Original article

Morphological characteristics of the optic nerve evaluated by confocal laser tomography (HRT3) and laser polarimetry (GDx-VCC) in a normal population from the city of Barcelona

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Objective: To evaluate morphological parameters of optic disk and retinal nerve fiber layer (RNFL) examined with confocal laser tomography (HRT3) and laser polarimetry (GDx-VCC) in a normal population, and analyze correlations of these parameters with demographic variables.

Patients and methods: Cross-sectional study in the context of a glaucoma screening campaign in the primary care center of Barcelona. The individuals selected were non-hypertensive Mediterranean Caucasians with risk for glaucoma development (individuals ≥60 years old or ≥40 years old with family history of glaucoma or intraocular pressure or myopia >3 diopter).

All subjects underwent a complete ophthalmic examination, confocal laser tomography (HRT3) and scanning laser polarimetry (GDx-VCC), with subjects having results within normal limits only being included. Structural parameters were analyzed along with age, refraction, and pachymetry based on the Spearman rank correlation test.

Results: A total of 224 subjects were included, with a mean age of 63.4±11.1 years. Disk areas, excavation and ring area were 2.14±0.52 mm², 0.44±0.34 mm² and 1.69±0.38 mm², respectively. The mean RNFL (GDx) was 55.9±6.9 μm. Age was correlated with lower ring volume, highest rate of cup shape measure, largest mean and maximum cup depth, lower nerve fiber index (NFI) and RNFL (all p-values below .05).
Conclusion: The mean values and distribution of several parameters of the papilla and the RNFL in normal Mediterranean Caucasians population are presented. A loss of thickness of the RNFL, ring thinning, and enlarged cup were observed with increased age.

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Características morfológicas del nervio óptico evaluadas por el tomógrafo láser confocal (HRT3) y polarimetría láser (GDx-VCC) en población normal en la ciudad de Barcelona

RESUMEN

Objetivo: Evaluar parámetros morfológicos de papila y capa de fibras nerviosas de la retina (CFNR) explorados con el HRT3 y el GDx-VCC en población normal y analizar correcciones con variables demográficas.

Pacientes y métodos: Estudio observacional transversal en el contexto de una campaña de detección de glaucoma en un centro de atención primaria de Barcelona. Se seleccionaron sujetos caucásicos de ascendencia mediterránea, no hipertensos y con riesgo de glaucoma (≥ 60 años o ≥ 40 años con alguno de los siguientes factores de riesgo: antecedentes familiares de glaucoma o de presión intraocular alta o miopía > 3 dioptrias). Se realizó exploración oftalmológica completa incluyendo tomografía láser confocal (HRT3) y polarimetría láser de barrido (GDx-VCC). Todos los sujetos incluidos presentan las pruebas dentro de la normalidad. Se analizaron parámetros estructurales con edad, refracción y paquimetría mediante el test de Spearman.

Resultados: Doscientos veinticuatro sujetos incluidos con una media de edad de 63,4 ± 11,1 años. Áreas de disco, excavación y anillo de 2,14 ± 0,52 mm²; 0,44 ± 0,34 mm² y 1,69 ± 0,38 mm², respectivamente. Valor medio de la CFNR (GDx) 55,9 ± 6,9 μm. La edad se correlacionó con menor volumen del anillo, mayor índice de morfología de la excavación, mayor profundidad media y máxima de la excavación y menor índice de fibras nerviosas y CFNR (p < 0,05).

Conclusión: Se proporcionan valores medios y distribución de numerosos parámetros de la papila y la CFNR en población caucásica normal de ascendencia mediterránea. Se observó una pérdida de espesor de la CFNR, adelgazamiento del anillo y aumento de la excavación con la edad.

