

# Correlation between Corneal Topographic Patterns and Refractive Status of the Eye in an Adult Iranian Population: Tehran Study

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## Abstract

**Purpose:** To evaluate the corneal topographic patterns in an adult Iranian population and investigate its correlation with the refractive status of the eye.

**Methods:** In a cross-sectional study named “Tehran Study,” 1023 samples were selected by the cluster sampling method from the downtown area of Tehran. Eight hundred and forty-nine adults aged over 15 years participated. All selected participants were refracted and underwent topography imaging.

**Results:** The patients’ ages ranged from 15 to 91 years with a mean of  $40.33 \pm 16$  years. The most frequent topographic patterns were symmetric bowtie (SB) (34%), SB with inferior steepening (SB-IS) (14.1%), and round (10.5%). The orders changed in categorization by refractive status: The most frequent pattern in all subgroups (emmetropia, myopia, and hyperopia) was SB with frequencies 32.7%, 35.8%, and 22.5%, respectively. Although the second order was asymmetric bowtie (AB) with AB-IS in the emmetropic and myopic subgroups, in the hyperopic subgroup, round pattern had the second place. The third place was different in all groups. The rarest patterns in the whole were SB with skewed radial axis (SRAX) and AB with SRAX. The first prevalent topographic pattern was SB in all age groups and in both genders. The prevalence of round pattern, irregular pattern, and SRAX significantly increased in older ages, and the prevalence of SB decreased in older ages. The first observed prevalent pattern was SB in both sexes, but the second most prevalent pattern was AB-IS and round in females and males, respectively.

**Conclusions:** Corneal topographic pattern might be related to the refractive status of the eye. The information about normal topographic patterns provides a reference for comparison with diseased corneas.

**Keywords:** Corneal topography, Hyperopia, Refractive error, Myopia, Topographic patterns

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## INTRODUCTION

The cornea is the most important refractive surface of the eye, and its shape directly affects the quality of vision and degree of refractive error. Knowledge of the shape of the “normal” human cornea, and the extent of inter-individual variations in corneal topography in populations helps in many diagnostic and therapeutic conditions such as contact lens fitting,

management of ectatic disorders, and evaluation of patients for refractive surgery.<sup>1-3</sup> In order to determine the early changes in the anterior level of the cornea that occur in the early stages of the disease, we first need to analyze the spectrum of normal topography that exists in populations. Since the prevalence of keratoconus in the Middle East has been proven to be higher,

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the importance of population-based studies in this region is more pronounced.<sup>4,8</sup>

Corneal topography is a well-known method for evaluating corneal shape. The common topographic corneal patterns have been discussed widely, and different patterns have been proposed as normal topographic patterns. This classification becomes especially important in differentiating diseases that affect the cornea, such as mild keratoconus, from normal when planning to have a corneal-based surgery. Knowing the frequency of each normal pattern in specific populations, such as populations with different ethnic backgrounds or in populations with different refractive status, is necessary for estimating the probability of being abnormal in each individual patient.

To reach this, a large population pool, including different ethnic background, age groups, and refractive error status should be gathered globally. There are many published studies in the literature discussing the frequency of topographic patterns; however, most of them report eye hospital/clinic-based populations, and only a few large population-based studies investigate this issue.<sup>1-5</sup> Furthermore, the need for evaluating the correlation between different parameters, most importantly refractive status, is obvious.

In this article, we report the corneal topographic patterns in a large population-based sample, including different age groups and refractive status. To the best of our knowledge, this is the first large population-based study on this topic.

## METHODS

This prospective cross-sectional study named “Tehran Study” was conducted by the Eye Research Center in collaboration with Digestive Disease Research Institute, Tehran University of Medical Sciences, to evaluate ocular health along with the general health status of the adult population of Tehran. In the eye branch of this mega-study, ocular history, assessment of vision-related quality of life, refraction, visual acuity (uncorrected, with habitual correction, and best spectacle correction), and corneal topography were performed for each participant. The sampling method was cluster sampling. The selection of clusters was based on introduced clusters by the Tehran Municipality. Sampling from each cluster was started in a clockwise pattern with a 10-house interval, and at most, two participants were selected from each house. Selection of gender and age of participants in each house was determined based on the predicted chance table. The next ballot from the same table was selected if there was no determined person in that house. One thousand and twenty-three samples were selected for study, of which 849 participants underwent topographic imaging.

