Original Article

Comparing morphologic features and complications of main clear corneal incision between junior and senior residents observed using anterior segment optical coherence tomography

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ABSTRACT

Background: Wound construction is a critical step in phacoemulsification. Using anterior segment optical coherence tomography (AS-OCT), we compared the morphological features and complications of main incisions made by junior or senior residents during phacoemulsification.

Methods: This cross-sectional comparative study included eyes with senile cataracts that underwent uneventful phacoemulsification with a clear corneal incision made by seven senior and eight junior ophthalmology residents. All eyes underwent postoperative image acquisition using AS-OCT on day one and at three months, examining for morphological features and potential complications of the main incision.

Results: We included 50 eyes of 50 patients with a male-to-female ratio of 22 (44%) to 28 (56%); 26 (52%) were operated on by junior residents and 24 (48%) by seniors. The mean geometric features of the main incisions and the frequency of early and late wound complications were comparable between the two groups (all $P > 0.05$). A significant correlation was found between the incision length and angle with the superior ($r = +0.80$; $P < 0.001$ and $r = -0.63$; $P < 0.001$, respectively) and inferior ($r = +0.84$; $P < 0.001$ and $r = -0.68$; $P < 0.001$, respectively) areas of the incision, as well as between the length and angle of incision ($r = -0.74$; $P < 0.001$). The number of planes in the wound architecture was not significantly different according to senior or junior resident status ($P > 0.05$). Although the number of eyes with stromal hydration was significantly greater for junior residents than for seniors ($P < 0.001$), the corneal thickness at the entrance to the cornea or the anterior chamber, presence of endothelial wound gaping, and Descemet's membrane detachment were comparable between eyes with and without stromal hydration (all $P > 0.05$). At three months, 29 (58%) patients returned for examination, in whom seven (24%) had late wound complications.

Conclusions: This study found no significant differences in the performances of junior and senior residents in terms of wound construction or its associated complications. However, considering the overall rate of some observed wound-related complications, we recommended revision of the resident educational curriculum concerning the structure and complications of the main incision.

KEYWORDS

cataracts, phacoemulsifications, corneas, surgical incision, postoperative complication, academic training, optical coherence tomography

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INTRODUCTION

Cataracts are the leading cause of blindness and the second leading cause of visual impairment worldwide [1]. They accounted for 39% and 33% of worldwide blindness cases in 1990 and 2010, respectively [2]. Phacoemulsification is a modern cataract surgery that involves the creation of a superior or temporal clear corneal incision 2 – 3 mm in length. The creation of small wounds has revolutionized modern cataract surgery, as they are self-sealed, astigmatically neutral, anatomically stronger, and have a low incidence of complications [3].

Anterior-segment optical coherence tomography (AS-OCT) has been successfully used during cataract surgery to evaluate the main incisional structure, intraocular lens (IOL) position, wound gaping, and stromal hydration [4]. Additionally, it offers the benefit of postoperative evaluation. It can effectively assess the presence of gaping, Descemet's membrane detachment, and wound coaptation in the main incision [5]. Furthermore, it can postoperatively assess the location and stability of the IOL, as well as the presence of a capsular block [6, 7]. The primary types of AS-OCT are time-domain and frequency-domain OCT [8].

Several studies have evaluated the complications related to phacoemulsification surgery performed by residents at distinct stages of education [9-11]. Studies have investigated the risk factors for capsular complications [12], postoperative endothelial cell loss [13], and outcomes of surgery [14] in junior residents and between senior and junior residents. However, to the best of our knowledge, studies using Fourier domain (FD)-OCT to compare morphological features or complications of incisions according to level of resident training are lacking.

This study used FD-OCT to evaluate the morphological characteristics and early and late complications of main corneal incisions after phacoemulsification cataract surgery and to compare these characteristics in incisions created by junior and senior groups of residents.

METHODS

This cross-sectional comparative study reviewed all patients who underwent phacoemulsification cataract surgery at Khatam-Al-Anbia Eye Hospital, Mashhad, Iran, over a four-month period. The study was approved by the Research and Ethics Committees of Mashhad University of Medical Sciences, Mashhad, Iran (ethical approval code: IR.MUMS.fm.Rec.1394.341). The study was conducted in compliance with the tenets of the Declaration of Helsinki, and all participants provided written informed consent.

We included eyes with senile cataracts that underwent uneventful phacoemulsification with a clear corneal incision and IOL placement into the capsular bag by senior or junior ophthalmology residents. We excluded eyes with a history of uveitis, glaucoma, corneal dystrophies, and previous ocular surgeries, as well as those that experienced any complications during or after surgery, such as vitreous loss, severe postoperative uveitis or endophthalmitis, pseudophakic bullous keratopathy, wound leakage requiring corneal suturing, or limbus-to-limbus corneal edema.