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Introduction

The prevalence of glaucoma is approximately 2.7% of the world population.1 In Spain, the estimated prevalence is of about 2.1% in the population >40 years, increasing with age to reach 3.7% between 70 and 80 years of age.2 Glaucoma is an optic neuropathy and accordingly optic nerve examination is a crucial assessment. In fact, measuring the optic nerve head, area and neuroretinal rim are essential for diagnosing and managing glaucoma.3,4 In the past 2 decades, several digital imaging techniques have been developed for objectively measuring in vivo various optic nerve head parameters (Heidelberg Retina Tomograph-HRT) and retina nerve fiber layer (RNFL) (confocal laser polarimetry-GDx), among others. HRT3 exploration acquires a topographic map of the optic nerve head utilizing 2 classification algorithms for glaucoma: (1) the Glaucoma Probability Score and (2) Moorfields regression algorithm, objectively calculating numerous papilla parameters.5,6 Scanning laser polarimetry (GDx) is a technique that provides a quantitative assessment of RNFL birefringence.7 This device scans and measures the delay of polarized light passing through the retina and compares this measure with a normal eyes database to provide the probability that the patient may or may not have glaucoma. The best GDx-VCC parameter is the nerve fiber indicator [NFI], an algorithm which, on the basis of a neuronal network, groups several parameters and develops a discriminative threshold value of approximately 30.8

Said imaging instruments include a database of normal subjects to establish the normality probability and classify every eye as being within or beyond the 95 or 99 percentage. Even though the software of said devices provides standard data raised on Caucasian populations, racial and ethnic differences have been described in optic nerve head parameters and RNFL thickness and various demographic locations utilizing HRT9-13 as well as GDx.14-16 Said differences could affect the correct extrapolation of results in patients. Presumably, the most precise improvement would be to have a comparative reference database as similar as possible to the population
being studied. In this way, adequate knowledge of the normal optic disk structure and RNFL, as well as its associations with demographic and biometric variables, together with the systemic diseases in each population would provide an important reference for adequately diagnosing glaucoma.

The objective of this study is to describe the morphological parameters of the papilla and RNFL explored with HRT3 and with GDx-VCC, analyzing in addition their correlation with demographic variables.

Methods

A transversal study was carried out in the context of a glaucoma detection telemedicine campaign carried out in glaucoma risk patients in a primary health area of Barcelona between January and August 2009. The study was approved by the Ethics Committee of the Institut Mar d’Investigacions Médiques (IMIM) of the Barcelona Parc de Salut Mar. Participating subjects were informed about the nature of the study and signed an informed consent.

The primary health care center (PHC) selected for the screening campaign was PHC Larrard, which includes a registered population of 46,368 inhabitants (of which 23,527 are >40 years). Initially, 1,600 subjects aged ≥ 40 years were randomly selected for the detection campaign and classified by age and sex. Screening was proposed only to subjects with: (1) Age ≥ 60 years or (2) Age ≥ 40 years with at least one glaucoma risk factor [myopia above ≥ 3 dioptres and/or familial glaucoma history and/or high intracocular pressure (IOP)] and were available for telephone communications.

In the initial sample (n = 1,600), one patient was registered twice, 36 had died, 626 could not be found, 181 of those who were found did not fulfill the inclusion criteria and 342 declined participation. Finally, 414 subjects voluntarily participated in the glaucoma telemedicine screening campaign, of whom 60.14% were >60 years without other risk factors, and 14.7% were >40 years with at least one of the risk factors described above. For the purposes of the present study, only the subjects classified during the campaign as normal were included in the study, as well as those having a visual acuity ≥ 0.8; IOP <22 mmHg in both eyes, refraction below −6D myopia diopters or +3 hypermetropia, and HRT and GDx within normal limits. HRT was regarded as normal if the result of the Moorfields regression algorithm fell within 95% of normal limits. GDx was regarded as normal if NFI was ≥ 30. The study excluded eyes with ocular diseases and/or previous ocular surgery except phacoemulsification without complications. Out of the 414 subjects examined in the detection campaign, 224 fulfilled the criteria for inclusion in the normality study and were taken into account for establishing the characteristics of the papilla and RNFL in the normal Caucasian population of Spanish lineage residing in said health area of Barcelona.

