• Clinical Research •

Refractive error and angle of deviation in basic esotropia versus exotropia: a comparative study

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Abstract

● **AIM:** To compare refractive error and angle of deviation in patients with basic esotropia and basic exotropia.

● **METHODS:** A retrospective review was conducted on the medical records of patients with basic-type strabismus. Demographic data, refractive error, best-corrected distance visual acuity (BCVA), and the horizontal and vertical angle of deviation between basic esotropia and exotropia patients were compared.

● **RESULTS:** Among the 7129 patients (mean age 22.98±14.81y) evaluated, 44.7% (3185 cases, 54.9% male) exhibited basic-type esotropia, while 55.3% (3944 cases, 53.9% male) presented with basic-type exotropia. Basic esotropia cases exhibited more hyperopic spherical equivalent measurements in both eyes (right: 0.53±3.07 *vs* left: 0.56±2.98 D) than those with basic exotropia (right eye: -0.33±2.84 *vs* left eye: -0.24±2.68 D, $P<0.001$ for both eyes). Patients with basic esotropia had significantly greater horizontal deviation angles (near: 36.08±18.87 PD and far: 35.56±18.75 PD) compared to those with basic exotropia (near: 33.75±16.11 PD and far: 33.26±15.90 PD, $P<0.001$). Conversely, patients with basic exotropia had slightly higher vertical deviation angles (near: 1.67±5.80 PD and far: 1.72±5.89 PD) compared to those with basic esotropia (near: 1.12±4.57 PD and far: 1.12±4.58 PD, $P<0.001$). Patients with basic esotropia underwent surgical intervention at younger ages compared to basic exotropia individuals (19.68±15.99 *vs* 25.66±13.20, $P<0.001$).

● **CONCLUSION:** Basic esotropia patients present more hyperopic refractive errors, better visual acuity, larger horizontal yet smaller vertical ocular misalignments, and tend to undergo strabismus surgery at younger ages relative to basic exotropia cases.

● **KEYWORDS:** basic esotropia; basic exotropia; refractive error; angle of deviation

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INTRODUCTION

Strabismus is a misalignment of the visual axes caused by dysfunction in neuromuscular control or anatomical abnormalities of the extraocular muscles, resulting in impaired binocular vision, sensory adaptations such as suppression or anomalous retinal correspondence, and potential deficits in stereopsis[1]. Strabismus affects approximately 1.5% to 3% of the population[2]. The implications of strabismus can be quite detrimental. Primarily, the condition results in the loss of binocular single vision and stereoscopic depth perception. Additionally, strabismus is the predominant underlying cause of amblyopia and thus represents a major contributing factor to visual disability among children[3-4].

The basic type of strabismus is characterized by little to no difference between the distance and near deviations[5]. Basic types of strabismus, both esotropia and exotropia, account for the majority of cases examined, requiring substantially different management approaches[6-7].

Accurate classification of strabismus and thorough characterization of clinical findings can enhance clinical decision-making and optimize patient management[8]. Identifying the predominant refraction patterns for each basic deviation type can facilitate early screening protocols and spectacle correction, potentially enhancing visual experiences and preventing the onset of visual impairment[9-11]. Numerous

studies have examined the distribution of refractive errors across various forms of strabismus, establishing that myopia is a significant independent risk factor for exotropia, while hyperopia correlates with an increased risk of esotropia in a dose-dependent manner[12-15].

Several studies have examined the distinct clinical features between patients with esotropia and those with exotropia, focusing on factors such as the age of onset of visual impairment, refractive errors, and the magnitude of deviation[13,16-17]. However, there have been no prior attempts to systematically investigate the refraction patterns associated with different types of basic strabismic deviations. In this population-based study, we examined whether basic exodeviation or esodeviation correlated with distinct refractive error patterns, visual acuity, and angle of ocular misalignment.

PARTICIPANTS AND METHODS

Ethical Approval Formal ethical approval for this study was obtained from the Institutional Review Board of Tehran University of Medical Sciences before study initiation (IR.TUMS.FNM.REC.1402.046). The research protocol and methodology strictly adhered to the ethical principles outlined in the Declaration of Helsinki. Informed consent was waived because of the retrospective nature of this study.