The learning curve of phacoemulsification indicates a significantly lower complication rate after the initial 80 procedures according to residents' surgical outcomes [15]. Thus, senior residents were selected among those in the third or fourth year of training who had independently performed more than 80 phacoemulsification surgeries. Junior residents were selected among those in the second year of training who had performed fewer than 20 independent phacoemulsification surgeries.

Surgeries were performed by seven senior and eight junior residents according to the Khatam-Al-Anbia Hospital residency training curriculum. All surgeries were performed under general anesthesia through a clear corneal incision. The main wound was made using a 3.2-mm disposable slit-angled keratome blade (MANI Inc., Utsunomiya Tochigi, Japan). Phacoemulsification was performed with the technique as described in detail elsewhere [16]. A monofocal single-piece foldable hydrophilic acrylic IOL (Akreos Adapt AO, Bausch & Lomb Inc., NY, USA) or a foldable hydrophobic acrylic IOL (AcrySof, SA60AT, Alcon Laboratories, Inc., Fort Worth, TX, USA) was inserted into the capsular bag. Stromal hydration was applied to the main wound incision, with leakage at the end of the surgery, by placing the tip of a 25-gauge blunt cannula in the side walls of the main incision and gently irrigating balanced salt solution into the stroma. This was repeated until the Seidel test result became negative. Finally, the eyes were patched for 24 hours using eye pads and an eye shield.

All patients had comprehensive pre- and postoperative ophthalmic examinations including measurement of uncorrected and corrected distance visual acuities using a Snellen visual acuity chart (auto chart projector CP 670; Nidek Co., Ltd., Gamagori, Japan), tonometry using the Goldmann applanation tonometer (AT900, Haag-Streit, Koeniz, Switzerland), and undilated and dilated slit-lamp biomicroscopy of the anterior segment and fundus (Photo-Slit Lamp BX 900; Haag-Streit) using a + 90-diopter double-aspheric fundus lens (Volk Optical Inc., Mentor, OH, USA).

One day after phacoemulsification, all eyes were unpatched and examined in detail. Chloramphenicol 0.5% (Chlobiotic, Sina Darou, Tehran, Iran) and betamethasone 0.1% (Betasonate, Sina Darou, Tehran, Iran) eye drops were administered as one drop every three hours, with gradual tapering and discontinuation over a period of one month.

Subsequently, all eyes underwent image acquisition using FD-OCT (Heidelberg Engineering, Heidelberg, Germany). A single examiner evaluated qualitative variables of each image, including: epithelial gaping (a crack in the limbal edge of the external wound surface) (Figure 1A), endothelial gaping (a crack in the edge of the internal wound surface or misalignment of its two sides) (Figure 1B), Descemet's membrane detachment (separation of Descemet's membrane from the stroma, visible as a hyper-reflective membrane in the internal wound surface) (Figure 1C), shape of the incisional wound, which may be triplanar (Figure 1D), biplanar (biplanar incision with a second shorter and steeper plane [Figure 1E] or with a second longer and flatter plane [Figure 1F]), or uniplanar (uniplanar curved incision [Figure 1G] or uniplanar near-to-straight incision [Figure 1H]). The position of the incision relative to the cornea was recorded for each eye (temporal if the incision was up to 20° relative to the horizontal line, and supratemporal if the incision was > 20° relative to the horizontal line).

Using the caliper incorporated into the FD-OCT device, other variables were evaluated, including the incision length (length of a line connecting the internal and external aspects of the incision) (Figure 2A), corneal thickness at the entrance to the cornea (length of a vertical line from the external aspect of the incision to the internal surface of the cornea) (Figure 2B), corneal thickness at the entrance to the anterior chamber (length of a vertical line from the internal aspect of the incision to the external surface of the cornea) (Figure 2C), incision angle (angle between a line tangent with the corneal epithelium and a line connecting the entrance and exit points of the incision) (Figure 2D), superior area of the incision (area between the curve of the incision, external surface of the cornea, and a vertical line from the internal aspect of the incision to the external surface of the