Complete anamnesis was performed, followed by visual acuity and refraction measurement with autorefractometer (Auto Ref-Keratometer RK-F1 Canon, Irvine, USA), of which the spherical equivalent was taken. Refraction was obtained automatically from 3 readings in every eye. Subsequently, optic nerve head images were captured with HRT3 and GDx-VCC, 3 captures for each eye without pupil dilatation by nonmedical personnel (nurses or optometrists) specifically trained and with experience. The HRT3 contour line was drawn by the same operators with 6–8 points. Only good quality images were accepted (standard deviation ≤ 40 μ). For GDx-VCC, the same operators verified alignment, focus and lighting with quality indices ≥ 6.

IOP was measured with the ICare rebound tonometer (ICare, Tiola OY, Helsinki, Finland). Three alternate IOP measures without anesthetic were taken for every eye, calculating the average of the 3 takes. If the tonometer software reported high standard deviations between takes, the entire tonometry was repeated. High IOP was established above 21 mmHg obtained directly with the ICare device (without correction). Ultrasound pachymetry was performed with advance IOP advance (Heidelberg Engineering) applying topical anesthetic.

The assessed HRT3 parameters were disk area (mm²), cup area (mm²), ring area (mm²), quotient of cup/disk areas, cup volume (mm³), ring volume (mm³), mean cup depth (mm) and cup index morphology (cup shape).

The GDx-VCC parameters were NFI, TSNIT, superior average, inferior average, TSNIT standard deviation and inter-eye symmetry.

Statistical analysis

Differences between male and female subjects were analyzed in the demographic variables by means of Χ² for student for independent data in continuous variables. For categorical variables, Fisher’s exact test was applied. For papilla and RNFL characteristics, Wilcoxon range test was applied after verifying that the distribution of said variables did not fit within the normal distribution. The relationship between papilla characteristics (HRT) and RNFL (GDx) was analyzed vis-à-vis age, refraction and pachymetry by means of Spearman’s coefficient. For all the analyses the value of p < 0.05 was considered as statistically significant. The statistical analysis was carried out with the SPSS v.19.0 software.

Results

Overall, 224 subjects included 137 (61.2%) females and 87 (38.8%) males with a mean age of range 63.4 years ± 11.1 (40–89 years). All the patients included in the study were voluntary Caucasians of Mediterranean descent. The demographic characteristics of age, sex, pathological history, refraction and pachymetry are detailed in Table 1. The stratification of the population by age groups is shown in Table 2. No statistically significant differences were found between the group of males and females as regards age, visual acuity or refraction. Subjects reporting high IOP and glaucoma familial history were separately analyzed and compared with the remaining population regarded as normal in the study, without finding significant differences.

Optic nerve head morphology (HRT3)

Overall, 394 eyes of 224 subjects were included, i.e., subjects with good image quality. The mean values and standard
deviation are shown in Table 3. No significant differences were found between females and males. The only observation is that the disk area (2.08 ± 0.50 vs. 2.26 ± 0.58 mm²; p = 0.010), cup area (0.41 ± 0.36 vs. 0.52 ± 0.36 mm²; p = 0.001) and cup volume (0.09 ± 0.12 vs. 0.11 ± 0.10; p = 0.003) were significantly larger in males than in females. As regards ratios, differences were observed in males in the cup/disk quotient (0.18 ± 0.12 vs. 0.22 ± 0.12; p = 0.007) and the vertical cup/papilla quotient (p = 0.008). The ring/disk area quotient was higher in the group of females (0.82 ± 0.12 vs. 0.78 ± 0.12; p = 0.007) (Table 3).

