Chapter 4. Clinical Interpretation of the Printout

The GDx VCC single exam printout presents the relevant diagnostic information of RNFL assessment in a simple and easy to understand format. For each scan, an age-matched comparison is made to the normative database and any significant deviations from normal limits are flagged as abnormal. Quantitative RNFL evaluation is provided through four key elements of the printout: the Thickness Map, the Deviation Map, the TSNIT graph, and the Parameter Table. These main sections of the printout are discussed in detail below along with the Fundus Image which is useful for image quality purposes. The GDx VCC Serial Analysis printout presents diagnostic information for evaluating RNFL changes over time. The Serial Analysis printout is discussed at the end of the chapter.

Key Features of the Printout

Fundus Image

The fundus image is useful to check for image quality. It allows the user to see if the image is well focused, if it is evenly illuminated, if the optic disc is well centered, and if the ellipse is properly placed around the ONH (see Figure 4.1).

Thickness Map

The thickness map shows the RNFL thickness in a color-coded format. RNFL thickness is represented using a color scale that follows the color spectrum going from blue to red.

Figure 4.2 shows the color-scale map. Thick RNFL values are colored yellow, orange, and red while thin RNFL values are colored dark blue, light blue, and green. Figure 4.3 shows an example of a healthy eye and a glaucomatous eye. A healthy
eye has yellow and red colors in the superior and inferior regions representing thick RNFL regions and blue and green areas nasally and temporally representing thinner RNFL areas. In glaucoma, RNFL loss will result in a more uniform blue appearance (see figure 4.3).

**Deviation Map**

The deviation map reveals the location and magnitude of RNFL defects over the entire thickness map (see Figure 4.4). The Deviation Map analyzes a 128 x 128 pixel region (20° x 20°) centered on the optic disc. To reduce variability due to slight anatomical deviations between individuals, the 128 x 128 pixel thickness map is averaged into a 32 x 32 square grid, where each square is the average of a 4 x 4 pixel region (called super pixels). For each scan, the RNFL thickness at each super pixel is compared to the age-matched normative database, and the super pixels that fall below the normal range are flagged by colored squares based on the probability of normality. Dark blue squares represent areas where the RNFL thickness is below the 5th percentile of the normative database. This means that there is only a 5% probability that the RNFL thickness in this area is within the normal range, determined by an age-matched comparison to the normative database. Light blue squares represent deviation below the 2% level, yellow represents deviation below 1%, and red represents deviation below .05%. The Deviation Map uses a grayscale fundus image of the eye as a background, and displays abnormal grid values as colored squares over this image. This helps the user determine precisely the location of the abnormalities. Figure 4.5
shows several examples of the Deviation Map for eyes at different stages of disease, starting with a healthy eye. For comparison, the Thickness Map and visual field is also shown.

**Figure 4.5.** The correlation between the Deviation Map (bottom), visual fields (top right), and the Thickness Map (top left) is shown for a normal, pre-perimetric, moderate, and advanced glaucoma eye. The visual field insert for each eye is the Pattern Standard Deviation (PSD) plot for that eye. For the normal eye, the Thickness Map has thick regions superiorly and inferiorly (yellow and red colors), the Deviation Map is clear, and the PSD plot has no abnormal values. In the pre-perimetric example, there is a wedge-shaped RNFL defect visible on the Thickness Map in the inferior-temporal region. This defect is clearly illustrated on the Deviation Map; however, the PSD plot for this eye is still normal. This finding is common with the GDx VCC and is one of its biggest strengths: to detect glaucomatous damage before standard visual field tests. For the moderate and advanced glaucoma examples, the RNFL defects visible in the Thickness Map and Deviation Map correlate well with the visual field defect.

**TSNIT Map**

The TSNIT map is displayed at the bottom of the printout. TSNIT stands for Temporal-Superior-Nasal-Inferior-Temporal and displays the RNFL thickness values along the calculation circle starting temporally and moving superiorly, nasally, inferiorly, and ending temporally (see Figure 4.6). In a normal eye the TSNIT plot follows the typical ‘double hump’ pattern, with thick RNFL measures superiorly and inferiorly and thin RNFL values nasally and temporally.