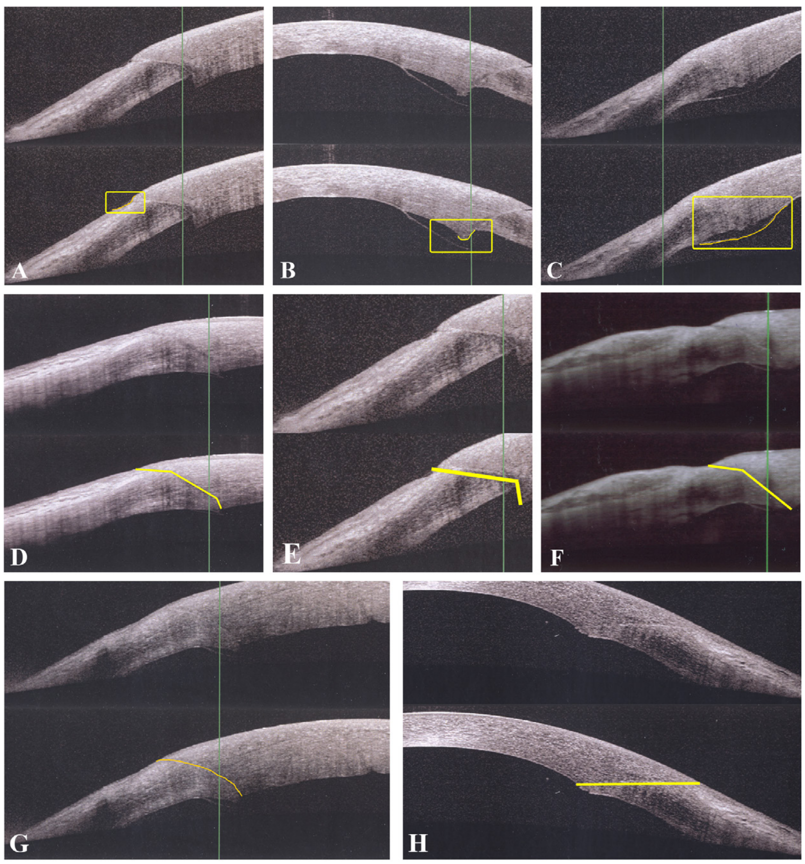

Figure 1. (A-H) Qualitative variables of the main incision assessed using Fourier domain optical coherence tomography device (Heidelberg Engineering, Heidelberg, Germany) one day after phacoemulsification. (A) Epithelial gaping: a crack in the limbal edge of the external wound surface. (B) Endothelial gaping: a crack in the edge of the internal wound surface or misalignment of its two sides. (C) Descemet's membrane detachment: separation of Descemet's membrane from the stroma, visible as a hyper-reflective membrane in the internal wound surface. (D-H) Shape of the incisional wound, which may be (D) triplanar; (E, F) biplanar, (E) biplanar incision with a second shorter and steeper plane or (F) with a second longer and flatter plane; or (G, H) uniplanar, (G) uniplanar curved incision or (H) uniplanar near-to-straight incision.