The results of the correlation analysis between age and refraction (spherical equivalent) with various HRT3 parameters are shown in Table 4. A significant volume reduction in the ring, mean depth and maximum cup depth were observed, together with increases in the cup morphology index with higher age (Fig. 1). The disk area increased with lower

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Overall sample (n = 224)</th>
<th>Females (n = 137)</th>
<th>Males (n = 87)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>63.4 ± 11.1 (40–89)</td>
<td>63.9 ± 11.7 (41–89)</td>
<td>62.7 ± 9.9 (40–88)</td>
<td>0.456</td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>17 (7.6)</td>
<td>7 (5.1)</td>
<td>10 (11.5)</td>
<td>1.00)*</td>
</tr>
<tr>
<td>Arterial hypertension (%)</td>
<td>61 (27.2)</td>
<td>35 (25.4)</td>
<td>26 (29.9)</td>
<td>0.281**</td>
</tr>
<tr>
<td>Cardiocirculatory disease (%)</td>
<td>57 (25.4)</td>
<td>37 (26.8)</td>
<td>20 (23)</td>
<td>0.277**</td>
</tr>
<tr>
<td>Familial high IOP history (%)</td>
<td>22 (9.8)</td>
<td>15 (10.9)</td>
<td>7 (8)</td>
<td>1.00)**</td>
</tr>
<tr>
<td>Familial glaucoma history (%)</td>
<td>26 (11.3)</td>
<td>18 (13.5)</td>
<td>8 (9.1)</td>
<td>1.00)**</td>
</tr>
<tr>
<td>Corrected visual acuity</td>
<td>0.9 (0.8–1)</td>
<td>0.9 (0.8–1)</td>
<td>0.9 (0.8–1)</td>
<td>0.607</td>
</tr>
<tr>
<td>IOP, mmHg</td>
<td>13.8 ± 3.1 (6.7–22)</td>
<td>13.4 ± 3.1 (6.7–22)</td>
<td>14.3 ± 3 (8.3–20.3)</td>
<td>0.723</td>
</tr>
<tr>
<td>Spherical equivalent, Dp</td>
<td>0.17 ± 2 (–7/7.5)</td>
<td>0.27 ± 1.87 (–5.5/6)</td>
<td>0.33 ± 2.21 (–7/7.5)</td>
<td>0.583</td>
</tr>
<tr>
<td>Pachymetry, μ</td>
<td>559.8 ± 41.7 (452–729)</td>
<td>554 ± 37.1 (452–644)</td>
<td>567.4 ± 47.2 (472–729)</td>
<td>0.033*</td>
</tr>
</tbody>
</table>

Value of p T for student for independent samples. *p < 0.05.
Value of p for a Fisher’s exact statistics ** p < 0.05.

| Table 2 – Distribution table of patients by age and sex in the studied sample. |
|---------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Age group                       | Total             | Females           | Males             | Females           | Males             | Females           |
| 40–49                           | 18                | 25                | 49                | 31                | 14                | 0                 |
| 50–59                           | 14                | 12                | 41                | 18                | 2                 | 0                 |
| 60–69                           | 6.3               | 5.4               | 18.3              | 8                 | 0.9               | 0.38              |
| 70–79                           | 32                | 37                | 90                | 49                | 16                | 0                 |
| 80–89                           | 14.3              | 16.5              | 40.2              | 21.9              | 7.1               | 0                 |
| 90–99                           | 22.3              | 21.03             | 20.77             | 18.54             | 13.71             | 3.62              |
| Population of PHC Larrard       | 5256              | 4947              | 4886              | 4361              | 3226              | 851               |
| % of total                      | 100               | 100               | 100               | 100               | 100               | 100               |