Individuals were first examined by an optometrist, and a general history was obtained. Patients with a history of any trauma to the eye, recent contact lens wear, and history of ocular surgery were excluded. Patients with distance corrected visual acuity (DCVA)

<7/10 or abnormal retinoscopy examination (e.g., scissoring reflex) were also excluded. There were no restrictions on the range of refractive error. Topography was then performed for patients. The patient was excluded if there was any error in reading the topographic map. There were no restrictions on the range and regularity of keratometry.

Both eyes of the patients were subjected to initial examination and refraction, but due to the similar nature of the two eyes, topographic and statistical analyses were performed only in the right eye of all patients to avoid statistical bias. Patients with antimetropic refraction were excluded.

One of the authors who was a general ophthalmologist at the time of the study (F.B.) read all topographic patterns and double checked cases in which she was unsure of the classification with a cornea specialist (F.A.).

The tenets of the Helsinki Declaration were followed, and Institutional Review Board of Tehran University of Medical Sciences approval was obtained (98-03-43-26563).

After recording the demographic data, including sex and age, all participants were dry refracted using both auto refractometer (Potec Auto Refractometer-Keratometer PRK-5000 Korea) and manual retinoscopy by a team of five experienced optometrists who followed the same protocol. The objective refraction results were used for the analysis.

Corneal topography was performed with Astramax (LaserSight, USA) corneal topographer. AstraMax is a stereoscopic topographer that assesses information radially, circumferentially, and stereoscopically. Its three-camera system enables individual triangulation of every point of the cornea.<sup>4</sup> Good alignment and image quality were evaluated, and images were repeated until a satisfactory image was obtained.

Emmetropia was defined as spherical equivalent (SE) error between +0.5 diopter (D) and -0.5 D. Hyperopia was defined as SE refractive errors  $>+0.5$  D. Myopia was defined as SE errors  $<-0.5$  D. Astigmatism was defined as  $<-0.5$  D cylinder in the negative form of writing refractive error.

Rabinowitz classification was used in this study to classify the topographic patterns, including inferior steepening (IS), superior steepening (SS), asymmetric bowtie (AB) with SS, AB with IS, AB with skewed radial axis (SRAX), symmetric bowtie (SB), SB with SRAX, oval, irregular, and round.<sup>5</sup>

The data were analyzed using the SPSS software version 21 (IBM Corp., Armonk, NY, USA). To present the data, we used mean, standard deviation, and mediated range. Age-sex standardized prevalence of each pattern was reported with a 95% confidence interval. In the calculation of the standardized prevalence, the age and sex distribution of the Tehran population obtained from the statistical center of Iran based on the last survey of the population census and housing was used. In the calculation of the 95% confidence interval and *P* values, we considered the design effect. The prevalence of different topographic patterns in participants with different refractive

errors and gender was evaluated.  $P < 0.05$  was considered statistically significant.

## RESULTS

Of the total 1023 enrolled participants in the study, 858 adult participants aged over 15 years residing in the downtown area of Tehran participated in this population-based study (response rate: 83.87%). After applying the exclusion criteria, topography was performed for 849 subjects, and their data were analyzed. Forty-three and seven tenth percent of patients were female, and 56.3% were male. The patients' age ranged from 15 to 91 years with a mean of  $40.33 \pm 16$  years.

The types of refractive errors in the study population were as follows: 529 emmetropic (62.3%), 143 myopic (16.8%), 64 hyperopic (7.5%), 74 unilateral myopic (8.7%), and 39 unilateral hyperopic (4.6%) subjects. Three antimetropic patients (0.3%) were excluded from the analysis.

The most frequent patterns were SB (34%), AB-IS (14.1%), and round (10.5%). The least frequent patterns were SB with SRAX (1.7%) and then AB with SRAX (3.7%). The orders changed in categorization by refractive status groups, i.e., the most frequent pattern in all subgroups (emmetropia, myopia, and hyperopia) was still SB with frequencies 32.7%, 35.8%, and 22.5%, respectively. Although the second order was still AB-IS in the emmetropic and myopic subgroups (14.7% and 16.1%, respectively), in the hyperopic subgroup, round pattern had the second place (17.9%). The third place was different in all groups, with round pattern in emmetropia (12%), oval pattern in myopia (10.1%), and irregular pattern in the hyperopic group (13.9%), gaining the third frequent order [Table 1 and Figure 1].