**Figure 4.6.** The TSNIT graph for a healthy eye. The normal range (95%) for a given age is shown in the shaded area.
The TSNIT Graph shows the curve (or function) of the actual values for that eye along with a shaded area which represents the 95% normal range for that age. In a healthy eye, the TSNIT curve will fall within the shaded area. When there is RNFL loss, the TSNIT curve will fall below this shaded area, especially in the superior and inferior regions. In the center of the printout at the bottom, the TSNIT graphs for both eyes are displayed together. In a healthy eye there is good symmetry between the TSNIT graphs of the two eyes and the two curves will overlap. However, in glaucoma, one eye often has more advanced RNFL loss and therefore the two curves will have less overlap. A dip in the curve of one eye relative to another is indicative of RNFL loss.

Parameters

The parameters are displayed in a table in the center of the printout (See Figure 4.7). The TSNIT parameters are summary measures based on RNFL thickness values within the calculation circle. These parameters are automatically compared to the normative database and are quantified in terms of probability of normality. Normal parameter values are displayed in green, abnormal values are color-coded based on their probability of normality. The probability levels used are the same as the Deviation Map: dark blue represents a 5% likelihood of being normal, light blue represents the 2% level, yellow 1%, and red 0.5%. As with the Deviation Map, red values indicate the most severe RNFL defect.

The calculation circle is a fixed circle (or more precisely a fixed size band) centered on the Optic Nerve Head (ONH). The band is 0.4 mm wide, and has an outer diameter of 3.2 mm and an inner diameter of 2.4mm. The inner and outer locations of the band are shown on the printout super-
imposed over both the Fundus Image and the Thickness Map (see Figure 4.8).

The five TSNIT parameters are: TSNIT Average, Superior Average, Inferior Average, TSNIT Standard Deviation (TSNIT SD), and Inter-eye Symmetry. Descriptions of each are given below.

**TSNIT Average:** The average RNFL thickness around the entire calculation circle.

**Superior Average:** The average RNFL thickness in the superior 120° region of the calculation circle (see Figure 4.9).

**Inferior Average:** The average RNFL thickness in the inferior 120° region of the calculation circle (see Figure 4.9).

**TSNIT SD:** This measure captures the modulation (peak to trough difference) of the double-hump pattern. A normal eye will have high modulation in the double-hump RNFL pattern, while a glaucoma eye will typically have low modulation in the double-hump pattern. As a result, high modulation will have a high TSNIT SD value while low modulation will have low TSNIT SD value (see Figure 4.10). This measure represents the standard deviation value of the TSNIT Graph.
**Inter-eye Symmetry**: Measures the degree of symmetry between the right and left eyes by correlating the TSNIT functions from the two eyes. Values range from −1 to 1, where values near one represent good symmetry. Normal eyes have good symmetry with values around 0.9. The parameter is very useful because in glaucoma, one eye is often more advanced than the fellow eye. This measure is the Pearson Product correlation coefficient (r-value) from the correlation of the TSNIT curves of the two eyes. Figure 4.11 shows an example of the symmetry in a healthy eye and a glaucomatous eye.

![Inter-eye Symmetry](image)

**Figure 4.11.** The Inter-eye Symmetry measure is based on the symmetry of the TSNIT graph from the two eyes. In a normal subject, the RNFL profiles of the two eyes are very similar, resulting in good symmetry, and a high Inter-eye Symmetry value (left side). In glaucoma, however, as one eye is frequently more advanced than the fellow eye, the symmetry between the two eyes is reduced (right side).

**The Nerve Fiber Indicator (NFI)**

The NFI is a global measure based on the entire RNFL thickness map. It is calculated using an advanced form of neural network, called a Support Vector Machine (SVM). It was trained on a large sample of representative healthy and glaucomatous eyes and utilizes information from the entire RNFL thickness map to optimize the discrimination between healthy and glaucomatous eyes. The output of the NFI is a single value that ranges from 1-100 and indicates the overall integrity of the RNFL. The NFI is not color-coded based on probability like the other parameters, but rather it is based on an absolute scale.

Output values range from 1 –100, with classification based on the ranges:

- 1-30 -> normal
- 31-50 -> borderline
- 51+ -> abnormal

Clinical research has shown that the NFI is the best parameter for discriminating normal from glaucoma\textsuperscript{53,54}. The sensitivity and specificity of the NFI has been reported to be extremely high, with values of 89% and 98% respectively\textsuperscript{53}. 

