Changes in Anterior Chamber Dimensions Following Small Incision Lenticule Extraction (SMILE)

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Research Article

Keywords: Small incision lenticule extraction, anterior segment, topography, iridocorneal angle

Posted Date: May 3rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-321519/v1

Abstract

Purpose

To evaluate the changes in anterior chamber dimensions including horizontal anterior chamber diameter (HACD), anterior chamber depth (ACD), and iridocorneal angle (ICA) following small incision lenticule extraction (SMILE) using Scheimpflug-Placido disk tomographer (Sirius).

Methods

The records of the 73 eyes of 47 patients who received SMILE for myopia and myopic astigmatism were retrospectively reviewed. Preoperative and 6-month postoperative measurements of central corneal thickness (CCT), HACD, ACD, ICA, nasal anterior chamber angle (nACA), and temporal anterior chamber angle (tACA) were obtained by tomography, and compared with paired t-tests. Pearson's correlation and linear regression tests were used to evaluate the relationship between these parameters.

Results

The CCT, HACD, and ACD values decreased significantly at 6-month postoperatively ($p < 0.05$ for all). ICA, nACA, and tACA showed no statistically significant difference postoperatively ($p = 0.54$, $p = 0.118$, and $p = 0.255$, respectively). Pearson's correlation analysis confirms negative relationship between Δ-HACD and Δ-tACA ($r=-0.475$, $p < 0.01$), and a loose negative relationship between change in ACD and change in ICA ($r=-0.282$, $p = 0.016$). Age and Δ-tACA were found as predictive parameters for Δ-HACD and, Δ-ICA was a predictor for Δ-ACD.

Conclusion

While HACD and ACD decreased significantly, there was no significant change in ICA, nACA and tACA. Changes in HACD and ACD should be considered in terms of subsequent surgeries after SMILE.

Introduction

Small incision lenticule extraction (SMILE) is a relatively new corneal refractive surgical method, when compared to its precedents such as laser in situ keratomileusis (LASIK) [1]. Several studies have reported positive outcomes regarding safety, stability, and efficacy; which brought globally acceptance and application [2–5].

Besides altering the cornea, corneal refractive surgery has an impact on the anterior segment structures as well. Several studies have evaluated the changes in anterior segment parameters, such as anterior chamber depth (ACD) and posterior corneal elevations after LASIK and SMILE using different tomography systems [6–9]. However, there is a paucity of published information about how the iridocorneal angle (ICA), and the other dimensions associated with it are affected following SMILE.

Anterior chamber dimensions following corneal refractive surgery is essential for evaluation of the eyes for possible further procedures like phakic intraocular lens (IOL) implantation. Likewise, morphology of the anterior segment plays a crucial role in the development angle-closure glaucoma. Assessment of the anterior segment parameters, therefore is of great clinical importance.

The non-contact Sirius tomography system (CSO, Costruzione Strumenti Oftalmici, Florence, Italy) acquires data by combining a Scheimpflug camera with a Placido disc-based tomographer, and provides repeatable data from the different structures of anterior segment [10, 11].

To the best of our knowledge, a study about the effect of SMILE on anterior segment parameters including the iridocorneal angle and other associated dimensions has not been published yet. In the current study, our aim was to evaluate the changes of anterior segment dimensions following SMILE using Sirius Scheimpflug-Placido disk tomographer.

Material And Method

Patients and Clinical Examination

The records of patients who received SMILE for myopia and myopic astigmatism between 2012–2019 at the Refractive Surgery Clinic of University of Health Sciences Beyoglu Eye Training and Research Hospital were retrospectively reviewed.

The study followed the tenets of Helsinki Declaration and approved by the local ethical committee and the ethical committee at University of Health Sciences Okmeydanı Training and Research Hospital. Patients' informed consents were obtained preoperatively.

The inclusion criteria included age over 20 years, spherical refractive error less than −10.0 diopter (D) with an astigmatism less than −5.0 D, normal preoperative tomographical pattern, and estimated postoperative residual stroma of at least 250 µm. Additionally, patients who had a tomography imaging with a good acquisition quality with centration and coverage more than 90 percent both preoperatively and 6-month postoperatively were included in this study. The thinnest corneal pachymetry was at least 500 µm with a stable refractive status for at least 2 years. Patients with ocular pathologies other than myopia and with systemic disease or treatment were excluded.