There was a significant difference in the topographic patterns comparing the results of the two genders. The first prevalent pattern was symmetric bow tie in both sexes, but the second prevalent pattern was asymmetric bow tie with IS and round in females and males, respectively ( $P < 0.001$ ) [Table 2].

The first prevalent topographic pattern was SB in all age groups and in both genders. The only exceptions were

males between 61 and 70 years and females over 70 years. Round pattern (26.2%) and AB with SRAX (50%) were the most frequent patterns, respectively. The second frequent pattern in males was the round pattern in all age groups except males under 19 and over 70 years old. The second frequent patterns in almost all age groups in females were AB with SS or IS. The statistical comparison of the topographic patterns between male and female populations at different age groups showed a significant difference, as shown in Table 3.

All statistical studies were performed in the subgroup of people with astigmatism above 0.5 diopters. The results did not significantly change. The frequency of patterns in people with astigmatism more than 0.5 diopters is shown in Table 4.

## DISCUSSION

Studies have shown that keratoconus is more prevalent in the Mediterranean regions.<sup>6-8</sup> Since topography plays an important role in the diagnosis of keratoconus, population-based data about topographic patterns could be very helpful in this context. Rabinowitz *et al.* provided the most common classification of the topographic patterns.<sup>5</sup> Some patterns such as SRAX are more associated with keratoconus.<sup>9,10</sup> In this study, we investigated corneal topographic patterns in healthy

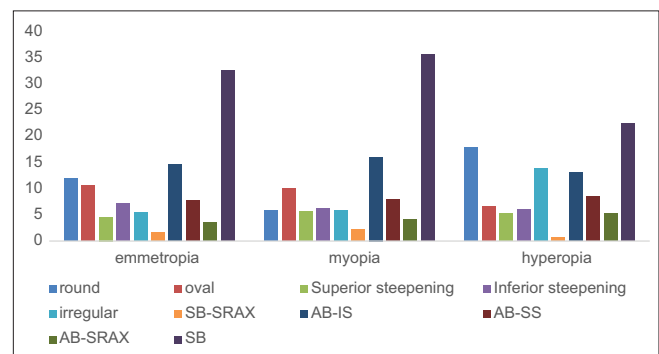


Figure 1: Prevalence (percent) of topographic patterns in different refractive errors

Table 1: Prevalence of topographic patterns in different refractive errors

Topographic pattern	Refractive status, n (%)		
	Myopia	Emmetropia	Hyperopia
Round	21 (5.9)	<b>58 (12.0)</b>	<b>27 (17.9)</b>
Oval	<b>36 (10.1)</b>	51 (10.6)	10 (6.6)
Superior steepening	20 (5.6)	22 (4.6)	8 (5.3)
Inferior steepening	22 (6.2)	35 (7.2)	9 (6.0)
Irregular	21 (5.9)	26 (5.4)	<b>21 (13.9)</b>
Symmetric bow tie with skewed radial axis	8 (2.3)	8 (1.7)	1 (0.7)
Asymmetric bowtie with inferior steepening	<b>57 (16.1)</b>	<b>71 (14.7)</b>	20 (13.2)
Asymmetric bowtie with superior steepening	28 (7.9)	37 (7.7)	13 (8.6)
Asymmetric bowtie with skewed radial axis	15 (4.2)	17 (3.5)	8 (5.3)
Symmetric bowtie	<b>127 (35.8)</b>	<b>158 (32.7)</b>	<b>34 (22.5)</b>

There was a significant relationship between refractive error and topographic pattern. Bold text indicates a statistically significant value ( $P=0.002$ )

**Table 2: Prevalence of topographic patterns in relation to gender**

Topographic pattern	Prevalence (%)		
	Male	Female	Total
Round	<b>15.0*</b>	8.2	11.2
Oval	10.0	9.7	9.8
Superior steepening	6.9	4.7	5.7
Inferior steepening	5.8	7.4	6.7
Irregular	7.7	5.2	6.3
Symmetric bowtie with skewed radial axis	2.5	1.1	1.7
Asymmetric bowtie with inferior steepening	9.6	<b>17.7*</b>	14.1
Asymmetric bowtie with superior steepening	6.9	8.7	7.9
Asymmetric bowtie with skewed radial axis	2.7	4.4	3.7
Symmetric bowtie	<b>32.9*</b>	<b>32.9*</b>	<b>32.9*</b>

