Ballbar Viewer Users Guide

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Introduction

The *Ballbar Viewer* allows users to analyze ball bar measurement data when performing interim checks on their CMM. Interim checks are necessary to ensure that the CMM is running properly and can also be used to verify changes to the machine, such as a software upgrade, have not adversely affected accuracy.

Overview

The *Ballbar Viewer* utility is a split window with the upper section showing a visual representation of the measurement positions and the lower section showing a histogram and text analysis of the measurement. The tolerance is set using the tolerance widget and information from the selected ballbar position is displayed in the measurement area. The machine dimension widget allows the user to set the dimensions of the CMM so that the relative location of the measurement pattern can be seen. Illustration 1 shows the various widgets on the left and right side.

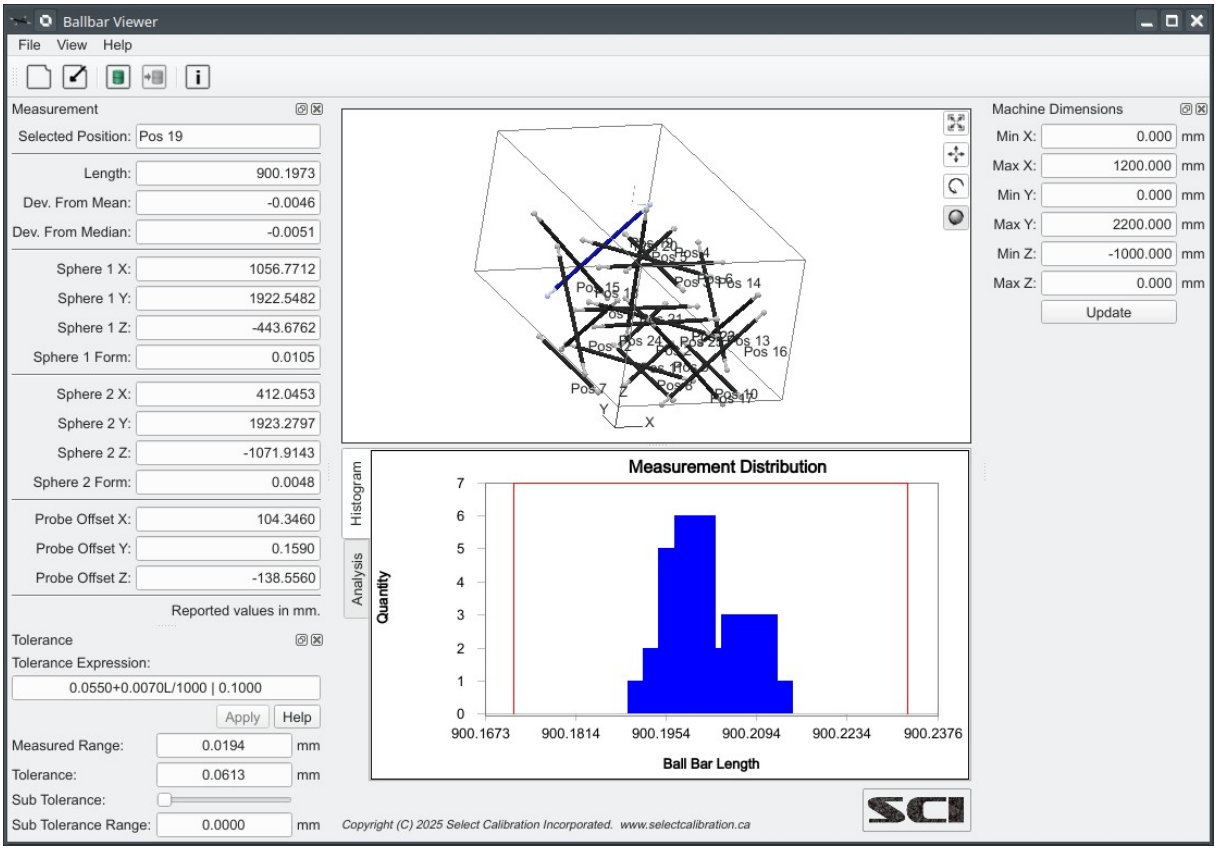

Illustration 1: Ballbar Viewer utility showing the model of the ball bar measurement positions, tolerance, selected position data, machine dimensions, and the analysis of the ballbar measurements.

