Anatomy and Pathology

Posterior Precortical Vitreous Pockets and Connecting Channels in Children on Swept-Source Optical Coherence Tomography

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Purpose. We observed the posterior vitreous in children using swept-source optical coherence tomography (SS-OCT).

Methods. The normal right eyes of 73 children (ages, 3–11 years) were studied using SS-OCT with 12-mm horizontal and vertical scans in the posterior fundus.

Results. Posterior precortical vitreous pockets (PPVPs), narrow liquefied spaces along the vitreoretinal interface in the macula (mean, 165.4 ± 35.2 μm [depth] × 3327 ± 615.7 μm [width]), were observed at age 3 in horizontal scans. The PPVPs enlarged to 382.9 ± 51.8 × 4486.5 ± 342.3 from ages 4 to 6 ($P < 0.01$) and 524.9 ± 60.3 × 5485.9 ± 307.5 after age 7 ($P < 0.01$). In all subjects, the depth and width were means of 426.4 ± 38.2 and 4834.4 ± 228.1 μm, respectively. There were significant correlations between the PPVP size and age (PPVP depth, $r = 0.42$, $P < 0.001$; PPVP width, $r = 0.42$, $P < 0.001$), but not refractive error. The PPVP posterior wall was not visible in all eyes. The PPVP and Cloquet's canal appeared as separate spaces at ages 3 and 4 years. The connecting channel between the PPVPs and Cloquet's developed in 7.7%, 11.1%, 12.5%, 27.3%, 40%, 37.5%, and 50% at ages 5, 6, 7, 8, 9, 10, and 11, respectively.

Conclusions. The PPVPs emerged in front of the macula as a solitary space in early childhood. They first were narrow liquefied spaces anterior to the macula at age 3 and evolved to small boat-shaped spaces that gradually enlarged with age. The channels connecting the PPVPs and Cloquet's canal begin to form after age 5. Their presence suggests a physiologic role of the PPVPs.

Keywords: posterior precortical vitreous pocket, Cloquet's canal, connecting channel, swept-source optical coherence tomography

Investigative Ophthalmology & Visual Science

The vitreous is a gel-like structure that occupies approximately four-fifths of the ocular volume. At birth, the posterior vitreous gel is secondary vitreous. Cloquet's canal is the remnant of the primary vitreous that arises from the optic disc, traverses the core vitreous, and ends in the retrolental space. It is known that vitreous changes its structure after birth to adulthood. Eisner[1] reported that vitreal tracts emerge during adolescence and become fully develop in adulthood. Worst[2,3] reported the presence of cisternal systems in the fully developed vitreous body in young adults. He described "bursa premacularis," which is situated on the convexly detached vitreous cortex in the macular area. Kishi and Shimizu[4] discovered the presence of posterior precortical vitreous pockets (PPVPs) in adult eyes and explained their role in various vitreoretinal interface diseases. Although PPVP and bursa premacularis are defined differently, many investigators call PPVP as bursa premacularis.[5–9] Because of the vitreous transparency, it is difficult to observe the vitreous structure in vivo. Triamcinolone-assisted vitrectomy provided the chance to observe the PPVP intraoperatively.[10,11] Spectral-domain optical coherence tomography (OCT) enabled partial visualization of the PPVP.[6,12–14] Newly developed swept-source OCT (SS-OCT) visualizes the entire structure of the PPVP in vivo, which accelerated the study of the vitreous.[7–9,15] We previously reported the anatomic characteristics of the PPVP and precursor stage of posterior vitreous detachment in normal adults.[7,14] In the current study, we clarified the evolution of the PPVP in children using SS-OCT.

Methods

The study included 28 normal children and 45 children (39 girls, 34 boys) who visited the strabismus service at Gunma University Hospital, but had no ocular abnormalities except for minor refractive errors. The subjects underwent a complete ophthalmic examination in both eyes, including measurement of the refractive error and best-corrected visual acuity (BCVA) level, anterior segment examination, and indirect ophthalmoscopy. The ages of the children ranged from 3 to 11 years (mean, 83.8 ± 3.1 months; age 3, $n = 8$; age 4, $n = 8$; age 5, $n = 14$; age 6, $n = 9$; age 7, $n = 8$; age 8, $n = 11$; age 9, $n = 5$; age 10, $n = 8$; and age 11, $n = 2$).