In this cross-sectional study, we retrospectively reviewed medical records of patients who underwent strabismus surgery at Farabi Eye Hospital, Iran, from January 1, 2012, to March 1, 2023. Of the more than 13 000 cases who underwent strabismus surgery, 7129 patients met the inclusion criteria for basic type horizontal strabismus. Basic exotropia is defined by the presence of equal angles of deviation or an angle less than 10 prism diopters (PD) of difference at near and distance, according to Burian's classification[5]. Similarly, basic esotropia is characterized by equal angles of deviation or an angle of difference of 10 PD or less at both near and distance[18]. The inclusion criteria were 1) patients with basic exotropia or esotropia characterized by a difference of less than 10 PD between the deviation angles measured at near and distance fixation, 2) participants older than 3.5y with sufficient cooperation. The exclusion criteria were 1) patients with a history of prior strabismus surgery, refractive surgery, or other ocular procedures, 2) individuals with concurrent ocular pathologies such as retinal diseases, optic nerve disorders, or ocular trauma, 3) patients with neurological or developmental conditions affecting visual function, such as cerebral palsy or neurodegenerative diseases, 4) patients with severe amblyopia, defined as a best-corrected distance visual acuity (BCVA) of ≥0.8 logMAR.

The following preoperative data were collected and analyzed: cylindrical and spherical equivalent (SE), BCVA, and angle of deviation at distance and near (measured in PD). Refractive errors were classified as myopic when the SE measured -0.50 diopters (D) or more and as hyperopic when the SE was +0.50 D or higher. The SE is calculated as the sum of the spherical power and half the cylindrical power[19]. The routine ophthalmology examinations included automated refractive error measurement using a Topcon KR-8900 autorefractor (Topcon Corporation, Tokyo, Japan), with the results subsequently verified through manual retinoscopy with a Heine beta 200 device (Heine Optotechnik, Herrsching, Germany). The angle of deviation was measured by an alternate prism-cover test for near (40 cm) and far (6 m) separately by looking at an accommodative target. Extraocular motility, ductions, and versions were also evaluated. Refractive correction was worn by all participants throughout the examinations. The distribution patterns of SE and cylindrical components of refractive error and mean values of angle of deviation were determined and compared in the patients diagnosed with basic esotropia and basic exotropia.

Statistical Analysis Data collected from medical record reviews were thoroughly analyzed using the SPSS-24 statistical software package from IBM. Descriptive and inferential statistical techniques were employed to summarize and compare collected metrics. The normality of distributions was assessed using the Shapiro-Wilk test. Differences between patients with basic esotropia and exotropia were statistically analyzed across all study parameters using the independent samples *t*-test, based on the results of the normality assessment. A significance level of 5% was set for all statistical tests to identify meaningful differences between the basic strabismus conditions.

RESULTS

A total of 7129 individuals with basic strabismus with a mean age of 22.98±14.81y [3875 (54.4%) males] were included in our study. Among the patients, 3944 (55.3%) were diagnosed with basic exotropia, exhibiting a mean age of 25.66±13.20y, while 3185 (44.7%) had basic esotropia, with a mean age of 19.68±15.99y. Age, BCVA, refraction (SE and cylinder), and horizontal and vertical deviation angles in patients with basic esotropia and exotropia are reported in Table 1.

The mean age at the time of surgical intervention was 19.68±15.99y for patients with basic esotropia, while it was 25.66±13.20y for those with basic exotropia. Patients with basic esotropia exhibited significantly better BCVA compared to those with basic exotropia in both the right (0.16±0.35 *vs* 0.23±0.55 logMAR) and left (0.18±0.40 *vs* 0.24±0.56 logMAR) eyes (P<0.001). The mean SE measurements in both eyes were significantly more hyperopic in patients with basic esotropia (right eye: 0.53±3.07 and left eye: 0.56±2.98 D) compared to those with basic exotropia (right eye: -0.33±2.84 and left eye: -0.24±2.68 D, P<0.001 for both eyes). The mean cylindrical refractive error was notably greater in both eyes of