![Normal Good Symmetry](image) ![Glaucoma Poor Symmetry](image)
Clinical Examples

This section discusses the interpretation of the printout using examples of a normal eye, and eyes with glaucoma at early, moderate, and advanced stages. The printout’s key areas are the Fundus Image, the RNFL Thickness Map, the Deviation Map, the TSNIT Graph and the Parameter Table. Comparison of each scan to the normative database allows accurate and rapid interpretation in one exam.

Normal Example

The printout below shows a normal example. When interpreting a scan, it is helpful to go through the five key areas of interest sequentially.
1. **Fundus Image** - The first thing to consider in the interpretation of a scan is whether it is of high quality. Every image has a Q score representing the overall quality of the scan. The Q score (displayed above the Fundus Image) ranges from 1-10, with values 8-10 representing acceptable quality. This score is based on a number of factors including focusing, illumination, centering of the optic disc and ellipse placement. Image quality can also be determined by a qualitative assessment of the Fundus Image. Notice the Fundus Image is very sharp and well focused, also there is adequate illumination over the entire scan (i.e., there are no large areas that are very dark), and the optic disc is well centered.

2. **Thickness Map** - This map contains yellow and red areas superiorly and inferiorly, denoting areas of thick RNFL, and blue and green areas nasally and temporally, denoting thinner RNFL areas. This RNFL pattern is typical of a normal eye. For younger eyes, there will be more red in the scan, and for older eyes there will be less red and more yellow due to the RNFL loss with age.

3. **Deviation Map** - Because the RNFL thickness of these eyes is normal at all locations, the Deviation Map is clear and does not contain any colored super pixels (no abnormal values). In some healthy eyes, however, a few colored-squares may be present due to statistical chance, but the number is usually minimal and confined to the dark blue colors (indicating the most mild abnormality, or p < 5%).

4. **TSNIT Graph** - The TSNIT curve for both eyes is within the shaded area, indicating the RNFL measures are in the normal range for that age. In addition, the TSNIT symmetry graph in the middle shows very similar TSNIT patterns for both eyes, which is normal.

5. **Parameter Table** - This table displays 6 summary measures that should be considered when interpreting a printout. Each parameter captures a different aspect of the RNFL profile (see above section on parameters for a description). In this example, all the parameters are in green, indicating that they fall within the normal range. If they were abnormal, they would be color-coded based on the probability of abnormality. The NFI values for these eyes are also normal. Values of 4 and 10 are well below 30, and within the normal range.
The Visual Fields for this patient show a superior arcuate scotoma in both eyes.

1. Fundus Image
   - Well focused
   - Evenly illuminated
   - Well centered

2. Thickness Map
   - RNFL thinning Superior OS
   - Wedge defects Inferior OU

3. Deviation Map
   - Extensive RNFL loss Superior OS
   - Wedge defects Inferior OU

4. TSNIT Graph
   - Falls outside shaded area in Inferior region OU
   - Falls below shaded area Superior OS

5. Parameter Table
   - Abnormal:
     - TSNIT Average and Inferior Average OU
     - Superior Average and TSNIT SD OS
     - IES value
     - NFI OS
     - NFI values abnormal OU
Early Glaucoma Example

This example is a 30 year old Asian male with POAG OU. He is myopic with a sphere of –5.25 in both eyes and tilted optic discs. Treated IOP is 18 mm Hg in both eyes. His visual fields show a superior arcuate scotoma in both eyes, worse in the right eye. The MD in the right eye is –3.56 and –2.59 in the left eye, and his PSD is 4.7 in the right eye and 2.1 in the left eye. These global indices are indicative of early glaucomatous field loss.

The GDx VCC scan reveals the following:

1. **Fundus Image** - The image is well focused and the optic disc is well centered. The illumination of the scan is not ideal (notice the temporal side is brighter than the nasal side), but it is acceptable. Poor illumination becomes a problem when there are large regions that are so dark that features are no longer distinguishable in the Fundus Image.

2. **Thickness Map** - The Thickness Map reveals RNFL thinning in both eyes. In the right eye, there is thinning in the inferior region, as evidenced by an absence of yellow and red colors compared to the superior region. In the left eye there is RNFL thinning in the superior region, along with focal thinning in the inferior region. Notice the dark, wedge-shaped thinning (darker colors) in the inferior-temporal region.