Two investigators (DL, HI) performed SS-OCT (DRI OCT-1 Atlantis; Topcon, Tokyo, Japan) using 12-mm horizontal and vertical scan lines through the fovea and optic disc. All subjects

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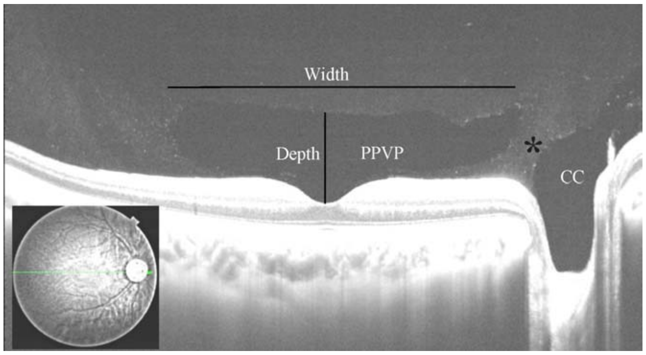

Figure 1. An OCT 12-mm horizontal scan through the fovea in the right eye of a 7-year-old boy. The depth and width of the PPVP represents the size of PPVP. The *black asterisk* indicates the septum between the PPVP and Cloquet's canal (CC).

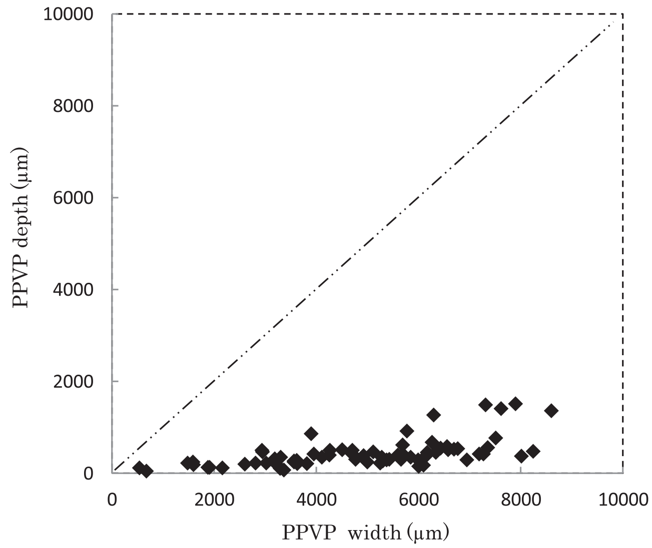

Figure 2. In the 71 eyes with a PPVP, the widths are (Student's *t*-test, $t = 19.3$, $P < 0.001$) significantly longer than the depths.

were sitting during the examination. The vitreous mode was used to obtain clear visualization of the posterior vitreous. The focus was adjusted to obtain the best image of the PPVP and Cloquet's canal. We measured the depth and width of the PPVP (Fig. 1) in all eyes to determine the size of the PPVP from the horizontal scanning line through the fovea. When Cloquet's canal or the connecting channel was not visible in the standard horizontal scan, we performed further horizontal scans as often as possible to visualize the structures at the posterior pole, especially around the optic disc. After obtaining the SS-OCT images, we modified the contrast and brightness to enhance the structure of the posterior vitreous.

We investigated the relationship between the PPVP and Cloquet's canal in the posterior vitreous. We compared the depth and width of the PPVPs in three age groups: ages 3, 4 to 6, and 7 to 11 years. In all subjects, we analyzed the correlation between the PPVP size, and subjects' age and refractive errors.