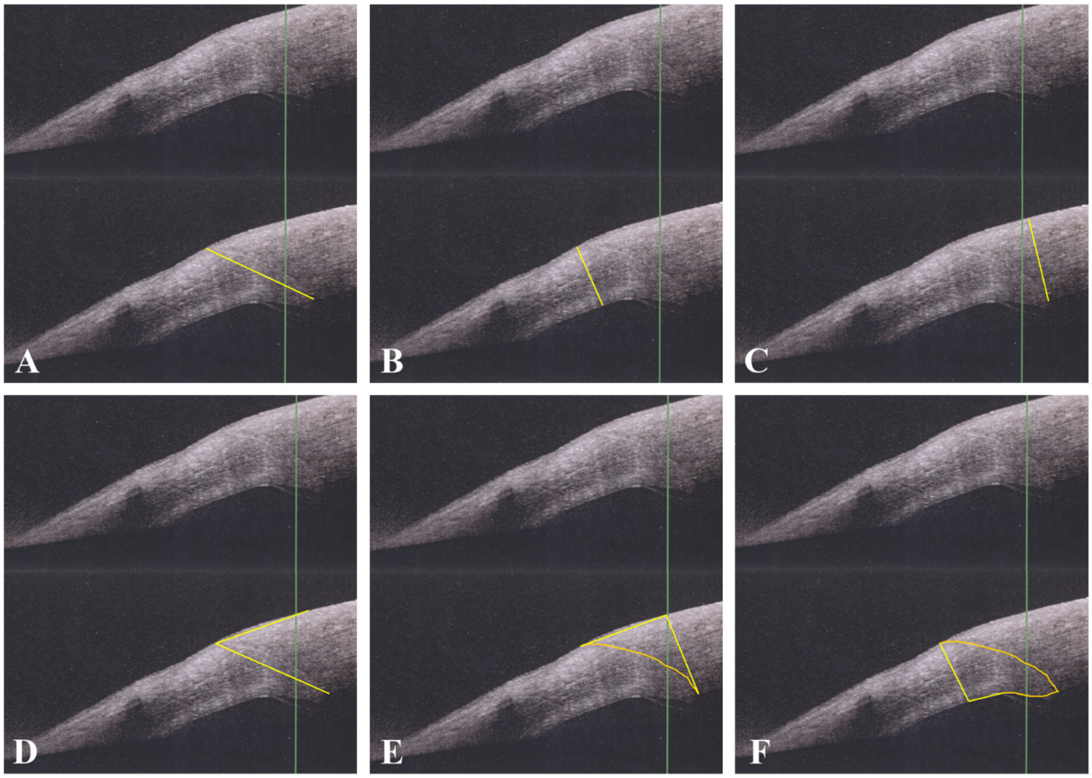

Figure 2. (A-F) Quantitative variables of the main incision measured using the caliper incorporated into the Fourier domain optical coherence tomography device (Heidelberg Engineering, Heidelberg, Germany) one day after phacoemulsification. (A) The incision length: length of a line connecting the internal and external aspects of the incision. (B) Corneal thickness at the entrance to the cornea: length of a vertical line from the external aspect of the incision to the internal surface of the cornea. (C) Corneal thickness at the entrance to the anterior chamber: length of a vertical line from the internal aspect of the incision to the external surface of the cornea. (D) Incision angle: angle between a line tangent with the corneal epithelium and a line connecting the entrance and exit points of the incision. (E) Superior area of the incision: area between the curve of the incision, external surface of the cornea, and a vertical line from the internal aspect of the incision to the external surface of the cornea. (F) Inferior area of the incision: area between the curve of the incision, internal surface of the cornea, and a vertical line from the external aspect of the incision to the internal surface of the cornea.

cornea) (Figure 2E), and inferior area of the incision (area between the curve of the incision, internal surface of the cornea, and a vertical line from the external aspect of the incision to the internal surface of the cornea) (Figure 2F).

Patients who returned for the third month of follow-up were examined using a slit lamp, as outlined previously, and underwent image acquisition by FD-OCT to identify late wound complications, including posterior wound retraction (a step-off or recession of the edge of the internal surface of the wound with a relatively blunt border) (Figure 3A) and fibrous overgrowth (a hyper-reflective prominence on the edge of the internal surface) (Figure 3B).

Statistical analyses were performed using IBM SPSS software (version 20.0; IBM Corp., Armonk, NY, USA). The normality of data distribution was evaluated using the Shapiro – Wilk test. Quantitative and qualitative data are expressed as mean (standard deviation [SD]) and frequency (percentage), respectively. The independent *t*-test and chi-square test was used to compare quantitative and qualitative data between the two groups, respectively. Quantitative data from more than two groups with parametric distributions were compared using a one-way analysis of variance. Post-hoc analysis using Tukey's test was performed for pairwise comparisons between groups. Pearson's correlation coefficient was used to measure the linear correlation between two data sets. A P-value < 0.05 was considered statistically significant.

RESULTS

In total, 50 eyes of 50 patients with a male-to-female ratio of 22 (44%) to 28 (56%) were included, of whom 26 (52%) were operated on by junior residents and 24 (48%) by seniors. Twenty-nine (58%) phacoemulsification surgeries were performed on the right eye and 21 (42%) on the left eye. The main incisions were temporal

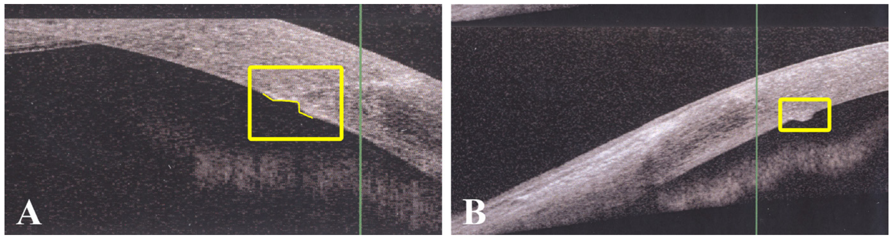

Figure 3. The main wound complications in patients who returned for the third month of follow-up using Fourier domain optical coherence tomography device (Heidelberg Engineering, Heidelberg, Germany). (A) Posterior wound retraction: a step-off or recession of the edge of the internal surface of the wound with a relatively blunt border. (B) Fibrous overgrowth: a hyper-reflective prominence on the edge of the internal surface.

and supratemporal in 17 (34%) and 33 (66%) eyes, respectively. The temporal position was significantly more common in the right eye than in the left ($P = 0.012$). Concerning geometric features of the main incision in all operated eyes, the mean (SD) of corneal thickness at the entrance to the cornea, corneal thickness at the entrance to the anterior chamber, incision length, incision angle, superior area of the incision, and inferior area of the incision were 808.6 (64.8) µm, 979.8 (93.8) µm, 1569.1 (285.2) µm, 40.2° (8.1°), 0.5 (0.1) mm^2, and 0.8 (0.2) mm^2.

As shown in Table 1, the mean (SD) geometric features of the main incision and the frequency of early or late wound-related complications were not statistically significant between senior and junior residents (all $P > 0.05$).