Table 3 – Descriptive measures of pachymetry with HRT3 and its correlations with age, spherical equivalent and pachymetry.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean (SD)</th>
<th>Median</th>
<th>Females (n = 237)</th>
<th>Males (n = 157)</th>
<th>Age</th>
<th>Spherical equivalent</th>
<th>Pachymetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disk area (mm²)</td>
<td>2.14 ± 0.52</td>
<td>2.06</td>
<td>2.08 ± 0.50</td>
<td>2.26 ± 0.58*</td>
<td>−0.052</td>
<td>−0.155**</td>
<td>0.003</td>
</tr>
<tr>
<td>Cup area (mm²)</td>
<td>0.44 ± 0.34</td>
<td>0.39</td>
<td>0.41 ± 0.36</td>
<td>0.52 ± 0.36*</td>
<td>−0.041</td>
<td>−0.031</td>
<td>0.038</td>
</tr>
<tr>
<td>Ring area (mm²)</td>
<td>1.69 ± 0.38</td>
<td>1.66</td>
<td>1.67 ± 0.37</td>
<td>1.73 ± 0.41</td>
<td>−0.041</td>
<td>−0.176**</td>
<td>−0.032</td>
</tr>
<tr>
<td>Cup/disk areas quotient</td>
<td>0.19 ± 0.12</td>
<td>0.19</td>
<td>0.18 ± 0.12</td>
<td>0.22 ± 0.12*</td>
<td>−0.024</td>
<td>0.007</td>
<td>0.046</td>
</tr>
<tr>
<td>Ring/disk areas quotient</td>
<td>0.80 ± 0.12</td>
<td>0.80</td>
<td>0.82 ± 0.12*</td>
<td>0.78 ± 0.12</td>
<td>0.024</td>
<td>−0.007</td>
<td>−0.046</td>
</tr>
<tr>
<td>Cup volume (mm³)</td>
<td>0.09 ± 0.10</td>
<td>0.05</td>
<td>0.09 ± 0.12</td>
<td>0.11 ± 0.10*</td>
<td>−0.077</td>
<td>0.037</td>
<td>0.065</td>
</tr>
<tr>
<td>Ring volume (mm³)</td>
<td>0.44 ± 0.16</td>
<td>0.42</td>
<td>0.45 ± 0.16</td>
<td>0.45 ± 0.17</td>
<td>−0.116**</td>
<td>−0.111**</td>
<td>−0.106**</td>
</tr>
<tr>
<td>Mean cup depth (mm)</td>
<td>0.17 ± 0.07</td>
<td>0.18</td>
<td>0.17 ± 0.08</td>
<td>0.19 ± 0.08*</td>
<td>−0.132</td>
<td>−0.038</td>
<td>0.038</td>
</tr>
<tr>
<td>Maximum cup depth (mm)</td>
<td>0.51 ± 0.20</td>
<td>0.53</td>
<td>0.51 ± 0.22</td>
<td>0.54 ± 0.20*</td>
<td>−0.172</td>
<td>−0.076</td>
<td>0.078</td>
</tr>
<tr>
<td>Cup morphology index</td>
<td>−0.20 ± 0.05</td>
<td>−0.19</td>
<td>−0.20 ± 0.06</td>
<td>−0.20 ± 0.07</td>
<td>0.154**</td>
<td>−0.111**</td>
<td>−0.062</td>
</tr>
<tr>
<td>Cup/horizontal papilla quotient</td>
<td>0.41 ± 0.20</td>
<td>0.43</td>
<td>0.40 ± 0.21</td>
<td>0.45 ± 0.20*</td>
<td>−0.038</td>
<td>0.040</td>
<td>0.060</td>
</tr>
<tr>
<td>Cup/vertical papilla quotient</td>
<td>0.29 ± 0.20</td>
<td>0.32</td>
<td>0.27 ± 0.21</td>
<td>0.33 ± 0.20*</td>
<td>0.009</td>
<td>−0.030</td>
<td>0.062</td>
</tr>
</tbody>
</table>

Differences between sexes: Wilcoxon p test, *p < 0.05.
Correlation variables: Spearman’s correlation coefficient p: *p < 0.05; **p < 0.01.
spherical equivalents ($p<0.05$; Fig. 2). That is, hypermetropics with higher grades exhibited the smallest papilla, while larger myopics had the larger ones. The same significant relationship was observed between spherical equivalent and ring area, ring volume and cup morphology index.

### Study of the retinal nerve fiber layer (GDx-VCC)

This study included 411 eyes with good quality images of 224 patients. The mean quality of images was $8.64 \pm 0.68$. The descriptive results of parameters obtained with GDx-VCC are shown in Table 4.