Importing Measurement Data

Measurement data can be imported into the *Ballbar Viewer* by one of two methods:

- Drag and Drop the measurement file onto the *Ballbar Viewer* utility program.

- Select *File – Import Ballbar Measurement* from the main menu or click on the corresponding toolbar button.

The measurement files typically use the extension '.DAT' but any file extension can be used provided the contents of the file is one of the expected formats.

Graphical View

The graphical view shows the measurement data in 3D and the axis indicators for reference. Measurements inside the current tolerance are shown in black where red indicates an out of tolerance measurement. Measurements below the sub tolerance setting are shown transparently. Selection of a ballbar will be highlighted in blue.

Measurement uncertainty is not considered for when deciding if a result is inside or outside of specification. This is the traditional method when using a ballbar so this is the method used by the *Ballbar Viewer* utility.

Display 3D Controls

The 3D model display is not fixed and can be manipulated in a variety of ways. The following table shows the different functions and modes of the graphic window:

Image	*Description*
	Scale to fit. Positions and sizes the display data within the dimensions of the window.
	Pan Mode. When enabled a right mouse button click and drag will move the position of the displayed model. For systems with a single mouse button use Ctrl + Mouse.
	Rotate 2D Mode. When enabled a right mouse button click and drag will rotate the model around the center of the viewport. For systems with a single mouse button use Ctrl + Mouse.
	Rotate 3D Mode. When enabled a right mouse button click and drag will rotate the model around the click position on the displayed model. For systems with a single mouse button use Ctrl + Mouse.

Selection Data

The ballbar measurements shown in the model window can be individually selected with a left mouse button click. When a ball bar has been selected information about the measurement will appear in the measurement dock and the selected ballbar will be highlighted in blue.

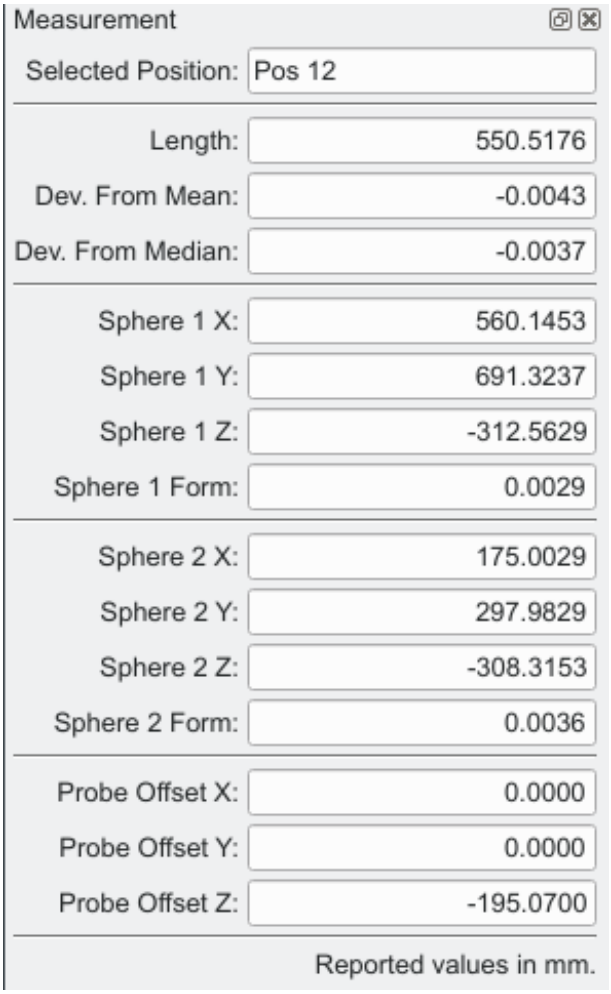

Illustration 2: Information returned from a selected ballbar position.

Table 1: Measurement Information:

Field Name	*Description*
Selected Position	Name assigned to the ball bar position.
Length	Actual measured length of the selected ballbar.
Dev. From Mean	Deviation of the selected position from the mean length.
Dev. From Median	Deviation of the selected from the median length.
Sphere 1 <XYZ>	XYZ location of the first ball bar sphere.
Sphere 1 Form	Form error of the first ballbar sphere.
Sphere 2 <XYZ>	XYZ location of the second ball bar sphere.
Sphere 2 Form	Form error of the second ballbar sphere.
Probe Offset.<XYZ>	Probe offset active for the ballbar measurement.