The incision length was directly correlated with the superior (r = + 0.80; $P < 0.001$) and inferior (r = + 0.84; $P < 0.001$) areas of the incision, whereas the angle of incision was inversely correlated with the superior (r = - 0.63; $P < 0.001$) and inferior (r = - 0.68; $P < 0.001$) areas of the incision. There was an inverse correlation between the length and angle of the incision (r = - 0.74; $P < 0.001$); thus, the angle of incision decreased with increasing incision length. The mean (SD) incision angles in the triplanar, biplanar, and uniplanar incisions were 33.9° (7.2°), 40.7° (7.2°), and 42.6° (9.7°), respectively, with no significant differences between the three incision planes ($P = 0.060$).

Concerning the number of planes in the wound architecture, 11 eyes (22%) underwent uniplanar incision (5 eyes [45%] had curved and 6 eyes [55%] had near-to-straight uniplanar incision), 32 eyes (64%) underwent biplanar incision (19 eyes [59%] had biplanar incision with a second shorter and steeper plane and 13 eyes [41%] had biplanar incision with a second longer and flatter plane), and 7 eyes (14%) underwent triplanar incision; there were no statistically significant differences in planes of incision between the senior- and junior-operated eyes ($P > 0.05$) (Table 1).

The mean (SD) incision lengths of the triplanar, biplanar, and uniplanar incisions were 1905.1 (343.6) µm, 1539.0 (215.1) µm, and 1441.6 (304.8) µm, respectively; this difference was statistically significant ($P = 0.001$). Pairwise comparisons revealed significantly longer triplanar incisions than uniplanar or biplanar incisions (both $P < 0.001$), but not between biplanar and uniplanar incisions ($P = 0.280$).

Of the 31 eyes with endothelial gaping (Table 1), 3 (10%) had a uniplanar incision, 23 (74%) had a biplanar incision, and 5 (16%) had a triplanar incision; Fisher's exact test showed that the difference was significant ($P = 0.030$). Of the 24 eyes with Descemet's detachment (Table 1), 8 (33%) had a uniplanar incision, 13 (54%) had a biplanar incision, and 3 (13%) had a triplanar incision. There was no significant association between the number of planes and the presence of Descemet's detachment ($P = 0.200$). Similarly, there was no significant association between the length or angle of the incision and the presence of Descemet's detachment ($P = 0.600$ and $P = 0.520$, respectively) or endothelial wound gaping ($P = 0.800$ and $P = 0.850$, respectively).

Stromal hydration was performed in 37 (74%) eyes and was significantly more common in junior-operated eyes (96%) than in senior-operated eyes (50%) ($P < 0.001$). As shown in Table 2, no statistically significant difference was found in corneal thickness at the entrance of the cornea or anterior chamber between eyes with and without stromal hydration, eyes with and without Descemet' detachment, or eyes with and without endothelial gaping (all $P > 0.05$) (Table 2). There was no significant association between performance of stromal hydration and the presence of endothelial wound gaping ($P = 0.520$) or Descemet's detachment ($P = 0.420$).

Of the 50 patients, 29 (58%) returned for a follow-up examination at three months. Overall, 7 (24%) eyes had late wound complications (Table 1). We observed posterior wound retraction in 3 (10%) eyes (two eyes operated on by a junior resident and one by a senior resident) and internal fibrous growth in 6 (21%) eyes (two eyes operated on by a junior resident and four by a senior resident). Of the six eyes with internal fibrous growth, 5 (83%) eyes had both Descemet's detachment and endothelial wound gaping on the one-day postoperative

Table 1. Comparison of geometric features at day one postoperative visit and complications of the main phacoemulsification incision at one day and three months postoperatively in eyes operated on by senior versus junior residents

Geometric feature or complication of the main incision at one day post-op	Senior resident (n = 24)	Junior resident (n = 26)	*P*-value
CT at the entrance to the cornea (μm), Mean ± SD	815.8 ± 76.3	802.0 ± 52.7	0.450
CT at the entrance to the AC (μm), Mean ± SD	994.1 ± 93.3	966.6 ± 94.1	0.300
Incision length (μm), Mean ± SD	1557.3 ± 254.7	1580.0 ± 320.7	0.780
Incision angle (degree), Mean ± SD	41.6 ± 9.5	38.9 ± 6.5	0.230
Superior area of the incision (mm²), Mean ± SD	0.5 ± 0.1	0.5 ± 0.1	0.770
Inferior area of the incision (mm²), Mean ± SD	0.7 ± 0.2	0.8 ± 0.2	0.620
Number of incisional planes (Uniplanar / Biplanar / Triplanar), n (%)	7 (29)/16 (67)/1 (4)	4 (15)/16 (62)/6 (23)	0.110
Position of incision related to the cornea (Temporal / Supratemporal), n (%)	8 (33)/16 (67)	9 (35)/17 (65)	0.920
Epithelial gaping, n (%)	1 (4)	2 (8)	1.000
Endothelial gaping, n (%)	16 (67)	15 (58)	0.510
Descemet's membrane detachment, n (%)	12 (50)	12 (47)	0.780
Incision-related complication at three months' post-op	**Senior resident (n = 15)**	**Junior resident (n = 14)**	***P*-value**
Posterior wound retraction, n (%)	1 (7)	2 (14)	0.590
Fibrous overgrowth, n (%)	4 (27)	2 (14)	0.650