A complete preoperative and postoperative ocular examination including slit lamp biomicroscopy, intraocular pressure (IOP) measurement with Goldmann applanation tonometer, and dilated fundus examination was performed. Uncorrected and corrected distance visual acuity (UDVA, CDVA) as well as objective and subjective refractions were recorded. At scotopic conditions, patients also underwent corneal tomography and anterior segment imaging by Sirius system with Phoenix software version

1.0.5.72 (CSO, Costruzione Strumenti Oftalmici, Florence, Italy) preoperatively and 6-month postoperatively, and their regularity was checked for eligibility for SMILE. Axial lengths (AL) of the patients were noted from the preoperatively obtained Nidek AL-Scan (Nidek CO, Aichi, Japan).

Sirius Scheimpflug-Placido Disk Tomographer

The Sirius tomography system (CSO, Costruzione Strumenti Oftalmici, Florence, Italy) combines a 360° rotating Scheimpflug camera with a Placido disc-based tomographer, and captures 25 slit images in less than a second. By processing these sections of the anterior and posterior corneal surface, which are measured by approximately 30,000 points from each surface, it reconstructs the anterior chamber on high resolution. From this information, measurements of anterior segment structures are obtained. Glaucoma analysis mode provides additional parameters by the built-in software.

Anterior segment parameters used in this study were central corneal thickness (CCT), horizontal anterior chamber diameter (HACD), iridocorneal angle (ICA), nasal anterior chamber angle (nACA), temporal anterior chamber angle (tACA), and anterior chamber depth (ACD). HACD is the distance between the vertices of iridocorneal angles. ICA is the average of the measured angles for the meridians whose angular position is included in the +/- 30° from the horizontal meridian. Nasal and temporal ACA are the given measurements from the glaucoma analysis mode of Sirius system, where the light is penetrable. ACD is the distance between the corneal posterior surface and the anterior surface of crystalline lens. The difference between the measurements at preoperative and postoperative 6-month were expressed with the symbol Δ.

Surgical Procedure

SMILE was performed with a VisuMax 500kHz femtosecond laser (Carl Zeiss Meditec, Jena, Germany). All surgical steps were performed as previously described in the literature [1]. Following parameters were all set same for every patient. A small-sized (S) interface was used. The spot energy was 140 nJ, and the spot distances were 3 μm for the lamellar cuts and 2 μm for the side cuts. The optical zone was determined as 6.5 mm, and cap diameter was intended to be 7.5 mm with a 50° side cut in the superior region. The minimum lenticule thickness was set to 15 μm, and lenticule side cut angle was 120°. Following the procedure, all patients received topical 0.5% moxifloxacin for 1 week, and topical 0.1% fluorometholone for 2 weeks. Preservative-free artificial tear drops were continued for at least 1 month. The lenticule and residual stromal bed thickness were also noted from the recorded data in the VisuMax device.

Statistical Analysis

Statistical Package for the Social Sciences version 22 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The Shapiro-Wilk test was employed to determine whether the variables were normally distributed. Descriptive analyses were recorded as the means and standard deviations for continuous variables. Paired t-tests were used to compare pre- and postoperative parameters. Pearson's correlation coefficient was used to evaluate the linear correlation between age, lenticule thickness, corneal thickness, corneal and anterior chamber parameters changed with surgery. Multiple linear regression analysis was performed to investigate the correlation of Δ-HACD, and Δ-ACD with other parameters. P values < 0.05 were considered statistically significant.

Results

Seventy-three eyes (38 right and 35 left) of 47 patients (20 male, 27 female) were included in the study. The baseline characteristics of patients are summarized in Table 1. The preoperative CDVA was improved statistically significantly at 6-month postoperatively (0.03 ± 0.05 and 0.01 ± 0.03, respectively, $p = 0.001$).

Table 1
Baseline characteristics of patients

Parameters	Mean ± SD (Range)
Age (year)	28.1 ± 5.34 (19–44)
Sphere (D)	-4.94 ± 1.76 (-1.50- -9.00)
Spherical equivalent (D)	-5.25 ± 1.84 (-1.63- -9.50)
Axial length (mm)	25.41 ± 1.03 (23.12–27.87)
Lenticule thickness (µm)	104.96 ± 27.24 (44–166)
Residual stromal thickness (µm)	329.31 ± 39.83 (253–441)

The preoperative and postoperative values and the changes in CCT, HACD, ICA, nACA, tACA, and ACD values are shown in Table 2. The CCT, HACD, and ACD values showed a statistically significant decrease at 6 months after surgery ($p < 0.05$ for all). There was no statistically significant difference between preoperative and postoperative ICA values ($p = 0.54$). Although temporal and nasal ACA values were increased, it was not statistically significant ($p = 0.118$, and $p = 0.255$, respectively).