Probe Data

The probe data is drawn graphically above the first sphere of the selected ball bar measurement. An example of the probe data display is shown in illustration 3.

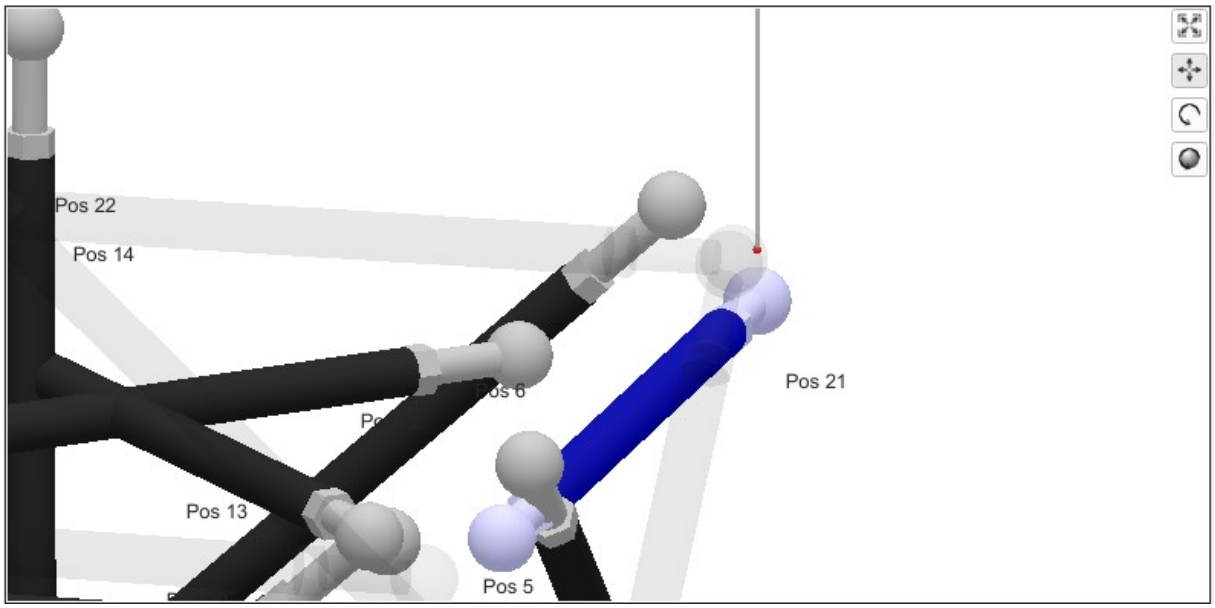

Illustration 3: View of various ballbar positions with the probe shown data above the first sphere of the selected position.

Previous versions of the Ballbar Viewer utility showed the probe representation for all measured positions. Starting with version 4.0 only the selected ballbar position shows the probe offset. This was done to reduce the amount of display clutter.

Most modern CMM's use an indexable probe head. Due to the unknowns the tool is always drawn with an XY + Z offset and will have an 'L' appearance. This may be addressed in a future version of the Ballbar Viewer utility.

OpenGL

The graphical view of the measurement is drawn using OpenGL. The operating system and hardware must support OpenGL version 2.x or higher in order to run this utility program with a visible model window. When running the *Ballbar Viewer* program on computers that only support OpenGL 1.x the graphics window will be replaced with an information window. An example of this information window is shown in illustration 4.