Abbreviations: n, number of operated eyes; post-op, postoperative; CT, Corneal thickness; μm, micrometer; SD, standard deviation; AC, anterior chamber; mm², square millimeters; %, percentage. Note: Senior residents, were selected among those in the third or fourth year of training who had independently performed > 80 phacoemulsification surgeries; Junior residents, were selected among those in the second year of training who had performed < 20 independent phacoemulsification surgeries.

Table 2. Comparison of corneal thickness between eyes with and without stromal hydration, Descemet's membrane detachment, and endothelial gaping

Characteristic of incision	CT at the entrance to the cornea (μm), Mean ± SD	CT at the entrance to the AC (μm), Mean ± SD
With stromal hydration (n = 37)	803.1 ± 61.8	987.9 ± 96.4
Without stromal hydration (n = 13)	824.2 ± 72.9	956.8 ± 85.2
P-value	0.310	0.300
With Descemet's detachment (n = 24)	824.8 ± 62.9	994.3 ± 85.4
Without Descemet's detachment (n = 26)	793.7 ± 64.0	966.4 ± 100.8
P-value	0.090	0.290
With endothelial gaping (n = 31)	810.9 ± 73.9	988.6 ± 103.9
Without endothelial gaping (n = 19)	804.8 ± 47.9	965.5 ± 74.8
P-value	0.750	0.400

Abbreviations: CT, corneal thickness; μm, micrometer; SD, standard deviation; AC, anterior chamber; n, number of eyes.

examination. Two eyes (7%) had both posterior wound retraction and internal fibrous overgrowth. At the three-month postoperative examination, none of the eyes showed Descemet's detachment or epithelial/endothelial wound gaping.

DISCUSSION

Using FD-OCT, we evaluated the geometric features and early and late complications of the main wound in phacoemulsification. We found no significant difference in the surgical performances of junior and senior residents concerning the morphological features of the main incision or its associated early and late wound complications.

Studies have evaluated the complications of phacoemulsification surgery performed by esidents with different training levels [9-11, 16]. Lee et al. investigated incision-related complications in patients operated on by distinct groups of residents. They reported a limited 0.6% general incidence of complications [9], which differs from our result. Cavallini et al. [17] compared the morphological features of the main incision in bimanual microincision cataract surgery between experienced and training surgeon groups. Both the mean incision length and angle of clear corneal incisions in each eye were significantly lower in the training group than in the experienced group. Endothelial wound gaping and posterior wound retraction in clear corneal incisions were observed in 11.6% and 9.8% of eyes operated on by a junior surgeon, and in 10.8% and 7.8% of eyes operated on by a senior surgeon after 18 months, respectively, which were comparable between the two groups [17]. Similarly, the morphological features of the main incision in eyes that underwent phacoemulsification by junior and senior residents were comparable in the current study.

The mean (SD) lengths and angles of incision reported by Teixera et al. and Schallhorn et al. were 1640 (220.0) μm, 1810 (270.0) μm and 38.5° (5.0°), 26.8° (5.5°), respectively [18, 19]. The mean (SD) length and inclination of incisions using AS-OCT by Cavallini et al. [17] in training surgeons (1318 [194] μm and 141.8° [6.4°]) were significantly lower than those of experienced surgeons (1427 [244] μm and 148.4° [5.4°]) [17]. We found no significant difference in the length or angle of the main phacoemulsification incision between eyes operated on by senior or junior residents. The observed differences between the results of the present and previous studies may be due to the type of microkeratome, different incision shapes, or differences in surgical techniques.

Fukude et al. [20] found that in eyes that underwent phacoemulsification with stromal hydration, corneal thickness at the clear corneal incision was significantly thicker at one day (1020.5 [98.0] μm versus 880.3 [79.6] μm) and at one week (908.9 [54.4] μm versus 840.3 [92.0] μm) after surgery compared with eyes without stromal hydration [20]. In contrast, we found no significant difference between these two groups of eyes, whereby the mean (SD) corneal thickness at the entrance to the cornea and anterior chamber were 803.1 (61.8) μm and 987.9 (96.4) μm for eyes with stromal hydration and 824.2 (72.9) μm and 956.8 (85.2) μm for eyes without stromal hydration, respectively. Further studies are required to determine the etiology of this controversy.