The correlations evaluated in the respective groups (age, refractive error, size of the PPVPs) were analyzed using Spearman's rank correlation coefficient test. To determine the significance of the differences, based on normal distribution of all data, the Mann-Whitney *U* test and Student's *t*-test were performed. Statistical analysis was performed using State CEL 2 in the Excel 2012 software (Microsoft Corporation, Redmond, WA, USA). The Bonferroni correction was used for multiple comparisons. A *P* value less than 0.05 was considered statistically significant.

This research adhered to the tenets of the Declaration of Helsinki. The participant's parents gave informed consent after explanation of the nature and possible consequences of the study. The research was approved by the Ethics Committee of Gunma University Graduate School of Medicine.

Results

The BCVAs of the 73 eyes ranged from 0.6 to 1.2 (average, 1.0 decimal VA). The refractive values ranged from −4 to +10.25 diopters (D; average, +1.95 ± 0.37 D).

Although the configurations and sizes of the PPVPs differed with age, a PPVP was observed in 71 (97.3%) of 73 eyes with the exception of two eyes of children aged 4 and 5 years. All PPVPs were boat-shaped with an elevated peripheral edge in the horizontal scan, and the widths of PPVP were longer than the depths in the 71 eyes ($t = 19.3$, $P < 0.001$; Figs. 1, 2). In the vertical scans, the superior portion of the PPVPs was elevated superiorly while the subjects were sitting; thus, the width and central depth of the PPVPs were not determined in the vertical scans.

Figure 3 shows the PPVPs in the horizontal scans obtained from the three age groups. Figures 4A and 4B show the comparison among the three groups in the depths and widths of the PPVPs. The PPVPs appeared as narrow liquefied spaces along the vitreoretinal interface in the macula (Fig. 3A) at age 3 years (mean depth, 165.4 ± 35.2 μm) in eight children. In 29 eyes with a PPVP in children ages 4 to 6 years (Fig. 3B), the PPVPs were deeper ($P < 0.05$; mean, 382.9 ± 51.8 μm) than those seen in children aged 3 years, but still shorter ($P < 0.05$) compared to subjects over 7 years. The anterior border of the PPVPs became more clearly demarcated in children over age 7 (Fig. 3C). The posterior wall or premacular vitreous cortex was too thin to identify. In 34 children aged 7 to 11 years (Fig. 3C), the PPVPs enlarged ($P < 0.05$) with a well-demarcated anterior border. The mean depth was 524.9 ± 60.3 μm. A thin vitreous cortex was seen at the periphery of the posterior wall of the PPVP. The widths of the PPVP in the children over 7 years (mean, 5485.9 ± 307.5 μm) were larger than in those who were 3 year old (mean, 3327 ± 615.7 μm) and those who were 4 to 6 years old (mean, 4486.5 ± 342.3 μm; $P < 0.05$ for both comparisons). However, although the widths of the PPVPs in the 4- to 6-year-old group tended to enlarge compared to those in the 3-year-old group, the difference did not reach significance ($P > 0.05$). In all 71 eyes in which a PPVP was identified, the depths ranged from 49 to 1512 μm (mean, 426.4 ± 38.2 μm) and the widths ranged from 545 to 8594 μm (mean, 4834.4 ± 228.1 μm). Figures 4C and 4D show that the depths and widths of the PPVPs increased with age (depth, $r = 0.42$, $P < 0.001$; width, $r = 0.42$, $P < 0.001$), but no significant correlation with the refractive error ($P > 0.05$) was seen. However, the refractive error shifted to myopia with increasing age ($r = -0.31$, $P < 0.05$).