Table 1 Comparative analysis of refractive error components, BCVA, and angle of deviation in patients with basic exotropia and basic esotropia

Parameters	*n*	Minimum	Maximum	Mean±SD	*P*
Age at first surgery (y)					<0.001
XT	3944	4.0	77.0	25.66±13.20	
ET	3185	4.0	81.0	19.68±15.99	
Cylinder (D)					
OD					<0.001
XT	3944	0.00	10.00	0.82±1.16	
ET	3185	0.00	8.50	0.73±0.98	
OS					<0.001
XT	3944	0.00	10.00	0.88±1.24	
ET	3185	0.00	9.50	0.77±1.00	
SE (D)					
OD					<0.001
XT	3944	-23.00	23.50	-0.33±2.84	
ET	3185	-29.00	16.50	0.53±3.07	
OS					<0.001
XT	3944	-28.00	17.00	-0.24±2.68	
ET	3185	-28.50	16.63	0.56±2.98	
BCVA (logMAR)					
OD					<0.001
XT	3465	0.00	0.7	0.23±0.55	
ET	2516	0.00	0.7	0.16±0.35	
OS					<0.001
XT	3457	0.00	0.7	0.24±0.56	
ET	2516	0.00	0.7	0.18±0.40	
Difference BCVA between OD and OS (logMAR)					<0.001
XT	3465	0.00	0.7	0.16±0.22	
ET	2516	0.00	0.7	0.16±0.21	
Horizontal deviation (PD)					
Near					<0.001
XT	3944	12	123	33.75±16.11	
ET	3185	10	133	36.08±18.87	
Distance					<0.001
XT	3944	14	123	33.26±15.90	
ET	3185	8	133	35.56±18.75	
Vertical deviation (PD)					
Near					<0.001
XT	3944	0	50	1.67±5.80	
ET	3185	0	45	1.12±4.57	
Distance					<0.001
XT	3944	0	50	1.72±5.89	
ET	3185	0	45	1.12±4.58	

SE: Spherical equivalent; BCVA: Best-corrected distance visual acuity; OD: Right eye; OS: Left eye; XT: Exotropia; ET: Esotropia; PD: Prism diopter.

individuals diagnosed with basic exotropia compared to those with basic esotropia (P<0.001). Patients with basic esotropia exhibited significantly greater horizontal deviation angles (at near fixation: 36.08±18.87 PD and far fixation: 35.56±18.75 PD) compared to those with basic exotropia (at near fixation: 33.75±16.11 PD and far fixation: 33.26±15.90 PD, P<0.001 for both fixations). Conversely, patients with basic exotropia demonstrated slightly higher vertical deviation angles (at near fixation: 1.67±5.80 PD and far fixation: 1.72±5.89 PD) compared to the basic esotropia

group (at near fixation: 1.12±4.57 PD and far fixation: 1.12±4.58 PD, P<0.001 for both fixations).

DISCUSSION

The relationship between esotropia and hyperopia, as well as the association between exotropia and myopic refractive errors and astigmatism, has been well-established in previous research studies[12,14,20]. However, no prior studies have directly compared refractive error measurement between basic esotropia and basic exotropia strabismus. This retrospective study represents the first attempt to investigate the refractive error and angle of deviation characteristics in patients with basic types of esotropia and exotropia. Patients with basic esotropia tended to exhibit more hyperopic refractive errors, better BCVA, and larger horizontal but smaller vertical angles of deviation compared to those with basic exotropia. Furthermore, basic esotropia patients tended to be younger at the time of their first strabismus surgery.

Early detection and comprehensive hypermetropic spectacle correction could potentially reduce the need for esotropia-correcting surgeries. Moreover, the rising incidence of myopia appears to be contributing to the increased development of childhood intermittent exotropia, further driving the higher demand for exotropia-related surgical interventions[21-22]. Similarly, this study demonstrated that exotropia surgical interventions comprised the majority of strabismus procedures performed, exceeding the number of esotropia corrections.