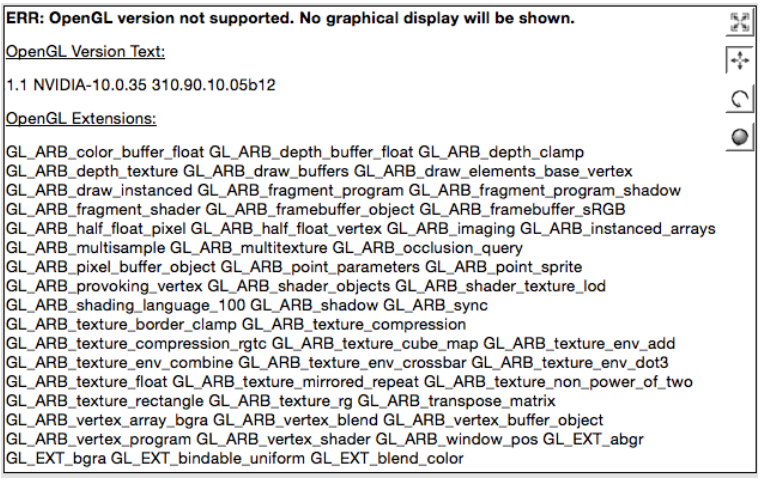

Illustration 4: Information screen that is displayed with unsupported OpenGL versions.

In the event the model view of the data is disabled the rest of the program will continue to work as expected.

Data View

The data view shows the measurements as a distribution histogram along with the numerical analysis. This data can help identify results which are not typical of the overall measurements.

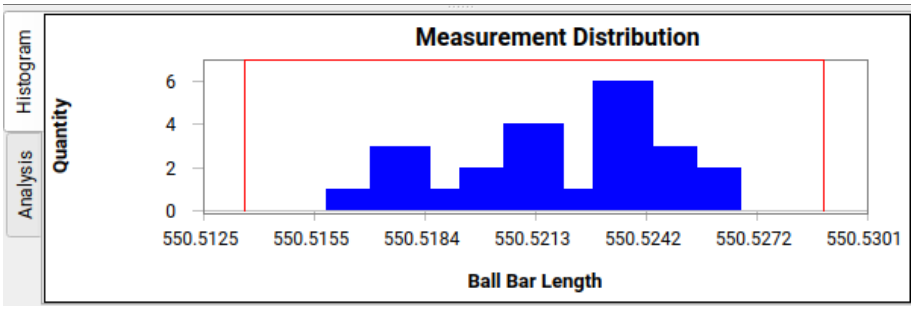

Illustration 5: Ballbar measurement analysis view.

The analysis view summarizes the measurement data with the following information:

```
Measurement Volume
-------------------------------------------------------------------------
          Start X:    -0.0347 mm
            End X:  1000.0019 mm
          Range X:  1000.0366 mm
          Start Y:    -0.0118 mm
            End Y:  2000.0498 mm
          Range Y:  2000.0616 mm
          Start Z: -1000.0151 mm
            End Z:     0.0065 mm
          Range Z:  1000.0216 mm

Measurement Statistics
-------------------------------------------------------------------------
Measurement Count:         22
   Minimum Length:   999.9900
```

```
    Maximum Length:  1000.0207
      Range Length:     0.0307
       Mean Length:  1000.0049
     Median Length:  1000.0053
     StdDev Length:     0.0085
         Tolerance:     0.0270

Estimated Range for 99% of Measurements: 0.02544
Number Outside of Estimated Range: 4

Individual Measurement Results
--------------------------------------------------------------------------

 Position Name           Length    Mean Dev.  Sph1 Form  Sph2 Form
--------------------------------------------------------------------------
BallBar 1.2.1 - 1     1000.0207     0.0158     0.0012     0.0023
BallBar 1.2.1 - 2     1000.0038    -0.0011     0.0007     0.0038
...
```

Table 2: Summary Information:

Parameter	*Description*
Measurement Volume	Describes the area of the machine as a cube with values that contain all of the ballbar measurements. The volume is based on the center positions of all measured spheres.
Measurement Count	Total number of ball bar measurements.
Minimum Length	The length of the shortest ball bar measurement.
Maximum Length	The length of the longest ball bar measurement.
Range Length	Difference in length between the shortest and longest ball bar measurement.
Mean Length	The average length of all ball bar measurements.
Median Length	The middle length between the shortest and longest measurement. If fliers exist in the measurements this will often be very different from the average length.
StdDev Length	The standard deviation of the length measurements.
Tolerance	The current working tolerance. This value is defined by entering a tolerance expression in the tolerance tab and calculated from the average ballbar length.
Estimated Range for 99%	The range of three standard deviations of the data.
Number Outside Estimated	The total number of length measurements that fall outside the estimated range of the length data.
Individual Measurements	A list of all the individual measurements that were used for the calculations.