The PPVPs and Cloquet's canal separate in the eyes of all subjects examined aged 3 and 4 years. Cloquet's canal was seen in 72 (98.6%) of 73 eyes (Figs. 1, 3) with the exception of one eye of children aged 5 years (PPVP had not been observed). With expansion of the PPVPs, the gel between the PPVPs and Cloquet's canals was attenuated and formed a septum (Fig. 3). The septum was thinned gradually, until the formation of a channel. The channel between the two spaces developed mostly at the superior edge of the septum (Fig. 3D). A connecting channel between the PPVPs and Cloquet's canals developed in 7.7% at age 5, 11.1% at age 6, 12.5% at age 7,

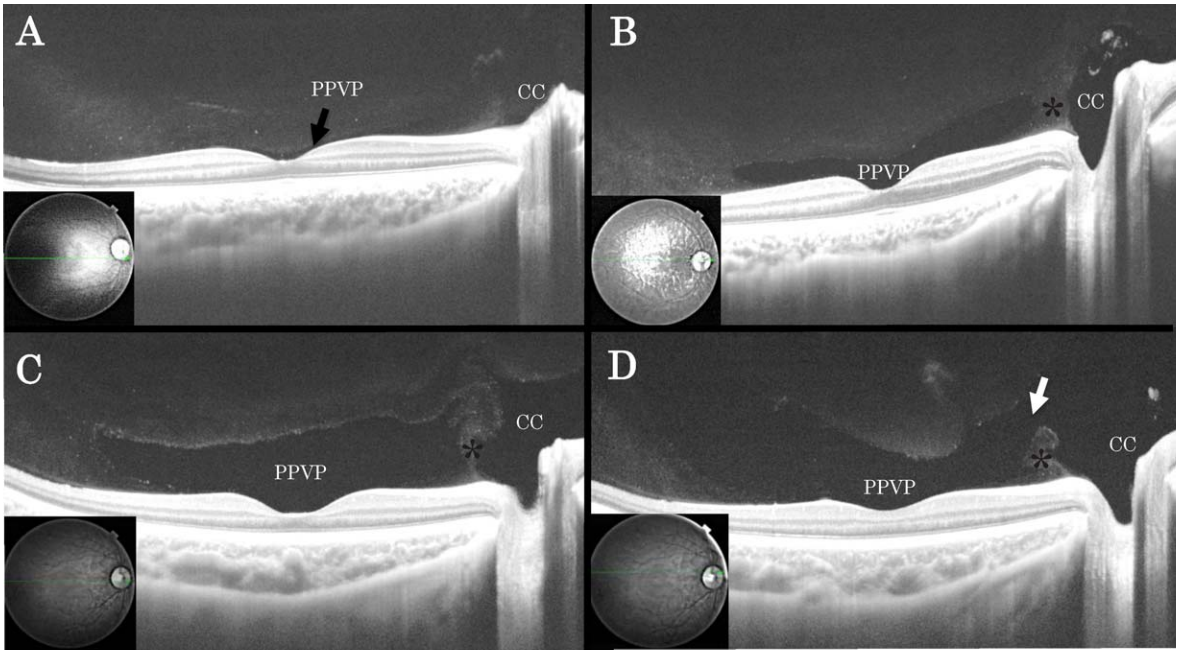

Figure 3. Three SS-OCT horizontal scans through the fovea of (**A**) a 3-year-old girl, (**B**) a 6-year 11-month-old girl, and (**C**) an 8-year-old girl. The PPVPs are seen clearly on the fovea and CC on the optic disc, but no connecting channels between the PPVPs and CC are seen. The *black arrow* (**A**) indicates a small PPVP on the fovea. (**D**) A SS-OCT image is a horizontal scan above the fovea in the same eye as in (**C**). The *white arrow* indicates a connecting channel between a PPVP and CC. The *black asterisks* indicate a septum between the PPVP and CC.