\*Bold text indicates a statistically significant value ( $P < 0.001$ )

individuals in a Tehran population to identify the variability of existing corneal patterns. An advantage of this study is the use of Rabinowitz *et al.*'s classification<sup>5</sup> that is much more detailed than Bogan *et al.*'s classification<sup>11,12</sup> and more useful in detecting corneal pathologies like ectasia.

The most frequent pattern observed in this study population, as in the Rabinowitz *et al.*, Riley *et al.*, and Liu *et al.* studies, and the Hashemi *et al.* study in Iran was symmetric bow tie (32.9%).<sup>11</sup> The second and third frequent patterns are also consistent with Hashemi *et al.*'s study.<sup>11</sup> However, AB patterns were more frequent in Bogan *et al.* and Kim *et al.*'s studies.<sup>12,13</sup> In general, bow tie patterns were dominant in our study (60.3%) like other studies.<sup>11-16</sup> SRAX, an important pattern associated with keratoconus, was observed in 5.4% of participants, which was less than Hashemi *et al.*'s study (12%) but more than Rabinowitz *et al.*'s findings (2%).<sup>5,11</sup> These differences may have originated from different topography systems, scales, maps, different populations, or selection biases. Table 5 presents the results of similar studies investigating the distribution of different corneal topography patterns.

**Corneal topography assessment as a function of refractive error**

With regard to refractive error, statistically significant changes were observed in some topographic patterns. The most frequent pattern in all subgroups (emmetropia, myopia, and hyperopia) was SB with frequencies 32.7%, 35.8%, and 22.5%, respectively, which means some degree of corneal astigmatism is usual. The second order was still AB-IS in emmetropic and myopic subgroups (14.7% and 16.1%, respectively), but in the hyperopic subgroup, round pattern had the second place (17.9%). The third place was different in all groups with round pattern in emmetropia (12%), oval pattern in myopia (10.1%), and irregular pattern in the hyperopic group (13.9%), gaining the third frequent order. To the best of our knowledge, this article is the first that investigates corneal topography changes as a function of refractive error. However, corneal parameters have

**Table 3: Prevalence of topographic patterns in relation to age groups in both genders**

Pattern	≤18 (%)		19-30 (%)		31-40 (%)		41-50 (%)		51-60 (%)		61-70 (%)		70+ (%)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1	0 (0.00)	2 (5.0)	17 (15.5)*	10 (7.4)	12 (12.1)*	8 (6.9)	18 (22.0)*	10 (7.0)	12 (14.3)*	16 (12.2)*	11 (26.2)*	4 (10.0)*	2 (8.0)*	0 (0.0)
2	2 (5.3)	3 (7.5)	9 (8.2)	13 (9.6)	13 (13.15)*	13 (11.2)	13 (15.9)*	20 (14.1)*	7 (8.3)	7 (5.3)	2 (4.8)	2 (5.0)	2 (8.0)*	1 (16.7)*
3	1 (2.6)	4 (10.0)*	6 (5.5)	6 (4.4)	8 (8.1)	3 (2.6)	3 (3.7)	9 (6.3)	10 (11.9)*	5 (3.8)	4 (9.5)	2 (5.0)	1 (4.0)	0 (0.0)
4	3 (7.9)	3 (7.5)	9 (8.2)	14 (10.3)*	6 (6.1)	7 (6.0)	4 (4.9)	7 (4.9)	3 (3.6)	12 (9.2)	2 (4.8)	2 (5.0)	1 (4.0)	0 (0.0)
5	1 (2.6)	1 (2.5)	5 (4.5)	5 (3.7)	5 (5.1)	4 (3.4)	5 (6.1)	9 (6.3)	11 (13.1)	8 (6.1)	5 (11.9)*	4 (10.0)*	5 (20.0)*	1 (16.7)*
6	0 (0.0)	0 (0.0)	1 (0.9)	0 (0.0)	2 (2.0)	2 (1.7)	0 (0.0)	2 (1.4)	6 (7.1)	1 (0.8)	3 (7.1)	2 (5.0)	0 (0.0)	0 (0.0)
7	8 (21.1)*	8 (20.0)*	11 (10.0)*	29 (21.3)*	10 (10.1)	21 (18.1)*	7 (8.5)	15 (10.6)*	6 (7.1)	26 (19.8)*	2 (4.8)	9 (22.5)*	2 (8.0)*	0 (0.0)
8	4 (10.5)*	3 (7.5)	5 (4.5)	12 (8.8)	8 (8.1)	14 (12.1)*	6 (7.3)	10 (7.0)	6 (7.1)	11 (8.4)	4 (9.5)	3 (7.5)	0 (0.0)	0 (0.0)
9	1 (2.6)	0 (0.0)	1 (0.9)	1 (0.7)	1 (1.0)	6 (5.2)	0 (0.0)	10 (7.0)	5 (6.0)	4 (3.1)	4 (9.5)	3 (7.5)	1 (4.0)	3 (50.0)*
10	18 (47.4)*	16 (40.0)*	46 (41.8)*	46 (33.8)*	34 (34.3)*	38 (32.8)*	26 (31.7)*	50 (35.2)*	18 (21.4)*	41 (31.3)*	5 (11.9)*	9 (22.5)*	11 (44.0)*	1 (16.7)*
Total	38 (100)	40 (100)	110 (100)	136 (100)	99 (100)	116 (100)	82 (100)	142 (100)	84 (100)	131 (100)	42 (100)	40 (100)	25 (100)	6 (100)

