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Original Research Article

Morphometric parameters of the optic disk in normal and glaucomatous eyes based on time-domain optical coherence tomography image analysis

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ABSTRACT

Background and objective: Assessment of optic disk morphology is essential in diagnosis and management of visual impairment. The aim of this study was to evaluate associations between optic disk morphometric parameters, i.e., size and shape, and age, gender, and ocular axial length in normal and glaucomatous eyes based on time-domain optical coherence tomography image analysis.

Materials and methods: It was a case-control study of 998 normal and 394 eyes with primary open angle glaucoma that underwent ophthalmological investigation and time-domain optical coherence topography scanning. Areas and shapes of the disk, cup, and neuroretinal rim were analyzed.

Results: The shape of the optic disk did not differ between the study groups, i.e., normal and glaucomatous case groups, but the disk area of the primary open angle glaucoma group was significantly larger. The shape of the small disk was significantly different, but the shape of the medium and the large disk did not differ between the study groups. The central area of the disk, i.e., cup area was significantly larger in the case group and its shape was significantly different between the study groups. No significant differences in the area of the cup and its shape, nerve fibers on the edge of the disk, i.e., neuroretinal rim area, were found between the study groups. There were significant associations between age, gender, and ocular axial length and morphometric parameters of the optic disk.

Conclusions: Informative results with regard to the size and shape due to various ocular characteristics between the healthy control group and patients suffering with primary open angle glaucoma were obtained. Both study groups were significant in size, which makes the findings interesting and important contribution in the field.

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1. Introduction

Morphometrics is a branch of morphology that represents the study of quantitative description of size and shape components of biological form and their variation in the population based on statistical analysis [1]. A considerable amount of work has been published examining the optic disk (OD) size-related parameters and their physiological and pathological associations; however, relatively little information is available describing shape features of the OD and their variations in general population [1].

Assessment of the OD, including a neuroretinal rim (NRR) and a cup, is one of the most crucial elements in diagnosing and monitoring blindness-related disorders, e.g., glaucoma [2,3]. The OD is a round/oval structure down which more than a million nerve fibers, i.e., axons of retinal ganglion cells, descend through a sheet that is known as a lamina cribrosa. These fibers are then bundled together behind the eye to form the optic nerve, which continues toward the brain. The NRR is a dense convergence of nerve fibers on an edge of the OD. An inferior rim is usually thicker than a superior rim, which is thicker than a nasal rim, and a temporal rim is the thinnest [4]. The cup is a central area to the OD (Fig. 1).

Glaucoma is a group of progressive optic neuropathies that have in common a slowly progressive degeneration of retinal ganglion cells and their axons, resulting in a distinct appearance of the OD and following pattern of visual loss [5]. It is estimated that glaucoma affects more than 66 million individuals worldwide and it is the second leading cause of blindness in the world, also the problem will increase as the population gets older [5]. The most common suspects to have glaucoma are those individuals with raised intraocular pressure (IOP) or with an asymmetric OD appearance [5]. Of the many types of glaucoma, primary open-angle glaucoma (POAG), in which the iridocorneal angle is open and normal in appearance, is perhaps the most common form of glaucoma [5,6].

Glaucoma is treatable and visual impairment caused by the disease is irreversible, therefore early detection is essential. Variation and qualitative evaluations of structural changes of the OD, the NRR, the cup-to-disk ratio and retinal nerve fiber layer (RNFL) defects have been found useful for evaluation of different degrees of glaucomatous damage [2].

Literature review provides various interpretations about the OD, the NRR and the cup; their parameters and relationships with general health indicators. The size of the OD area showed positive association with age [7,8], but other sources [9–11] informed that there was not enough evidence for the OD dependence on age. The OD area of the male gender was usually larger [7] but there were exceptions [11].

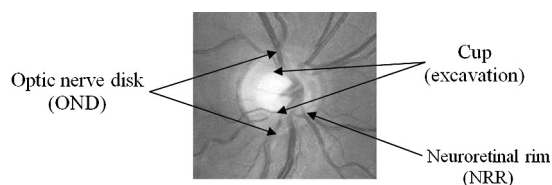


Fig. 1 – An image of the optic disk.

The NRR showed a strong positive correlation with the OD area [7]; for every 1 mm² increase in the OD area, the NRR area increased by 0.5 mm² [3]. The size of the NRR area showed possible correlation with age [3,9,12], but there were considerations that they were not significantly related [8,10,13]. Also several sources stated that the NRR was larger in the male gender [3,7]; meanwhile others informed that the RNN area was not found to be related to the gender [9,10,12]. According to the literature review the ratio of the NRR and the OD did not depend on the age [13]. The asymmetry of the NRR area was related significantly to the asymmetry of the OD area [3].

There is a wide variation of the optic cup size in the normal eyes and much of the variability resulted from the physiological relationship between the size of the cup and the OD [14]. A weak relationship of the vertical diameter of the cup and age [14], and gender [15] was reported. A horizontal diameter of the cup was usually larger in the male gender [15]. There was no significant correlation between the cup size and age, and gender [10]. A ratio of the cup to the disk has a tendency to increase about 0.1 between ages of 30 and 70 years [9]. Also this ratio was usually bigger in the male gender [12]. In general, the cup size was physiologically related to the OD size and pathologically to glaucomatous damage [14].

There are various interpretations about other OD parameters and their relationship with ophthalmic indicators. The OD area was positively associated with the ocular axial length (AL); as the AL increased by 1 mm, the OD area increased by 3.7% [8]. Also the OD was significantly larger in the highly myopic eyes [11], but other sources stated that there was no significant correlation between refraction data and the OD parameters [10].

Medical imaging and visualization technologies allow accurate analysis of visual system and help healthcare professionals to make accurate diagnostics of patients' condition [16]. Some of these technologies in the field of ophthalmoscopy are semi-automated imaging techniques such as confocal laser scanning tomography, laser scanning polarimetry or optical coherence tomography (OCT), which can offer objective and reproducible measurements, particularly topographic parameters of the OD and the RNFL [1].

In this study the OD parameters were obtained by time-domain optical coherence tomography (TD-OCT) (Fig. 2). OCT provides cross-sectional images of tissue structure on the micron scale in situ and in real time [17]. Similar results for morphometric study could be achieved only by a conventional histopathology, which requires removal of a tissue specimen and processing for microscopic examination but not in real time. Therefore, OCT is like a type of optical biopsy and is a powerful imaging technology for medical diagnostics with high axial resolution, automated outlining of the OD margin, and a consistent and stable reference plane for delineation of the NRR boundary [2,17].

The main goal of this study was to evaluate morphometric parameters of the OD and to assess the significance of age, gender, size of the OD and ocular AL as risk factors by performing a large scale research of control subjects and POAG patients of a local population based on TD-OCT image analysis by incorporating tools from geometry, biometrics and computer graphics. Since literature review provides various interpretations, the results of this study help to facilitate

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