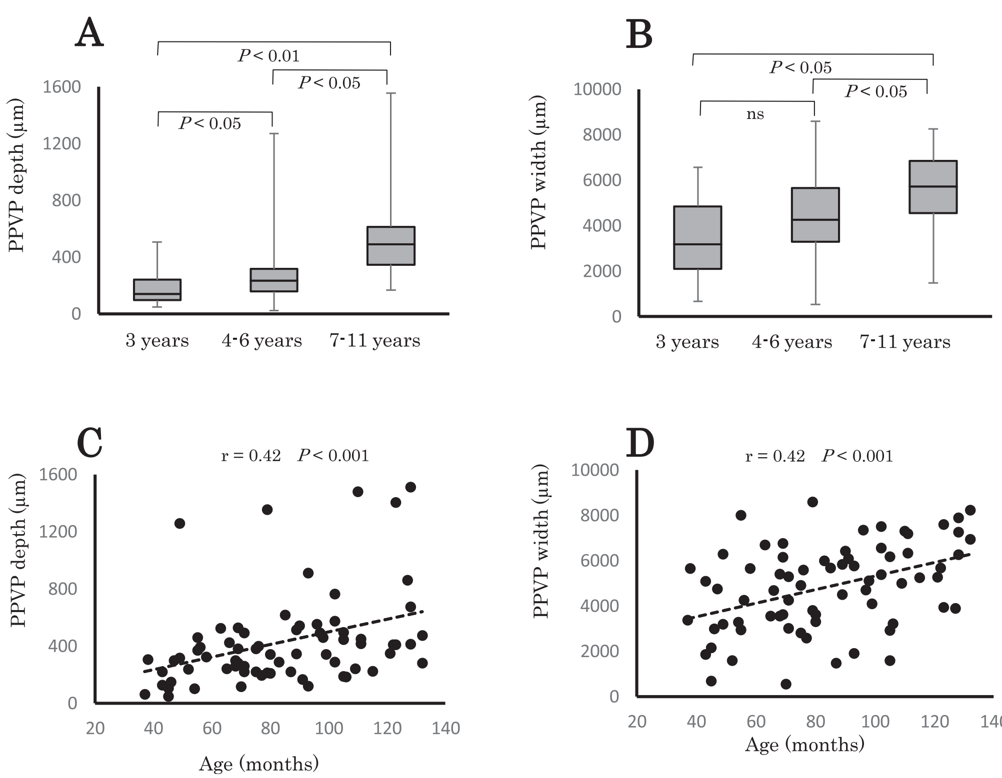

Figure 4. (**A, B**) The *boxplots* show the depth and width of the PPVPs in three age groups (3, 4–6, and 7–11 years). There are significant differences ($P < 0.05$, $P < 0.01$) except for the width between the 3-year-old age group and 4- to 6-year-old age group ($P > 0.05$). (**C, D**) The *scatterplots* show the relationship between the depth and width of the PPVPs and age (months). The width and depth increase with age. *r*, correlation coefficient of Spearman rank correlation test; ns, not significant.

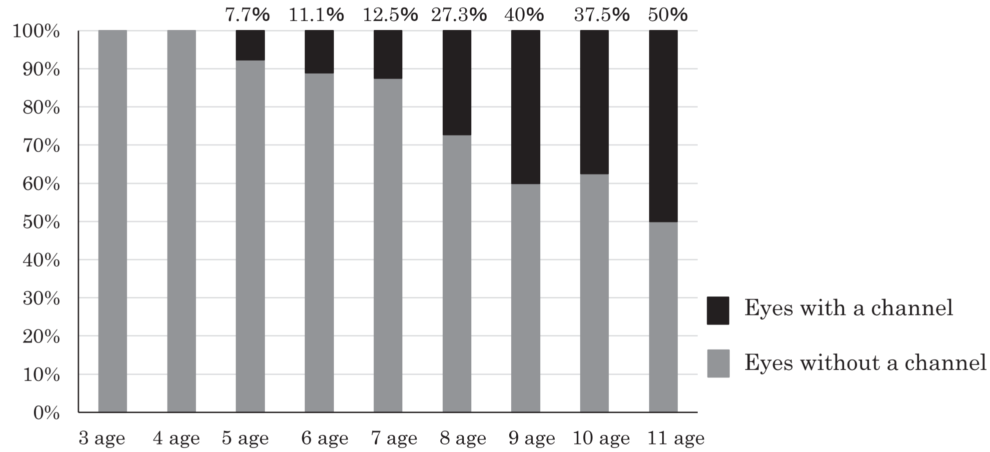

Figure 5. The numbers of eyes with and without a connecting channel between the PPVPs and CCs in each age group.