Our study found a reduction in the angle of incision with an increase in the incision length, whereas the surrounding superior and inferior areas increased, which is logically acceptable. Similarly, Calladine et al. found a significant negative correlation between the incision length and angle measured using AS-OCT [21]. Table 3 summarizes the findings of studies that have examined postoperative phacoemulsification wound-related complications using AS-OCT.

In the present study, the frequency of Descemet's membrane detachment [20, 24, 27] and epithelial wound gaping [20, 21, 23] at the one-day postoperative assessment were similar to those reported in previous studies. Nonetheless, endothelial wound gaping [20, 21, 24-26] had a higher incidence in our study; however, Xia et al. [23] reported a higher frequency of endothelial wound gaping, as noted in the current study (70% versus 62%). This discrepancy in the frequency of endothelial wound gaping in most published papers [20, 21, 24-26] can be attributed to the fact that posterior wound misalignment has been defined as independent of endothelial wound gaping in many studies. However, these complications are undividable and almost always occur simultaneously. All patients with endothelial wound gaps had posterior wound misalignment on at least one AS-OCT cut. Calladine et al. reported a loss of coaptation in 9% of patients [21]; however, we did not evaluate for this complication in our patients.

In an *in vivo* study by Taban et al., an increase in the angle of incision was associated with a higher risk of edge gaping at higher intraocular pressures in humans, and they defined 46 – 48° of clear corneal incision as the critical angle [29]; however, the mean angle of incision in our study (40.2°) was less than the critical angle. Consistent with the results of Dupont-Monod et al. [24], we found no significant correlation between the mean angle of the main incision and the presence of Descemet's membrane detachment or endothelial wound gaping.

Fukude et al. [20] evaluated the effect of stromal hydration of the main incision and found that the corneal thicknesses on the first day and first week postoperatively were significantly greater in eyes with stromal hydration. However, wound gaping and misalignment were comparable between eyes with and without stromal hydration [20]. Similarly, Calladine et al. [30] found a significantly longer incision length in eyes with stromal hydration than in those without. In addition, they observed a trend toward increased corneal thickness at the incision site with stromal hydration. Descemet's membrane detachment occurred in 63% and 25% of the eyes with and without stromal hydration, respectively. However, endothelial gaping, endothelial misalignment, and epithelial gaping were not substantially different [30]. In the current study, junior residents performed stromal hydration in significantly more eyes than senior residents did, which may imply a higher risk of wound leakage. Nevertheless, corneal thickness at the entrance of the cornea or anterior chamber was comparable between eyes with and without stromal hydration. Similarly, there was no significant difference in the presence of endothelial wound gaping or Descemet's membrane detachment between eyes with and without stromal hydration.

Ho et al. [31] found that patching eyes that underwent uncomplicated phacoemulsification with a clear corneal incision can significantly reduce epithelial gaping on postoperative day one. However, the patched and control groups showed no epithelial gaping on day seven postoperatively. There were no differences in Descemet's membrane detachment, endothelial gaping, or endothelial misalignment [31]. Similarly, in our study, all eyes in the junior and senior resident groups were patched until the day after surgery.

Table 3. Summary of studies that reported postoperative morphological features or early or late complications related to phacoemulsification clear corneal incision using AS-OCT

