 ± 0.75 [4.34–7.65] | 5.74 ± 0.75 [4.31–7.72] | 5.70 ± 0.25 [4.45–7.76] | 5.77 ± 0.75 [4.41–7.68] | 5.73 ± 0.75 [4.41–7.76] |
| LID for LR (mm) [range (mm)] | 6.74 ± 1.25 [5.11–7.74] | 6.75 ± 1.35 [5.14–7.96] | 6.74 ± 1.11 [5.11–7.96] | 6.84 ± 1.25 [5.12–8.06] | 6.84 ± 1.17 [5.15–8.16] | 6.84 ± 1.15 [5.12–8.16] |

*LID* limbus–insertion distance, *Group 1* children group, *Group 2* adult group, *MR* medial rectus, *LR* lateral rectus

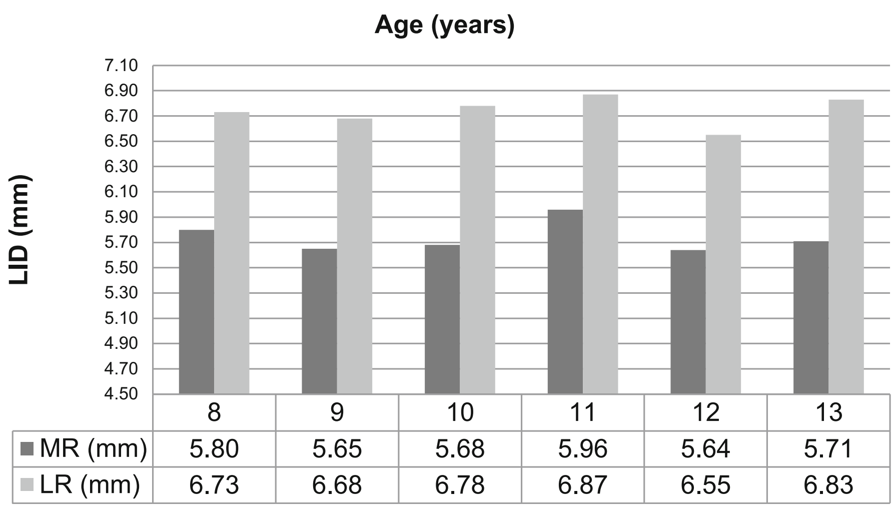


**Fig. 3** Mean limbus–insertion distance (LID) measurements medial rectus (MR) and lateral rectus (LR) via AS-OCT divided by age in group 1

Group 2

Forty cases (66.66%) were males and 20 (33.34%) were females among the adult cases. The mean age was 22.45 ± 1.46 years (min 25–max 30 years), and the mean spherical equivalent was + 0.78 ± 1.21 (min − 0.25 to max + 1.75). The LIDs in total and in the subgroups according to gender in group 2 are listed in Table 1.

Between group 1 and group 2, no statistically significant differences were found in the LIDs of either MR or LR ($p > 0.05$).

No statistically significant difference was found in the distances according to gender in groups 1 and 2 ($p > 0.05$).

MR measurements were completely similar to each other in the two groups. Although the difference in the LR LID measurements between the two groups was statistically insignificant, the mean LR LID measurement values were lower in group 1 (Table 1).

In the pediatric age-group, moderate positive relationship between LID measurements and spherical equivalent (0.62 for MR, 0.46 for LR) and very poor positive relationship between LID measurements and age and AL (Pearson test, 0.06 and 0.15 for MR, 0.09 and 0.18 for LR) were found using Pearson correlation coefficient.

## Discussion

LID measurements were reported to differ according to various factors, such as gender, ethnicity, and age, in morphological studies based on direct measurement [1, 13, 14]. Studies associated with the anatomical structure of EOM were conducted with advancements in imaging methods. CT and MRI successfully demonstrated the localization and thickness of muscles and tendon length [2, 3, 15]. LID was determined with a high accuracy in studies performed with UBM

[4, 5]. Pediatric age-groups were also evaluated in studies using those imaging modalities; however, the evaluations were performed either before strabismus surgery under general anesthesia or in older age-groups [4, 5, 16].

AS-OCT was first studied by Liu et al. [6] in 2011 to view the insertion points of EOMs and to determine the LID. In this study, LID measurement of the horizontal EOM of 16 adult patients with strabismus was defined preoperatively by AS-OCT and was reported to be correlated with the measurement taken intraoperatively by caliper. Park et al. [7], in their AS-OCT study, demonstrated that variable head positions had no effect on the measurement results.