27.3% at age 8, 40% at age 9, 37.5% at age 10, and 50% at age 11 (Fig. 5). In all subjects, a connecting channel between the PPVPs and Cloquet's canals was seen in 12 (16.9%) of all 71 eyes with a PPVP, and the incidence increased with age.

Discussion

The current study showed that PPVPs appeared as narrow liquefied spaces in front of the fovea at age 3. From age 4 years, the PPVPs enlarged and the anterior border became well demarcated. The PPVPs and Cloquet's canals were separate spaces in all children aged 3 and 4 years, but the channel connecting the two spaces was seen in 7.7% at age 5, which increased to 50% after age 11. Yokoi et al.[8] reported that a PPVP was not seen in a 2-year-old boy on SS-OCT images. Those investigators observed a vitreous crack anterior to the macula, which was connected to Cloquet's canal in a 3-year-old girl. The investigators observed a PPVP in an 8-year-old boy. The PPVPs always were observed in children over age 10 years.

Kishi and Shimizu[4] first reported the presence of PPVPs in autopsy eyes in which the vitreous was stained with fluorescein and observed by slit-lamp biomicroscopy. A PPVP was not present in the eye of a 2-year-old child, but local liquefaction was seen at the macula. The next youngest eye among their specimens was that of a subject who was 26 years, and this eye had a fully developed PPVP.

Itakura et al.[7] examined the posterior vitreous in 58 normal subjects who ranged in age from 22 to 40 years using SS-OCT. A PPVP was observed in all eyes.

Stanga et al.[15] also examined normal eyes aged 5 to 100 years using SS-OCT, They observed a bursa premacularis (or PPVP) detected in 57.1% of eyes. The bursa premacularis and Cloquet's canals coexisted in 97.8% of eyes.

The current study and previous reports have suggested that PPVPs emerge as small liquefied spaces in front of the macula, develop into a boat-shaped liquefied space at approximately ages 4 to 7 years, and fully evolve after age 10. The connecting channels between the PPVPs and Cloquet's canals were seen in 54 (93.1%) of 58 adults.[7] Since the incidence increased from 7.7% at age 5 to 50% at age 11 in the current study, this structure appears to develop during childhood.

Although many investigators view these cisternae or PPVPs as the result of age-related vitreous degeneration, the current results suggested that PPVPs and the connecting channels are anatomic structures in the vitreous that start to develop after 3 years of age and reach full development at approximately age 7 years.

Larsen[17] reported that the ocular axial length increases acutely after birth to age 1.5 years (first term), grows gradually from ages 2 to 5 years (second term), and grows minimally from ages 6 to 13 years (third term). The axial length reaches almost the same size as that in adults at age 7 from 17 mm at birth to approximately 23.50 mm. Along with the postnatal ocular growth, PPVPs and connecting channels also seem to develop.

We previously studied the role of PPVPs in various vitreoretinal interface diseases, such as macular holes, epiretinal membranes, and proliferative diabetic retinopathy.[5,18,19] Recent studies of normal adults and children using SS-OCT showed that PPVPs emerge as narrow liquefied space in front of the macula and gradually enlarge their size during childhood. Cloquet's canal was thought to be a remnant of the primary vitreous. However, Yokoi et al.[8] reported a liquefied crack that arose from Cloquet's canal and enlarged into a PPVP. Although there is no evidence to discuss the function of the PPVPs at this time, Cloquet's canal and the connecting channel may serve a route by which aqueous humor drains into the PPVP. The aqueous has a high concentration of vitamin C, which neutralizes the radicals generated in the crystalline lens. The macula appears to produce a high concentration of radicals. If aqueous humor drains into the PPVP, it may protect the macula from the stress of radical oxygen.

In conclusion, PPVPs emerged in front of the macula as a solitary space in early childhood. They first were narrow liquefied spaces anterior to the macula at age 3 and evolved to small boat-shaped spaces that gradually enlarged with age. The channels connecting the PPVPs and Cloquet's canals are anatomic structures that develop postnatally. Their presence suggests a physiologic role of the PPVPs.

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