Birch *et al*[23] reported a 60% prevalence of refractive accommodative esotropia (RAET), a form of basic esotropia, in hyperopic children aged 1 to 8y. This finding indicates an independent association between hyperopia and the development of this form of strabismus in young children. The underlying mechanism suggests that hyperopic refractive error increases the accommodative demand, which can lead to convergence misalignment. The predominant hyperopic refractive error profile appears to be a common pattern across other subtypes of basic esotropia. Large-scale epidemiological investigations have consistently reported a predominant hyperopic refractive error profile among patients diagnosed with infantile esotropia, where the near and far deviation angles are almost the same[24-25]. Even in cases of esotropia associated with non-committant strabismus, such as Duane's retraction syndrome type 1, both unilateral and bilateral variants tend to demonstrate a greater prevalence of hyperopic refractive error profiles[26]. Given the established correlation between higher initial hyperopia levels and larger esotropia angles[27], as well as significant reductions in hyperopia following spectacle correction in the RAET population[28], it is crucial to implement robust screening and provide timely corrective measures to help mitigate the development of strabismus.

Research has consistently reported a link between intermittent exotropia and myopia. The severity of myopia and astigmatism seems to have a dose-related effect, with stronger associations observed in patients with larger exodeviations[12]. The observed association has also been attributed to infantile exotropia[25]. In myopic individuals, the reduced accommodative effort required for near vision due to a larger accommodation lag, may contribute to suboptimal accommodative convergence, which disrupts fusional control and thereby leads to the development of exotropia[14]. Alternatively, increased vergence demand to control exodeviation may stimulate accommodation and contribute to myopic progression[29]. These findings suggest that the relationship between refractive error and strabismic conditions may extend beyond just the accommodative-vergence interactions, potentially involving subcortical neural pathways that may contribute to the development and progression of these interrelated visual impairments.

Consistent with our findings, Kim *et al*[30] demonstrated that esotropia patients exhibited significantly greater horizontal angle deviations compared to individuals with exotropia. While the difference in deviation angles is not clinically significant, it may be influenced by the duration of visual impairment and the age at which it begins. Notably, patients with RAET who experienced the onset of visual impairment before the age of two were found to exhibit larger deviation angles[31-32]. The reported mean age of the patients in our study represents their age at the time of surgical intervention. However, we lacked data on the age of onset of visual impairment, which could influence visual prognosis. Therefor, further comprehensive research is needed to understand visual acuity outcomes in basic-type strabismus better.

Our findings demonstrated a superior visual acuity in patients diagnosed with basic-type esotropia compared to those with basic-type exotropia. Despite the typically greater horizontal angle of deviation observed in esotropia cases, these patients underwent strabismus surgery at younger ages. This earlier surgical intervention likely reduced the risk of developing amblyopia, contributing to better visual acuity in the basic-type esotropia group compared to the basic-type exotropia patients.

This is the first comparative study of preoperative clinical characteristics in basic exotropia and esotropia patients undergoing strabismus surgery, with the largest reported sample size in the literature. Several limitations are associated with the retrospective design of this study. Notably, there is a lack of comprehensive data regarding the complete clinical profiles of basic strabismus cases, including the age at onset of visual impairment. Additionally, the single-center nature of this investigation may limit its generalizability, as it may not adequately represent the diversity of refractive error patterns across various ethnicities. The cross-sectional design of this study presents a significant limitation, as it restricts our ability

to understand the causal relationship between refractive error and strabismus. Moreover, this study did not consider potential confounding factors from comorbid conditions, such as amblyopia.

In conclusion, this large retrospective study offers important insights into the clinical profile differences between patients with basic esotropia and those with basic exotropia. The key findings demonstrate that esotropia tends to present with more hyperopic refractive errors, better visual acuity, and larger horizontal but smaller vertical ocular misalignment compared to exotropia. These results provide a foundation for exploring the underlying causes of these common forms of strabismus. The distinct neuro-refractive profiles identified suggest that tailored refractive and amblyopia management approaches may optimize outcomes for each strabismus subtype.

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