The results of the studies about the LID values of MR and LR in healthy or strabismic adults and the results of our study are listed in Table 2. The results of our study were similar to studies in the literature.

The study by Ngo et al. [9] in 2015 is the only AS-OCT study performed in the pediatric age-group; children with strabismus were evaluated in that study. The LID was evaluated by AS-OCT in cases to be operated on for the first time and in cases with a history of strabismus surgery, and the results of the preoperative measurement by caliper was compared between these groups. AS-OCT had a 78% imaging success rate and good correlation between AS-OCT and the intraoperative caliper measurement, even in horizontal EOM that underwent operation. Besides the compatibility of AS-OCT and intraoperative caliper measurement, AS-OCT's advantages are that the measurements are quick and thus avoid concentration problems in the pediatric age-group. There was no difficulty in determining the horizontal EOM reference points. The main advantage of AS-OCT is the elimination of the necessity of general anesthesia in order to perform the measurement in the pediatric age-group, which will let us obtain normative data in healthy children in a predetermined age range. Also, AS-OCT can easily assess the LIDs in strabismus patients, which a history of strabismus surgery but inadequate medical records for preoperative planning. We aimed to report the results of LID measurements in healthy children in a Turkish population in an age range of 8–13 years. We found the mean LID value for MR was 5.74 mm and for LR was 6.74 (Table 1).

This is the first study to compare the LID of horizontal EOM between healthy children and healthy adults via AS-OCT.

Although no statistically significant differences were found when the values of children were compared to the results of healthy adults (mean LID value for MR was 5.73 mm and for LR was 6.84 in healthy adults), the mean LID value for MR in adults was a little higher than that of the children. Both MR and LR LID values were similar to each other in both genders in both groups (Table 1).

Souza-Dias et al. [17] found that there was no statistically significant correlation between LIDs and refraction. We found moderate correlation between thus (Pearson correlation coefficient test, 0.62 for MR, 0.46 for LR). De-Pablo-Gómez-de-Liaño et al. [18] reported the LID values acquired using spectral domain and that they found no correlation in LIDs in

**Table 2** LID values of MR and LR of adult cases in the literature

| | Mean LID for MR (range LID for MR; mm) | Mean LID for LR (range LID for LR; mm) | Mean of age (range of age; years) |
|---|---|---|---|
| Liu et al. [6] | 5.72 ± 0.60 (4.62–6.82) | 6.80 ± 0.61 (5.8–7.86) | 28.65 ± 8.89 (19–46) |
| Park et al. [7] | 5.5 ± 1.0 (3.1–7.1) | 6.2 ± 0.6 (4.9–8.3) | 28.8 ± 5.2 (21–41) |
| 40° angle* | 5.4 ± 1.4 (2.6–8.6) | 5.8 ± 0.6 (4.8–6.8) | |
| 50° angle* | 5.1 ± 1.2 (2.7–8.2) | 6.4 ± 0.8 (4.9–9.2) | |
| 60° angle* | | | |
| Pihlblad et al. [10] | 5.7 ± 0.8 (4.3–7.8) | 6.8 ± 0.7 (4.8–8.4) | 40.8 ± 17.2 (21–79) |
| Current study | 5.73 ± 0.75 (4.41–7.76) | 6.84 ± 1.15 (5.12–8.16) | 22.45 ± 1.46 (25–30) |

*LID* Limbus–insertion distance, *MR* medial rectus, *LR* lateral rectus

*Angle between visual axis and the scanning axis terms of age and AL. In this study, we evaluated the LIDs of patients aged 6–85 years and did not divide the patients into subgroups according to age. We found very poor positive correlation between LIDs and age and AL (Pearson test, 0.06 and 0.15 for MR, 0.09 and 0.18 for LR) in pediatric group.

The limitations of this study are that all age-groups were not evaluated separately by age, children under 8 years old were excluded from the study, and the measurements were taken in a relatively small number of healthy individuals.

In conclusion, AS-OCT will help us to obtain normative data in healthy human populations in addition to being able to accurately and reliably measure LIDs.

**Authors' contributions** OBO, AI, and BG were involved in conception and design. IY, EDA, and SC collected the data. OBO, AI, SYO, and MT performed the analysis and interpretation.

**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical standard** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

**Human and animal rights** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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