Table 2
Postoperative changes in CCT, HACD, ICA, ACA and ACD values

	Preoperative (Mean ± SD)	**Postoperative (Mean ± SD)**	**Change (Δ) (Mean ± SD)**	***P***
CCT (μm)	552.92 ± 27.34	459.23 ± 45.55	-93.68 ± 32.13	< 0.001*
HACD (mm)	12.13 ± 0.65	12.07 ± 0.6	-0.05 ± 0.24	0.044*
ICA (°)	48.45 ± 5.86	48.26 ± 5.41	-0.19 ± 2.66	0.541
nACA (°)	50.55 ± 5.43	50.9 ± 4.88	0.35 ± 2.65	0.255
tACA (°)	46.59 ± 7.62	47.55 ± 6.67	0.95 ± 5.17	0.118
ACD (mm)	3.25 ± 0.27	3.22 ± 0.28	-0.03 ± 0.06	< 0.001*

CCT: central corneal thickness; HACD: horizontal anterior chamber diameter; ICA: iridocorneal angle; nACA: nasal anterior chamber angle; tACA: temporal anterior chamber angle; ACD: anterior chamber depth. $p < 0.05$ was statistically significant. *Statistically significant

Pearson's correlation analysis confirms negative relationship between Δ-HACD and Δ-tACA (r=-0.475, p < 0.01), and positive relationship between Δ-HACD and age (r = 0.210, p = 0.005). Linear regression was performed on change in HACD after surgery, with age, lenticule thickness, Δ-nACA, Δ-tACA, Δ-ICA and Δ-ACD as predictors. This revealed a significant model explaining 38.0% of the variability with age and Δ-tACA as significant coefficients (p = 0.005 and p = 0.002, respectively) (Table 3). Pearson's correlation analysis confirms the loose negative relationship between Δ-ACD and Δ-ICA (r=-0.282, p = 0.016). Linear regression on change in ACD after surgery with independent variables produced a significant (p = 0.05) model, explaining 17.0% of the total system variability. This model suggests that for each increase of 1 degree in Δ-ICA, the change in post-operative ACD will increase by 0.01 mm (p = 0.002) (Table 4).

Table 3
The multiple linear regression analysis for change in HACD

	B	Beta	*P*	95% C.I.	
				Lower	Upper
Age (years)	0.013	0.296	0.005*	0.004	0.023
LT (μm)	0.001	0.154	0.128	0.000	0.003
Δ-ACD (mm)	0.640	0.177	0.097	-0.118	1.398
Δ-ICA (°)	-0.019	-0.182	0.146	-0.045	0.007
Δ-nACA (°)	-0.017	-0.168	0.100	-0.037	0.003
Δ-tACA (°)	-0.020	-0.387	0.002*	-0.032	-0.007

LT: lenticule thickness; Δ-ACD: change in anterior chamber depth; Δ-ICA: change in iridocorneal angle; Δ-nACA: change in nasal anterior chamber angle; Δ-tACA: temporal anterior chamber angle. $p < 0.05$ was statistically significant. *Statistically significant

Table 4
The multiple linear regression analysis for change in ACD

	B	Beta	*P*	95% C.I.	
				Lower	Upper
Age (years)	-0.001	-0.087	0.490	-0.004	0.002
LT (μm)	-9.604E-5	-0.039	0.744	-0.001	0.000
Δ-HACD (mm)	0.066	0.240	0.097	-0.012	0.145
Δ-ICA (°)	0.012	0.433	0.002*	0.005	0.020
Δ-nACA (°)	0.001	0.048	0.691	-0.005	0.008
Δ-tACA (°)	-0.002	-0.164	0.281	-0.007	0.002

LT: lenticule thickness; Δ-HACD: change in horizontal anterior chamber diameter; Δ-ICA: change in iridocorneal angle; Δ-nACA: change in nasal anterior chamber angle; Δ-tACA: temporal anterior chamber angle. $p < 0.05$ was statistically significant. *Statistically significant

Discussion

The number of the patients who received SMILE has been increasing enormously, which makes it crucial for the ophthalmologists to comprehend its impact on the eye, not just on the cornea. There have been many studies in the literature evaluating the outcomes of corneal refractive surgery regarding corneal thickness and anterior chamber depth; however, most of them addressed LASIK patients and only a few focused on the anterior chamber angle structures. Moreover, the data in the majority of those studies were obtained from other tomography systems rather than Sirius Scheimpflug-Placido disc tomographer [6–8, 12, 13]. This study shows the change in the anterior segment dimensions including the angle-related measurements, and the possible factors affecting the outcome after SMILE.