**Figure 1** – Ratio between HRT parameters and age. Ring volume, mean and maximum cup depth and morphology index increase with age (years) (Spearman, $p<0.05$): (A) negative correlation between ring volume and age; (B) positive correlation between cup morphology index and age; (C) and (D) negative correlation between age and mean and maximum cup depth.
The only statistically significant differences between sexes were found in the TSNIT standard deviation parameter, which was higher in females (21.29 ± 3.81) than in males (20.23 ± 4.28), p < 0.05. No differences were found in the fiber layer parameters (Table 4).

The results of the correlation study between the parameters obtained with GDx vis-à-vis age and spherical equivalent are specified in Table 4. A positive correlation was observed between age and the NFI value, as well as a negative correlation of age with the superior average, TSNIT standard deviation and inter-eye symmetry (Fig. 3). In addition, a positive correlation was also obtained between quality and spherical equivalent (r = -0.181; p < 0.01) and between quality and pachymetry (r = 0.149; p < 0.01).

**Fig. 2 – Distribution of the average disk area in function spherical equivalent (discontinuous variable) according to whether they are: (A) hypermetropes or (B) myopic.** The area of disk (disk size) With tends to increase the degree of myopia and reduce With the grade of hypermetropia.

**Discussion**

Utilizing HRT3 and GDx-VCC, this study provides quantitative information about the optic nerve head characteristics and nerve fiber layer in normal Mediterranean subjects residing in Barcelona. It also analyzes its relationship with age and other ocular characteristics.

Different studies carried out with HRT (see Table 5 for a summary of the most important studies) have found significant differences in optic disk size and topography between different ethnic groups. Most of the said studies described significantly larger disk areas and cups in Afro-American subjects (2.17–2.67 and 0.61–0.69 mm², respectively) in comparison with Caucasian subjects (1.82–2.40 and 0.33–0.45 mm²).

The remaining assessed ethnic groups exhibited higher parameters than Caucasians but lower than the black race (Asian: 2.04–2.64 and 0.51–0.53 mm²; Hispanics: 2.56–2.57 and 0.45 mm²). In the present study, mean disk and cup area values of 2.14 ± 0.52 mm² and 0.44 ± 0.34 mm² were found. These data are very similar to those reported in other studies carried out with Spanish and Turkish populations suggesting that disk and cup size of subjects of Mediterranean lineage would be between those of Caucasian and Afro-American subjects, somewhat below Hispanics and somewhat above the Asian population. These differences could influence the comparisons in populations with different characteristics to those of the reference population utilized in databases. However, in the RNFL layer study performed with GDx-VCC, the results of the NFI values in the present study were quite comparable to those obtained in normal Caucasian subjects for NFI = 19.2–23.18 or NFI = 15.2 ± 7.60. If these data can contribute to discriminate between a normal subject and a subject with pre-perimetric early glaucoma, said subject should undergo additional examinations.

The present study has found significant differences between sexes in several parameters of HRT as well as GDx. Males exhibited larger disk and cup areas and volumes whereas females obtained significantly higher values for ring/disk area quotients and maximum contour elevation. As for GDx, the only differences were observed in the TSNIT deviation which, despite being higher for females, could be affected by other factors because it is a variability parameter. Existing data indicate that physiologically females have smaller papillae with smaller cups despite having the same...
RNFL thickness. Previous studies such as the Bridlington Eye Assessment Project\textsuperscript{26} or the Singapore Malay Eye Study\textsuperscript{27} have also described larger cup areas and volumes as well as higher ring volumes in males compared to females. These differences have given rise to a proposal for establishing a gender-specific database in the normality database of imaging devices. However, a high number of studies did not find differences in parameters based on sex.\textsuperscript{22-24} Even so, the fact that the present study comprised a higher percentage of females could be a factor of influence.