The sphere form error should be considered when reviewing measurement data. Measurements that show a large sphere form error for one or both spheres should not be trusted.

Tolerance

The tolerance widget of the *Ballbar Viewer* utility allows the user to enter a specification for the maximum allowed ball bar length variation. The specification expression can be a constant, a length dependent expression in the form of A+BL/C, or a length dependent expression with an upper limit in the form of A+BL/C|D. When a tolerance is entered in an unrecognized format the input field will be shown in red.

The sub tolerance option allows additional filtering of the displayed data. Measurements that are below the sub tolerance range are shown transparently. The sub tolerance makes it easier to find the measurement positions that are on the higher side of the tolerance but still within specification.

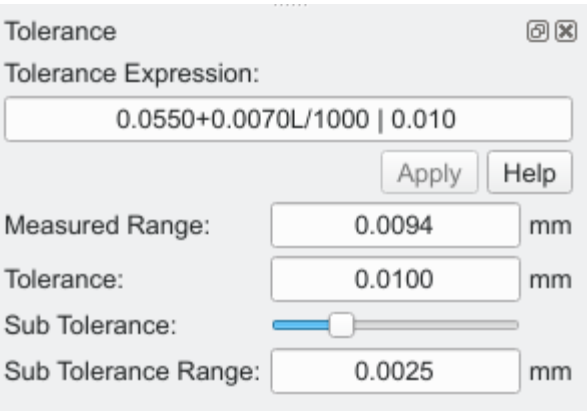

Illustration 6: Tolerance widget of the Ballbar Viewer utility program.

Machine

The machine widget allows the user to enter the actual dimensions of the CMM and will appear as a wire-frame box drawn in the model. This feature allows the user to see the relative location of the ballbar measurement pattern with respect to the machine dimensions.

Illustration 7 shows an example of the Machine Dimension setup. Dimensions are changed by editing the entries and pressing the *Update* button.

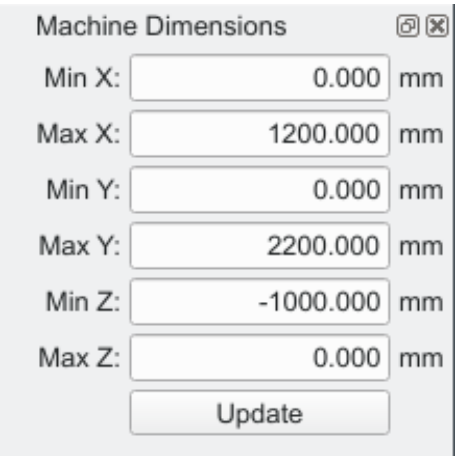

Illustration 7: Machine Dimensions setup.

The displayed ballbar positions include the tool offset and may appear outside the volume of the machine. This is normal effect from having a tool offset from the nominal reference point of the CMM. For example, a typical bridge CMM with a ballbar placed on the table measured and with a tool at angles A0B0 may appear up to the tool offset distance away from the bottom of the actual machine volume. Most machines cannot drive the bottom of the Z axis into the table but they can probe the table with a suitable tool.

Ballbar Measurement Data Files

The *Ballbar Viewer* utility current supports measurement files in three formats. The format of the data must meet the requirements listed below:

Legacy Format 1

- The first line in this file must be *BallBar_V1*
- Comment lines, if any, must start with a hash character #
- The format of each line is: <name>, <length>, SPHERE1<X,Y,Z>, SPHERE2<X,Y,Z>, PROBE_OFFSET<X,Y,Z>
- The first field of each entry line can contain text or a numeric value with all additional fields numeric. The first entry is for the name of the measurement.
- Each ballbar sphere position is in machine coordinates without the probe offset.

Legacy Format 2

- The first line in this file must be *BallBar_V2*
- Comment lines, if any, must start with a hash character #
- The format of each line is: <name>, <length>, SPHERE1<X,Y,Z>, SPHERE2<X,Y,Z>, SPHERE1 FORM, SPHERE2 FORM, PROBE_OFFSET<X,Y,Z>
- The first field of each entry line can contain text or a numeric value with all additional fields numeric. The first entry is for the name of the measurement.
- Each ballbar sphere position is in machine coordinates without the probe offset.