In this study, CCT, and ACD significantly decreased at postoperative 6-month, similar to previous studies with other tomography systems ($p < 0.05$ for both) [6, 9, 13]. In addition, we observed a significant decrease at HACD ($p < 0.05$), but no change at ICA ($p = 0.54$). Yassa et al. suggested that this discrepancy might be due to the accommodation of the patients while fixating to the tomography device for imaging, which causes the central lens shift more anteriorly whereas the periphery remains flatter [7]. However, although not statistically significant, in current study both temporal and nasal ACA increased postoperatively ($p = 0.118$, and $p = 0.255$, respectively).

Similar to our results, Yassa et al. and Zhou et al. reported that after LASIK, anterior chamber angle showed no difference postoperatively by using the data obtained from Sirius and Pentacam (Oculus, Wetzlar, Germany) tomography systems, respectively [7, 8]. In their study comparing different techniques to assess the status of ICA, Källmark et al. concluded that despite the lack of good agreement with gonioscopy, Sirius still might be a good option, since it is more comfortable for the patient, and it requires less skills to perform in an objective manner [14]. In terms of refractive surgery, it might also provide an essential insight for the glaucoma evaluation of the patient preoperatively.

Our analysis confirmed that age was positively, and Δ-tACA was negatively correlated with the Δ-HACD **(**Fig. 1, 2**).** HACD shows the distance between the two angles, which might be modified by both the angle structures and the anterior chamber dimension. This is the first time HACD was evaluated after refractive surgery; however a few studies evaluated the angle to angle diameter following cataract surgery, and they concluded that horizontal angle to angle diameter increased significantly more than the vertical diameter [15]. Prior to phakic intraocular lens (IOL) implantation, anterior segment dimensions, especially the horizontal corneal dimension (white-to-white or horizontal visible iris diameter) is checked regularly [16]. We believe HACD might also provide a critical contribution in the decision-making process of the appropriate size of the IOL for the eye. Due to new technological developments in the design and implantation techniques of intraocular lenses (IOL), together with the advancements of corneal refractive surgery, there will probably be more patients requiring subsequent and more sophisticated IOL implantation procedures in near future.

There was a significant negative correlation between Δ-ICA and Δ-ACD ($r = -0.282$, $p = 0.016$) **(**Fig. 3**)**. In their study, Nishimura et al. evaluated the effect of age on change in ACD after LASIK, and reported that there was a significant negative correlation, which was interpreted as ACD decreased in the younger patients (less than 40 years of age), but not in older patients [12]. In our study, the population consisted almost exclusively by young patients, which might explain the difference. Chen et al. found that despite the lack of correlation after 1 day, Δ-LT and Δ-ACD had a negative correlation following SMILE after 1 week [13]. However, this follow-up time is also shorter than ours, and this might have been a temporary outcome until the accommodative process adopts to the changes due to procedure. Our results suggest that even though ICA does not change after SMILE, its alteration has a significance on the change of ACD.

There are some limitations to this study. First, Sirius images were acquired by single measurement. However, the intrasession repeatability of Sirius has been already reported as successful by other studies [17], and the technician (HK) was very experienced, and we included the images only with good acquisition quality. Second, since the Sirius system uses a fixation target and light for imaging, this might have affected the accommodation and caused pupil constriction, and thusly the measurement of anterior chamber depth and the iridocorneal angle of the eyes. However, the room itself was dark during acquisition, and the conditions were similar at both preoperative and postoperative imaging. The retrospective nature of our study is the other limitation.

SMILE is now a frequently performed procedure, hence ophthalmologists require more and better insight about the possible impact of it on the eye. The current study supports the findings that CCT, ACD, and HACD significantly decreases after SMILE. Age and Δ-tACA are correlated with Δ-HACD, and there is a negative correlation between Δ-ICA and Δ-ACD. Therefore, it is important to evaluate the anterior segment structures of the eyes including the anterior chamber angle, before and after SMILE. This may especially be helpful for patients regarding glaucoma assessment and a possible subsequent IOL implantation.