The authors have found a certain correlation between age and some of the parameters taken by HRT3 as well as with GDx-VCC. It is well known that RNFL exhibits physiological losses with age, at the rate of 0.16–0.44 μm per year of age\textsuperscript{25-27} and which also affect papillary morphology.\textsuperscript{28,29} This physiological tendency is confirmed in the present study wherein a significant reduction in ring volume, mean and maximum cup depth and superior nerve fiber layer average were observed, as well as significant NFI increases. Previous studies carried out with HRTII found a significant relationship between age and disk area, cup/papilla ratio, cup area\textsuperscript{29} or only disk area.\textsuperscript{28} However, these parameters were not significant in the present study. The cup shape measure (cup morphology) increased significantly with age, which could indicate that the physiological changes that take place with age are morphologically similar to those produced by glaucoma even though they occur at slower rates and in lower amounts. In the present study, age also had an impact on the quality of HRT measurements, with

**Fig. 3** – Significant correlations of various GDx parameters (microns) with age (years) (Spearman, \( p < 0.05 \)): (A) NFI increases with age; (B) the superior average diminishes with age (week negative correlation); (C) standard deviation with TSNIT diminishes with age; and (D) with higher age, lower symmetry between both eyes.
significantly higher variability (higher SD) in older patients. Factors such as reduced cooperation and increased lens opacity in these patients could explain these findings. Several studies with GDx confirmed diminished nerve fiber layer with age, between 0.2 and 0.38 µm/year, although other studies did not find a significant relationship. In the present study, age-related fiber layer reduction was not significant for the global parameter (TSNIT), although it was for the superior thickness average in which, for the superior quadrant, a significant reduction of 0.004 µm/year took place. Similar to the present results, this age-related reduction was reported only in the superior and inferior regions.

Eyes with smaller spherical equivalent (more myopic) exhibited bigger disk (larger) and ring areas, similar to the results described by the Rotterdam Study carried out with photographs in which refractive error exhibited a weak relationship to disk and ring area. In what concerns studies carried out with HRT, controversial results have been found. Abe et al. obtained a positive significant correlation between cup parameters and refractive error as well as a negative correlation between ring parameters and refraction in 1800 normal Asian subjects between −5 and 5 D in contrast, other authors did not find significant associations between refractive error and HRT parameters in normal subjects. Still others refer that optic disk size is statistically independent from refraction within the range (−8 ± 4 D). The results of the present study observed in more myopic eyes higher cup morphology index with HRT were similar to the results reported by Nakamura et al. who found that the mean and maximum cup depths increased significantly with increased myopia in normal Japanese subjects (between −5 and 4.13 D). The contour ring positioning could explain the said correlations. However, HRT produces better image quality when the ametropia range is of −12 to 12 D, and the present study did not include eyes with high refractive defects, and accordingly its results have limited power to detect changes attributable to refraction.

The present study exhibits some methodological limitations. Firstly, functional tests were not performed and the inclusion thereof could have influenced results because some slight glaucomas with normal structures and altered function could have been included. However, matched results of 2 normal structural tests render such a situation improbable. Secondly, as in all randomized population studies, the percentage of participants is limited. If we add to this the impossibility of locating 30% of the sample due to faulty PHC data, this could have affected the sample distribution as per age and sex. The authors cannot state that the population studied as normal is representative, and considering that 21.8% of initial sample declined participation it is impossible to determine whether these subjects could exhibit the same properties as the studied population. Even so, Table 2 illustrates the percentages of cases included as per age and

![Table 5 - Optic nerve size and topography assessed with HRT according to different population studies on normal patients.](https://www.example.com/table5.png)
sex and the actual distribution of the reference population of said health center. No statistically significant differences were observed in the distribution of groups based on age between the studied sample and the population registered in the Larrard PHC.

In conclusion, the present study provides normality values for HRT and GDx parameters in a sample of normal Caucasian subjects of Mediterranean descent in the city of Barcelona. It also confirms some correlations between optic nerve morphology parameters and other demographic variables such as age or sex which are important and worthwhile remembering in clinical practice: (1) female patients have thinner corneal and physiologically smaller papillae and cups when compared to males; (2) age produces a physiological reduction of the neuroretinal ring with increased cup and diminished RNFL; (3) with smaller spherical equivalents (higher myopia) papillary size increases and quality of images worsens.

**Conflict of interest**

No conflict of interest was declared by the authors.

**References**


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