3. **Deviation Map** - The Deviation Map quantifies the RNFL loss that is present in the Thickness Map. There are numerous colored super-pixels in the inferior region of the right eye, signifying substantial RNFL loss in this area. In the left eye there is an extensive area of colored super-pixels in the superior region along with a narrow band of colored super-pixels in the inferior region that demarcate the wedge-shaped defect apparent on the Thickness Map. In all three areas of significant RNFL loss, there are red colored super-pixels indicating severe RNFL loss.

4. **TSNIT Graph** - The TSNIT Graph for the right eye has a dip in the inferior-temporal part of the curve that falls below the shaded area. For the left eye, the TSNIT Graph has two dips, a large one in the superior-nasal region and a smaller dip in the inferior-temporal region. All three dips fall outside the normal range and indicate significant RNFL loss. The location of these abnormal regions
correspond with the abnormal areas of the Deviation Map. This correspondence will always be present because the TSNIT graph shows the RNFL profile from the calculation circle, which is located within the Deviation Map.

5. Parameter Table - Numerous parameters fall outside the normal range, namely the TSNIT average and the Inferior Average for both eyes, the Superior Average and TSNIT SD for the right eye, and the Inter-Eye Symmetry. The Inter-Eye Symmetry is abnormal at the 0.5% level, indicating highly significant differences in the RNFL profile between the two eyes. For the right eye, the Inferior Average is also abnormal at the 0.5% level, indicating significant RNFL loss inferiorly. For the left eye, all the parameters are outside the normal limits. The TSNIT Average and Superior Average are highly significant (at the 0.5% level), indicating substantial overall RNFL loss that is worse superiorly than inferiorly for this eye.

The NFI for the left eye is 52, which is in the abnormal range. The NFI for the right eye is 23 which may be surprising because it is still normal (below 30), and it is caused by the fact that the RNFL loss for this eye is confined to a local inferior area. Because the NFI is a global parameter, there can be early glaucoma cases with focal RNFL loss only (wedge-shaped defects), where the NFI is still normal despite the Superior or Inferior Average parameter being abnormal. These focal defects are detected by the Deviation Map (see this example). There is good correspondence between the RNFL loss revealed with the GDx VCC and the visual fields. Both eyes show a superior arcuate defect in the PSD plots which correspond to inferior RNFL defects in the inferior-temporal region. However, there is a large superior RNFL defect present in the left eye while the corresponding inferior hemifield is still normal. This finding is common with the GDx VCC as RNFL defects are often present years before the visual field becomes abnormal \(^3\) (see also Chapter 1). This suggests that the left eye is at risk of developing a future visual field defect in the inferior quadrant since there is already corresponding substantial RNFL loss.
The Visual Fields for this patient show a clear nasal step inferiorly for both eyes.

1. Fundus Image
   - Well focused
   - Evenly illuminated
   - Well centered

2. Thickness Map
   - RNFL thinning Superior OU

3. Deviation Map
   - Extensive RNFL loss in Superior OU

4. TSNIT Graph
   - Falls outside shaded area (abnormal) in Superior region OU

5. Parameter Table
   - Abnormal TSNIT Average OU
   - Abnormal Superior Average OU
   - NFI abnormal OU
**Moderate Glaucoma Example**

This example is from a 63 year old African-American male. Intraocular pressure for this patient is 22 mm Hg for the right eye and 20 mm Hg for the left eye. The visual field for this patient reveals an inferior nasal step in both eyes. The MD and PSD for the right eye are –4.96 and 7.4 respectively and –4.14 and 6.31 for the left eye. The superior visual field for both eyes is still normal.

The GDx VCC scan reveals the following:

1. **Fundus Image** - The image is well focused, the optic disc is well centered, and the illumination is good.

2. **Thickness Map** - There is RNFL thinning in the superior-temporal region of both eyes. Notice the lack of yellow and red colors in these areas.

3. **Deviation Map** - There is a large cluster of colored super-pixels in the superior and superior-temporal region in both eyes. The large number of red super-pixels indicates the RNFL loss is extensive and severe.

4. **TSNIT Graph** - The TSNIT Graph for both eyes falls below the shaded area across a large portion of the superior and superior-temporal region.