Author (Year)	OCT device	Post-op image acquisition	Eyes (n)	Detachment of Descemet's membrane	Wound gape	Posterior wound misalignment
Torres et al. (2006) [22]	The Carl Zeiss Stratus AS-OCT	1-d post-op	20	NA	Wound gaping in 25.0%	In 45.0%
		1-m post-op	20	NA	Wound gaping in 10.0%	In 15.0%
Calladine et al. (2007) [21]	The Carl Zeiss Visante AS-OCT	Within 1 h post-op	34	In 62.0%	EpG 12.0% EnG 41.0%	In 65.0%
Xia et al. (2009) [23]	The Carl Zeiss Visante AS-OCT	1-d post-op	60	In 82.0%	EpG 12.0% EnG 70.0%	NA
Dupont-monod et al. (2009) [24]	The Carl Zeiss Visante AS-OCT	1-d post-op	35	In 51.0%	EnG 49.0%	NA
		8-d post-op	35	In 29.0%	EnG 9.0%	NA
Fukuda et al. (2011) [20]	Swept-source AS-OCT	1-d post-op	30	In 36.7%	EpG 6.7% EnG 30.0%	In 40.0%
		1-w post-op	30	In 3.3%	EpG 0.0% EnG 13.3%	In 13.3%
		2-w post-op	30	In 3.3%	EpG 0.0% EnG 6.7%	In 3.3%
Can et al .(2011) [25]	The RTVue-100 Fourier-domain AS-OCT system	1-d post-op	60	In 60.0%	EnG 23.3%	NA
		8-d post-op	60	In 38.3%	EnG 18.3%	NA
		1-m post-op	60	In 1.6%	EnG 3.3%	NA
Lyles et al. (2011) [26]	The Carl Zeiss Visante AS-OCT	1-d post-op	25	In main incision 4.0% In bimanual incision 10.0%	In main incision: EnG 12.0% and EpG 0.0% In bimanual incision: EnG 24.0% and EpG 4.0%	In main incision 52.0% In bimanual incision 14.0%
		1-w post-op	25	In main incision 0.0% In bimanual incision 4.0%	In main incision: EnG 4.0% and EpG 0.0% In bimanual incision: EnG 22.0% and EpG 0.0%	In main incision 60.0% In bimanual incision 12.0%
		1-m post-op	23	In main incision 0.0% In bimanual incision 0.0%	In main incision: EnG 4.0% and EpG 0.0% In bimanual incision: EnG 2.0% and EpG 0.0%	In main incision 35.0% In bimanual incision 14.0%
Wang et al. (2012) [27]	The RTVue-100 Fourier-domain AS-OCT system	1-d post-op	35	In 37.1%	In 58.7%	In 0.0%
		1-w post-op	7	In 14.3%	In 100.0%	In 0.0%
		1 to 3 m post-op	22	In 4.5%	In 31.8%	In 18.2%
Cavallini et al. (2012) [28]	RS 3000 Nidek AS-OCT system	16-m post-op	52	In 0.0%	EnG 1.9%	In 0.0%
Cavallini et al. (2016) [17]	Optos AS-OCT system	18-m post-op	160	In training surgeons: main incision 1.6% / secondary incision 0.0% In experienced surgeons: main and secondary incisions 0.0%	In training surgeons: main incision EnG 8.3%, EpG 1.6% / secondary incision EnG 11.6%, EpG 0.0% In experienced surgeons: main incision EnG 10.2%, EpG 0.0% / secondary incision EnG 5.4%, EpG 0.0%	In training surgeons: 0.8% In experienced surgeons: 0.0%
Current study	Heidelberg Fourier-domain AS-OCT system	1-d post-op	50	In 48.0%	EpG 6.0% EnG 62.0%	NA
		3-m post-op	29	In 0.0%	In 0.0%	NA

Abbreviations: AS-OCT, anterior segment optical coherence tomography device; post-op, post phacoemulsification image acquisition time; n, number of eyes; m, month; EnG, endothelial gape; EpG, epithelial gape; d, day; w, week; h, hour; NA, not available.

To the best of our knowledge, this study is the first to compare the postoperative morphological features and early and late complications related to the main phacoemulsification incision using an FD AS-OCT device between senior and junior ophthalmology residents. However, this study has certain limitations. First, we did not consider the ultrasonic power produced during ultrasound phacoemulsification and did not document postoperative intraocular pressures as possible confounding factors for wound integrity. Second, most patients did not return for the three-month postoperative follow-up. Thus, late postoperative wound-related complications were investigated in only 58% of eyes. This was because most patients who visited the tertiary referral hospital were from other cities, and despite calling and reminding them of the postoperative follow-up, they preferred to visit an ophthalmologist in the city of origin because of the distance. Although we found no significant differences in the morphological features or complications of the main wound between the junior and senior resident groups, due to the observed overall complication rate, we recommend revisions to the resident educational curriculum and supervision guidelines to instill more knowledge of the structure and possible complications of the main incision in phacoemulsification. Application of FD AS-OCT is highly recommended, as it is an excellent noninvasive imaging modality for evaluating postoperative morphological features, wound integrity, and complications of the main incision. A more integrated and detailed assessment could improve patient outcomes and determine the optimal incisional shape. Further studies addressing these limitations are required to provide stronger evidence and validate our preliminary findings.

CONCLUSIONS

We found comparable morphological features and early and late wound-related complications between the eyes operated on by junior and senior residents, indicating similar performance between these two groups of trainees in constructing phacoemulsification wounds. However, the considerable overall rate of some wound-related complications highlights the necessity of revising the resident educational curriculum related to wound construction and improving residents' knowledge of this critical step of phacoemulsification.

ETHICAL DECLARATIONS

Ethical approval: The study was approved by the Research and Ethics Committees of Mashhad University of Medical Sciences, Mashhad, Iran (ethical approval code: IR.MUMS.fm.Rec.1394.341). The study was conducted in compliance with the enets of the Declaration of Helsinki, and all participants provided written informed consent.
Conflict of interest: None.

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