Declarations

ACKNOWLEDGEMENTS

We would like to thank Kürşad Nuri Baydili, PhD for assistance with statistical analysis, and Havva Kanbak (HK) for performing Sirius tomography imaging.

Compliance with Ethical Standards

The authors have no conflicts of interest to declare that are relevant to the content of this article.

The authors did not receive any funds/grants or support from any organization for the submitted work.

No animals were involved in this study.

The study followed the tenets of Helsinki Declaration and was approved by the local ethical committee of Beyoglu Eye Training and Research Hospital and the ethical committee at University of Health Sciences Okmeydanı Training and Research Hospital.

Patients' informed consents and consent to publish were obtained preoperatively.

Author Contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Yusuf Yıldırım, Burçin Kepez Yıldız, Şenay Aşık Nacaroğlu, Adem Tellioğlu.

The first draft of the manuscript was written by Beril Tülü Aygün and Ahmet Kırgız and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

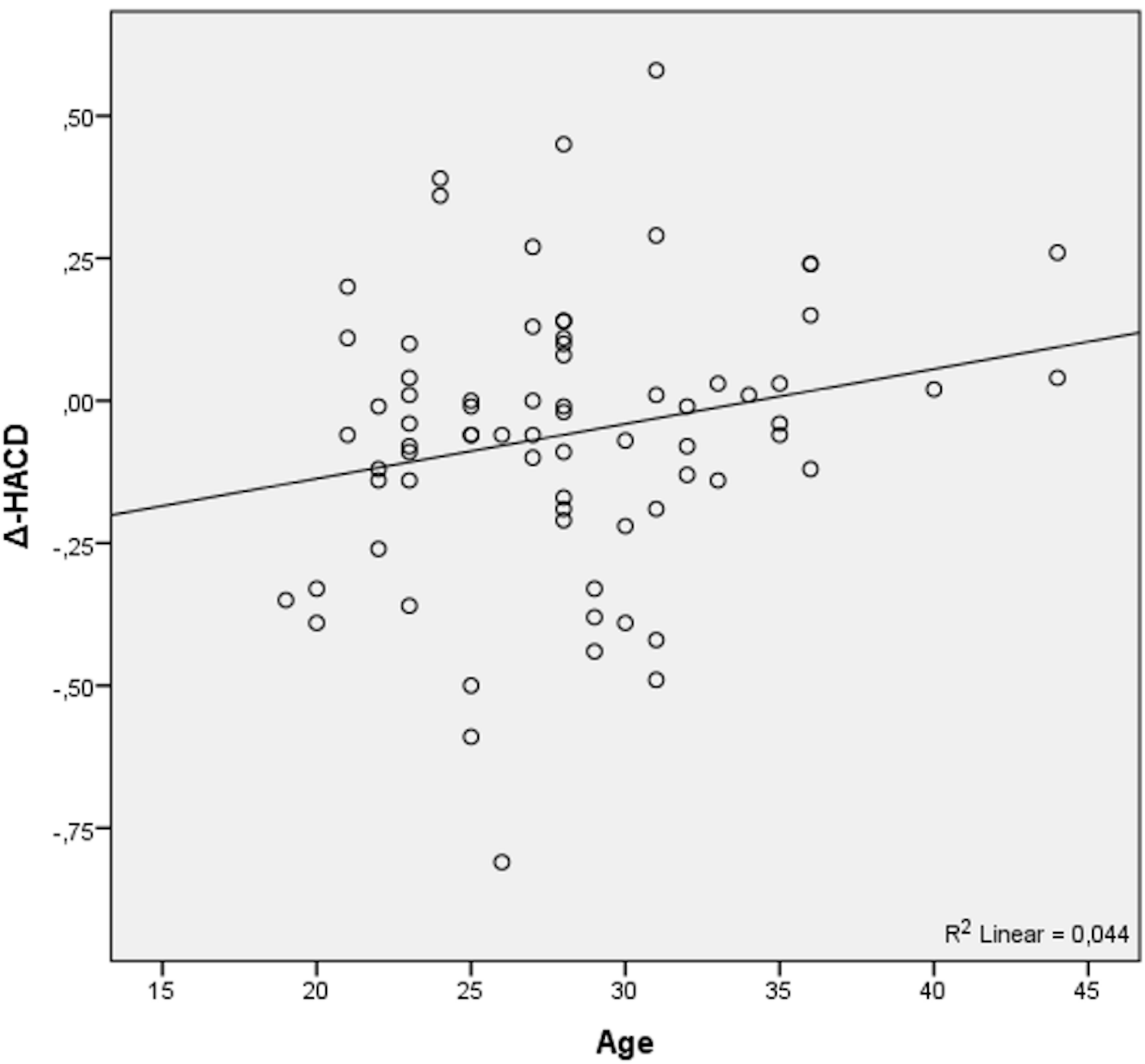

Figure 1

Linear regression of horizontal anterior chamber diameter change (Δ-HACD) with age

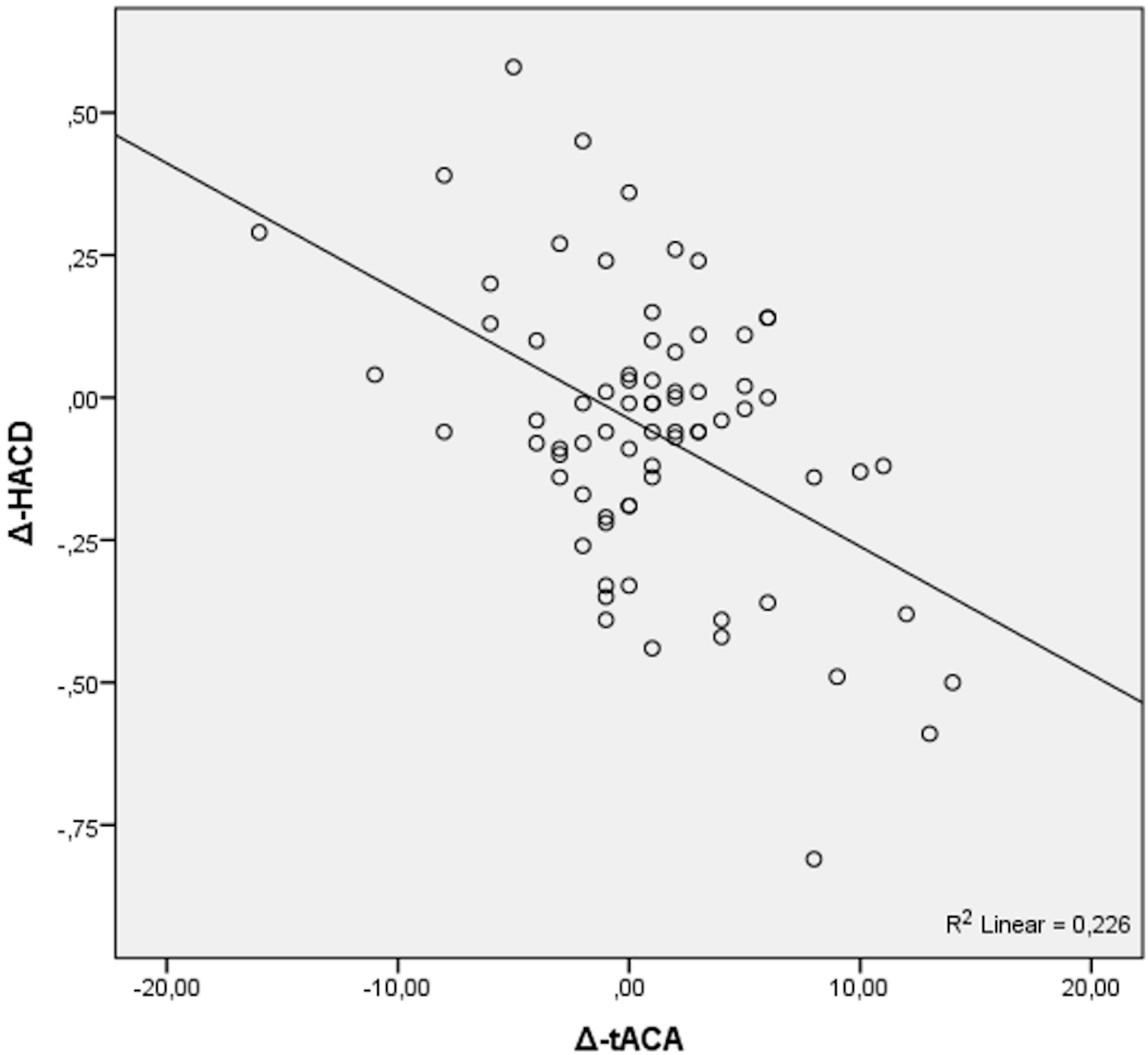

Figure 2

Linear regression of horizontal anterior chamber diameter change (Δ-HACD) with temporal anterior chamber angle change (Δ-tACA)