5. **Parameter Table** - The parameter table shows the TSNIT Average and the Superior Average are outside the normal range for both eyes. The probability level for these parameters are 0.5%, indicating severe RNFL loss. The right eye NFI is well within the abnormal range (65), and for the left eye an NFI of 49 is close to the cut-off between a borderline/outside-of-limits classification (50). The NFI score is along a continuum, so the cut-off values should be considered as gradual and not strict. Therefore a value of 49 for the left eye, along with the other information available on the printout, indicates an abnormal RNFL profile.

The correspondence between the RNFL loss and the visual field loss is very good. Both eyes show an inferior arcuate defect in the PSD plots, with corresponding superior RNFL defects on the GDx VCC.
Advanced Glaucoma Example

The Visual Fields for this patient show superior loss in the right eye and both superior and inferior loss in the left eye.

1. Fundus Image
   - Well focused
   - Evenly illuminated
   - Well centered

2. Thickness Map
   - Severe RNFL thinning Superior and Inferior OU

3. Deviation Map
   - Extensive RNFL loss in the Superior and Inferior regions at the $p < 0.5\%$ level OU (most severe)

4. TSNIT Graph
   - Falls outside shaded area in Superior and Inferior regions OU

5. Parameter Table
   - All Abnormal OU
   - NFI values abnormal OU
Advanced Glaucoma Example

This example is a 69 year old African-American male with advanced visual field loss OU. The MD and PSD for the right eye is –11.29 and 14.91 respectively, and –18.81 and 11.73 for the left eye. The GDx VCC scan reveals the following:

1. Fundus Image - The image is well focused, the optic disc is well centered, and the illumination is good.

2. Thickness Map - There is extensive RNFL thinning in the superior and inferior regions of both eyes, more advanced inferiorly. Notice the almost uniform blue appearance of the RNFL profile, which is indicative of advanced stage of the disease.

3. Deviation Map - There is a large cluster of colored super-pixels in the superior and inferior regions of both eyes. The large number of red super-pixels indicates the RNFL loss is extensive and severe. The cluster of colored super-pixels is larger and more extensive inferiorly for both eyes.

4. TSNIT Graph - Both eyes fall below the shaded area across a large portion of the superior and inferior regions in both eyes. In the inferior region of both eyes, the curve is essentially flat, indicating advanced RNFL loss. In the superior region of both eyes, there is a large dip in the curve in the superior-temporal region.

5. Parameter Table - Every parameter is abnormal, with all but one at the most severe level. The NFI is 86 and 98, for the right and left eye, which indicates severe global RNFL damage. There is very good correlation between the RNFL loss and the visual field loss. However, in this example, the RNFL loss detected with the GDx VCC is more advanced than the visual field loss. The extensive RNFL loss in the inferior regions of both eyes and superior region OS matches the visual field loss in the corresponding hemifield. In the right eye, there is superior RNFL loss as well, however the inferior visual field is still normal. This suggests that the inferior visual field hemifield may develop a defect in the near future.
Split Bundles vs Wedge Defects

Many RNFL profiles demonstrate a single RNFL bundle in the superior and inferior regions. This pattern results in the typical double hump profile. See below for a healthy eye that exhibits a double hump profile. Notice that the RNFL is thickest in the superior and inferior regions and thinner in the nasal and temporal regions.

Many normal eyes, however, exhibit a split bundle. A split bundle is when the RNFL bundle is divided into two more-or-less nearly symmetrical segments. The split bundle occurs where the RNFL is thickest, in the superior and inferior regions. Below is an example of a healthy eye with split bundles in both the superior and inferior regions. It is more common, however, for the split bundle to be present only in the superior region and not in the inferior region. The resulting RNFL profile will have 3 or 4 humps rather than 2. Notice in this example the large dip in the RNFL thickness in the superior and inferior regions (red arrows).
An eye with a large split bundle can sometimes result in a mild defect displayed on the Deviation Map. The example below (left) is a healthy eye with a split bundle in the superior regions of both eyes, but larger in the left eye. Notice that the Deviation Map in the left eye shows a mild defect in the superior region corresponding to the dip in the split bundle. This defect is represented by a cluster of super-pixels flagged at the 5% level. This region is normal, but because of the large split bundle, the RNFL values fall below the normal range in this area. This RNFL pattern should not be confused with a true wedge defect.