Patterns: 1: Round, 2: Oval, 3: Superior steepening, 4: Inferior steepening, 5: Irregular, 6: Symmetric bowtie with skewed radial axis, 7: Asymmetric bowtie with inferior steepening, 8: Asymmetric bowtie with superior steepening, 9: Asymmetric bowtie with skewed radial axis, 10: Symmetric bowtie. \* Bold text indicates a statistically significant value ( $P < 0.05$ )

**Table 4: Frequency of patterns in people with astigmatism more than 0.5 diopters**

	Male (%)	Female (%)	Total (%)
Round	8.5	6.8	7.6
Oval	10.5	4.5	7.3
Superior steepening	3.3	5.7	4.6
Inferior steepening	3.9	9.7	7.0
Irregular	7.8	3.4	5.5
Symmetric bowtie with skewed radial axis	6.5	2.8	4.6
Asymmetric bowtie with inferior steepening	13.1	19.9	16.7
Asymmetric bowtie with superior steepening	6.5	4.5	5.5
Asymmetric bowtie with skewed radial axis	5.2	8.0	6.7
Symmetric bowtie	34.6	34.7	34.7

been evaluated according to the refractive error in several studies.<sup>18-20</sup> A positive correlation was reported between corneal asphericity (Q) and SE refractive error in a myopic patient in Carney *et al.*'s study,<sup>18</sup> but this correlation was not confirmed in hyperopic patients in Mainstone *et al.*'s study.<sup>19</sup> Budak *et al.* showed that as the degree of myopia and negative asphericity increased, the corneal radius of curvature decreased.<sup>20</sup>

#### **Corneal topography assessment as a function of age**

We investigated the relationship between age and topographic patterns. In our study, the prevalence of round pattern, irregular pattern, and SRAX significantly increased in older ages, and the prevalence of SB decreased in older ages. In this study, 50% of females over 70 years had AB with SRAX. However, considering that there were only six females in this subgroup, this might mean that the sample size was not sufficient to judge. In Hashemi *et al.*'s study, the dominant patterns in older individuals were round, oval, and irregular.<sup>11</sup> Irregular pattern may be caused by different corneal changes such as degenerative disorders and corneal scars secondary to minor diseases such as phlyctenule or foreign bodies, so this is not surprising to observe increased prevalence in older age groups. Besides, age-related corneal topographic changes have been investigated in other studies.<sup>21-23</sup> In Topuz *et al.*'s study, a change was found from the vertical bowtie pattern in individuals younger than 30 to a round pattern in those older than 30.<sup>22</sup> Hayashi *et al.* reported a bowtie astigmatism in subjects younger than 40 years, a round pattern in participants between 50 and 60 years, and a horizontal oval steep pattern (against the rule astigmatism) in participants between 70 and 80 years.<sup>21</sup> Goto *et al.* investigated gender- and age-related differences in the corneal topography in a normal population. They showed that corneal irregularity increases with age for both genders.<sup>23</sup> The exact reason for age-related corneal pattern changes is not clear, but it could be attributed to changes in the tear film quality and decrease in muscular tone and palpebral pressure.<sup>22,24</sup>