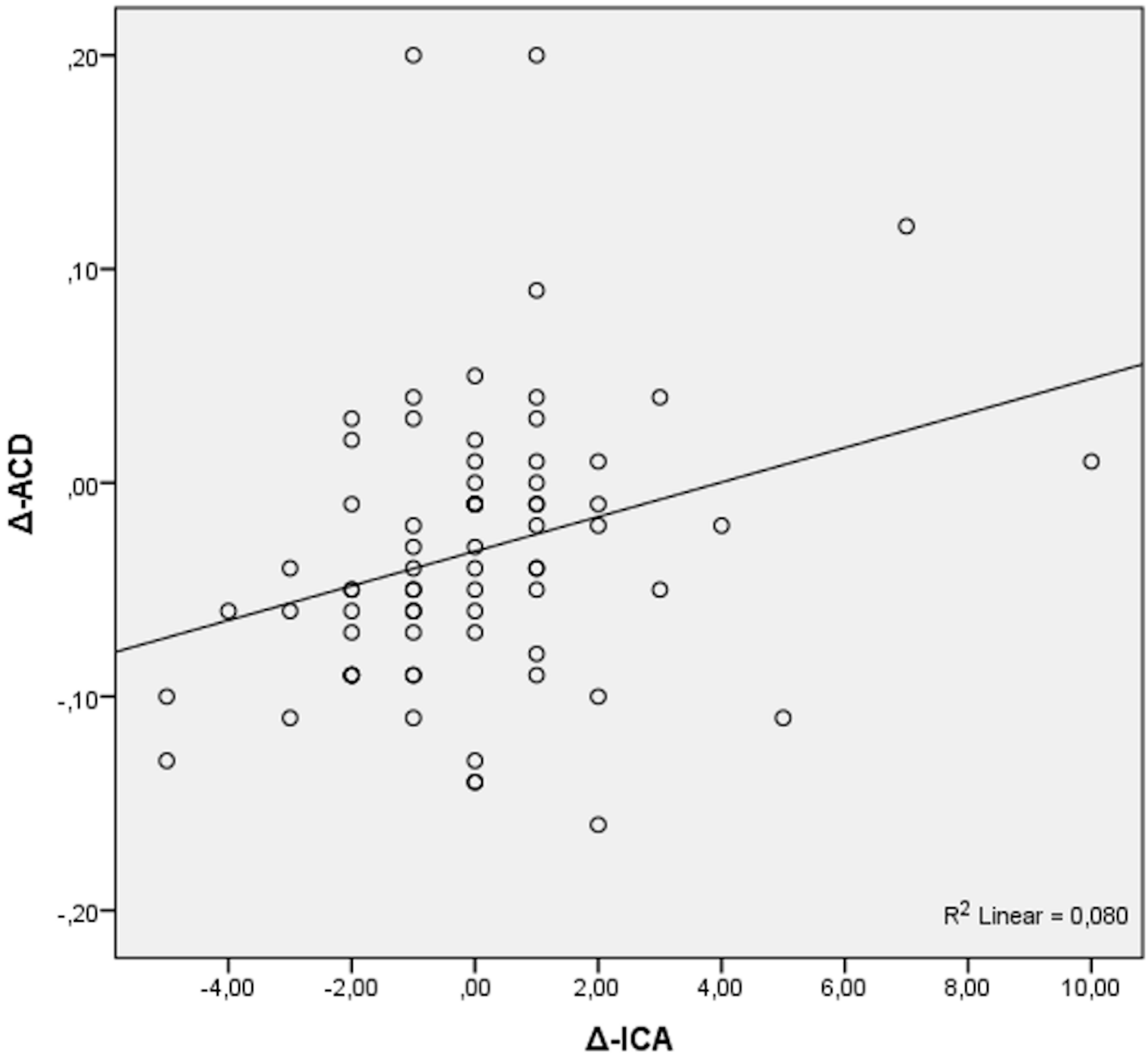

Figure 3

Linear regression of anterior chamber depth change (Δ-ACD) with iridocorneal angle change (Δ-ICA)