A true wedge defect can be distinguished from a defect due to a large split bundle by the pattern and location of the defect on the Deviation Map. The above example on the right shows an eye with a wedge defect. Notice the defect on the Deviation Map is located more temporal relative to the defect on the split bundle example. The location of the defect in split bundles is directly superior or inferior to the disc while the wedge defect is more arcuate, wedge shaped, and temporal to the superior and inferior regions. Also, the wedge defect extends all the way to the optic disc while the defect in the split
bundle does not reach the edge of the disc. A wedge defect will also be more likely to include super-pixels at the more severe level of abnormality compared to the split bundle defect. Notice in this example the split bundle defect has super-pixels flagged at the 5% level while the wedge defect includes super-pixels flagged at the 2% level as well. It is common for wedge defects to include super-pixels that are abnormal at more severe levels, such as the 1% level or worse.

A true wedge defect is frequently visible in the Thickness Map as well as the Deviation Map. In this example, the wedge defect is visible as a dark blue arcuate wedge in the superior-temporal region of the Thickness Map. Notice the dark blue wedge has visible borders and extends to the optic disc margin. The RNFL changes around the defect in the split bundle example are more gradual, and distinct borders are not visible in the Thickness Map. The RNFL changes in a wedge defect are steeper at the edge of the defect, making the borders more visible.

The three main clues to distinguish a split bundle defect from a wedge defect are 1) location: split bundle defects are most often directly superior or inferior to the disc while wedge defects are usually more temporal, 2) extent: split bundle defects do not extend all the way to the disc margin while wedge defects do extend to the disc margin, and 3) visibility: split bundles are not easily visible on the Thickness Map while wedge defects frequently are visible.
Detecting RNFL Change Over Time: Serial Analysis

The GDx VCC monitors RNFL change over time and displays this analysis in a printout called Serial Analysis. The Serial Analysis printout has five key elements that should be considered when assessing RNFL change over time. These elements include the Thickness Maps, Deviation Maps, Deviation from Reference Maps, Parameters Tables, and TSNIT Graph.

1. Thickness Maps
2. Deviation Maps
3. Deviation from Reference Maps
4. Parameter Tables
5. TSNIT Graphs

Serial Analysis can compare up to four exams. The exams are in order from earliest to most recent. The first exam is the baseline or reference exam, and all follow-up exams are compared to this baseline exam. A colored rectangle to the left of the Thickness Map contains the date and quality score of each exam. The same color is used in the TSNIT graph to indicate which TSNIT curve
corresponds to which exam (i.e., yellow rectangle for first exam corresponds to yellow curve on the TSNIT graph).

RNFL change can be qualitatively assessed with the Thickness Maps. In the Serial Analysis the Thickness Map in the example shows the how the RNFL profile may change with progressive glaucomatous damage. The example above is a simulation, however, the pattern of loss in the superior and inferior areas is indicative of actual glaucomatous loss. Notice the diminished red and yellow colors in the superior and inferior regions with each follow-up exam.

RNFL change will also be detected with the Deviation Maps. The number of colored super-pixels will increase with progressive RNFL loss. The severity of loss at each super-pixel may also increase (probability level will decrease indicating more severe damage). In this example the eye is initially healthy and the Deviation Map does not show any colored super-pixels. After the second follow-up, however, the RNFL loss is below the normal limits and the Deviation Map now contains numerous colored super-pixels.

The Deviation from Reference Map displays the RNFL difference, pixel by pixel, of the follow-up exam compared to the baseline exam. If the difference exceeds 20 microns at any pixel, the pixel is color coded according to the legend (see printout). RNFL change is color coded in 20 micron increments, where the first 20 micron change is coded dark green, a 40 micron change is coded light blue, 60 is dark blue, etc. (see legend). By the second follow-up exam, the Deviation from Reference Map shows regions where the RNFL change exceeds 20 microns in the superior and inferior areas.

The areas of RNFL change shown on the Deviation from Reference Map will frequently correspond to the areas of loss detected by the Deviation Map. However the correspondence is not always exact because the Deviation Map shows loss compared to the normative database while the Deviation from Reference Maps shows RNFL change over time in the same eye.