#### **Corneal topography assessment as a function of gender**

Investigating the relationship between gender and pattern, there was no significant difference in the most frequent pattern between males and females, like the Hashemi *et al.* and Rabinowitz *et al.* studies,<sup>5,11</sup> and the dominant pattern in all of these studies was SB in both sexes. However, the second prevalent pattern was significantly different between the two genders in our study, round in males and AB-IS in females. Goto *et al.* reported a significant difference in the corneal curvature of the older group (50 years or older) in relation to gender: older men had a significantly higher potential for against-the-rule astigmatism than women in their study, but an increase in irregularity with age was not gender related. The rationale for their categorization at age 50 years was the fact that sex hormones and their receptors decrease significantly at this age.<sup>23</sup> However, in this study, there was no significant difference between males and females over 50 years, and SB was the most frequent pattern in both genders older than 50 years.

None of the participants in this study had keratoconus. Initial history taking and examination by the team of optometrists excluded the patients with low DCVA or abnormal retinoscopy examination. The authors accept the limitation of potential inclusion of subclinical or very mild keratoconus patients in the study due to lack of complete evaluation considering elevations (both posterior and anterior). The other limitation of this study is that patients were not examined by slit-lamp. Therefore, cases such as corneal scar or pterygium were either excluded if they caused retinoscopy error, or they were interpreted as irregular topography.

In conclusion, the results of this study demonstrate the relationship between topographic patterns and the refractive status of the eye in a wide age range and provide a possible standard of topographic patterns in healthy Iranian adults.

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Nil.

**Table 5: Comparison of the prevalence (%) of normal topography patterns in different studies**

Study	Place	Number of studied eyes	Age range (mean)	Corneal topography pattern					SB	SB-SRAX	Total				
				Round	Oval	SS	IS	Irregular				AB-IS	AB-SS	AB-SRAX	
Rabinowitz et al. <sup>5</sup>	California, USA	390	39±12	25.1	20.8	4.1	12.1	5.9	7.4	2.3	0.5	10.2	20.3	1.5	21.8
Hashemi et al. <sup>11</sup>	Tehran, Iran	788	40.9±16.9	16	6.6	1.4	4.7	3.3	16.7	10	7.6	24.3	29	4.7	33.7
Bogan et al. <sup>12</sup>	Georgia, USA	399	37.1±13.6	22.6	20.8	-	-	7.1	-	-	-	32.1	-	-	17.5
Liu et al. <sup>15</sup>	Miami, USA	94	23-78 (47.32)	6.52	26.07	-	-	4.53	-	-	-	23.91	-	-	39.13
Riley et al. <sup>14</sup>	Auckland, New Zealand	451 (cataract surgery)	74.9±9.8	29	10	2	3	13	8	3	1	12	28	2	30
Kim et al. <sup>13</sup>	Korea	232	17-86 (50.5)	6.9	13.4	-	-	19	-	-	-	42.7	-	-	18.1
Kim and Chang <sup>16</sup>	Gyeongju, Korea	200	18-55 (29)	7.5	14.5	-	-	12.5	-	-	-	32.5	-	-	33
Kanpolat et al. <sup>17</sup>	Ankara, Turkey	114 (emmetrope)	25-46 (27.2)	14	11.4	-	-	12.3	-	-	-	33.3	-	-	29
Current study	Tehran, Iran	849 (right eye)	15-91 (40.33)	11.2	9.8	5.7	6.7	6.3	14.1	7.9	3.7	25.7	32.9	1.7	34.6

AB: Asymmetric bowtie, SB: Symmetric bowtie, SS: Superior steepening, IS: Inferior steepening, AB-IS: Asymmetric bowtie with inferior steepening, AB-SS: Asymmetric bowtie with superior steepening, AB-SRAX: Asymmetric bowtie with skewed radial axis, SB-SRAX: Symmetric bowtie with skewed radial axis

**Conflicts of interest**

There are no conflicts of interest.

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