A glaucomatous eye may have RNFL loss on the first exam which progresses over time and the number of flagged super-pixels on the Deviation Map may increase. However this progressive loss may not exceed 20 microns and thus may not be displayed on the Deviation from Reference Map.
Conversely, there could be a case where an eye with above average RNFL measures initially shows a 20 micron loss over time. This loss would be displayed on the Deviation from Reference Map, however it may not fall below the normal limits because the initial value was very high, and thus would not be displayed on the Deviation Map.

The Parameter tables show the parameter values for each exam in the first column, the exact probability value when the parameter is significantly different from the normative database (when \( p < 5\% \)), and the absolute difference of the parameter of the follow-up exam compared to the baseline exam. Progressive RNFL loss will cause the parameter values to decrease and the NFI to increase.

The TSNIT Graph shows the TSNIT curves for all exams. The color of the TSNIT curve corresponds to the color of the vertical rectangle next to each exam (i.e., blue curve on the TSNIT graph corresponds with the blue rectangle for the second exam). The TSNIT curves are overlaid on the shaded area representing the normal range for that age. RNFL loss will result in a lower TSNIT curve on the follow-up exam compared to the baseline exam. Notice in the example the purple and blue follow-up TSNIT curves are lower than the baseline yellow curve, signifying progressive RNFL loss.

Image alignment

In order to accurately detect RNFL change over time, the follow-up images must be properly aligned with the baseline image. There are two main options available for image alignment.

The default option aligns the images based on the intensity profile (illumination pattern) of the Fundus Image. This image alignment method shifts follow-up exams to best match the intensity profile of the baseline image. Follow-up images can be shifted horizontally, vertically, and rotated relative to the baseline image to create the best possible match.

The second method aligns the images using the ellipse location. This method shifts the follow-up images to align the ellipses with the baseline image. The second method requires more operator involvement and the ellipse must be carefully positioned for all exams.

If image alignment is poor with the default method, the second method can be chosen by
pressing the System, then More, then Compare Alignment buttons from the main screen. The Compare Alignment Options screen allows the user to switch alignment methods.

For Serial Analysis, the parameter values (and quality score) on the follow-up exams may change slightly from the single exam printout. These measures are calculated based on the location of the ellipse. The location and size of the ellipse in the baseline exam is used for the follow-up exams. When the follow-up exams are shifted to align with the baseline exam, then the location of the ellipse in the follow-up exams may change slightly, which would change the exact value of the parameters and quality score.

Normally there is very little change to these values because the images do not normally need to be shifted very much. If there is a large change in these values, check the accuracy of the image alignment and switch alignment methods if needed.

Summary

The GDx VCC printout provides comprehensive RNFL assessment to aid the clinician in the diagnosis of glaucoma. Through the comparison of each scan to the normative database, an age-matched analysis is provided to accurately detect RNFL abnormalities. RNFL abnormalities are revealed through the Thickness Map, Deviation Map, the TSNIT graph, and the Parameter table. The NFI is a highly discriminating parameter that provides a global assessment of the RNFL profile. The other parameters also provide relevant information that help the clinician determine the RNFL integrity by providing statistical probability values to various aspects of the RNFL. The TSNIT graph is a cross sectional analysis where the 'double hump' RNFL pattern can be assessed. The Deviation Map is one of the most important features of the printout because it reveals the location and severity of RNFL loss across a large area.

In most cases, accurate RNFL assessment can be determined from the Thickness Map, the Deviation Map, and the NFI. The Thickness Map will have more blue in the superior and inferior regions when there is RNFL loss. This loss will be displayed on the Deviation Map when it exceeds the
normal limits. The degree of loss can be determined by the probability value of the colored squares on
the Deviation Map (dark blue indicates mild loss, red indicates severe loss). The NFI is a sensitive pa-
rameter and values above 30 indicate possible RNFL loss, and values above 50 indicate a high likeli-
hood of RNFL loss. Frequently there will be good correspondence of these three elements of the print-
out. However in some borderline or difficult cases, these three elements may not be in agreement. For
example, when there is a focal RNFL defect only, the NFI may be normal while the Deviation Map de-
tects the local damage (e.g., see the early glaucoma example in this chapter). In all cases, each of the
features of the printout should be considered in combination when making a clinical decision.