Current Format

- The first line in this file must be *B89.4.1_Data:Version=1:Type=BallBar*
- Comment lines, if any, must start with a hash character #. The exception to this rule is a title line and underscore used to identify the columns of the data.
- The format of each line is: <name>, <length>, SPHERE1<X,Y,Z>, SPHERE2<X,Y,Z>, SPHERE1 FORM, SPHERE2 FORM, PROBE_OFFSET<X,Y,Z>
- The first field of each entry line can contain text or a numeric value with all additional fields numeric. The first entry is for the name of the measurement.
- Each ballbar sphere position is in machine coordinates and includes the probe offset. This is different from the first two input formats and is more in-line with other types of measurement file formats.

All three versions are similar in content but have differences that affect how the data is processed by the end software.

It is important that the <XYZ> sphere locations for each of the file formats are written with or without the probe offset depending on the desired output file format. One good way to validate that everything is setup properly is to measure one ballbar position using two differently oriented probes. When reviewing the results in the *Ballbar Viewer* utility the two positions should appear to be on top of each other. If the two positions appear offset to each other by a significant distance then likely the sphere positions do not properly take into account the probe offset in relation to the selected file format.

The majority of current CMM software offset the coordinate position by the active probe offset.

Database

Starting with version 5 of the *Ballbar Viewer* utility measurement data can be stored in a SQLite database. The database allows past results to be loaded and combinations of results to be exported in a summary format in order to identify trends or other changes over time.

The database is created and initialized automatically so no special steps are needed to setup this feature. The location of the database for GNU/Linux and Unix operating systems is in a sub folder of the users home folder called ‘.ballbarviewer’ where the Windows versions create a sub folder called ‘.ballbarviewer’ in the same directory as the executable.

Windows versions of the Ballbar Viewer utility are intended to be portable and not something suitable for installation. Storing settings and data below the executable is ideal for portable applications and not for installed applications.

The layout of the database table can be shown using the following SQLite command:

```
PRAGMA table_info('table_name');
```

where 'table_name' is the name of the database table to inspect.

Database Tables

The following shows the layout of the tables used by the *Ballbar Viewer* utility.

Table 3: Database Table 'date'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	Yes	Unique value used to cross reference date entries in other tables.
entry	TEXT	No	Date text.

Table 4: Database Table 'time'

Name	*Type*	*Primary Key*	*Comment*
time_id	INTEGER	Yes	Unique value used to cross reference time entries in other tables.
date_id	INTEGER	No	Reference value to a specific date.
entry	TEXT	No	Time text.

Table 5: Database Table 'summary'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	No	Reference value to a specific date.
time_id	INTEGER	No	Reference value to a specific time.
count	INTEGER	No	Number of ballbar measurements used to create the summary data.
min_length	REAL	No	Minimum ballbar length.
max_length	REAL	No	Maximum ballbar length.
mean_length	REAL	No	Average ballbar length.
median_length	REAL	No	Middle ballbar length.
stdev_length	REAL	No	Standard deviation of the variation in the ballbar length.

Table 6: Database Table 'data'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	No	Reference value to a specific date.
time_id	INTEGER	No	Reference value to a specific time.
name	TEXT	No	Name of the ballbar position.
sph1_x	REAL	No	X position for the first sphere.
sph1_y	REAL	No	Y position for the first sphere.
sph1_z	REAL	No	Z position for the first sphere.
sph2_x	REAL	No	X position for the second sphere.

Name	*Type*	*Primary Key*	*Comment*
sph2_y	REAL	No	Y position for the second sphere.
sph2_z	REAL	No	Z position for the second sphere.
sph1_form	REAL	No	Form error of the first sphere.
sph2_form	REAL	No	Form error of the second sphere.
tool_x	REAL	No	X tool offset.
tool_y	REAL	No	Y tool offset.
tool_z	REAL	No	Z tool offset.

Illustration 8 shows an example of using the Qt *SQLBrowser* utility to get a list of the average ballbar length from the data stored in the summary table foutside of the *Ballbar Viewer* utility. It is not easier to do it this way but does demonstrate how any suitable utility can be used to query collected data.

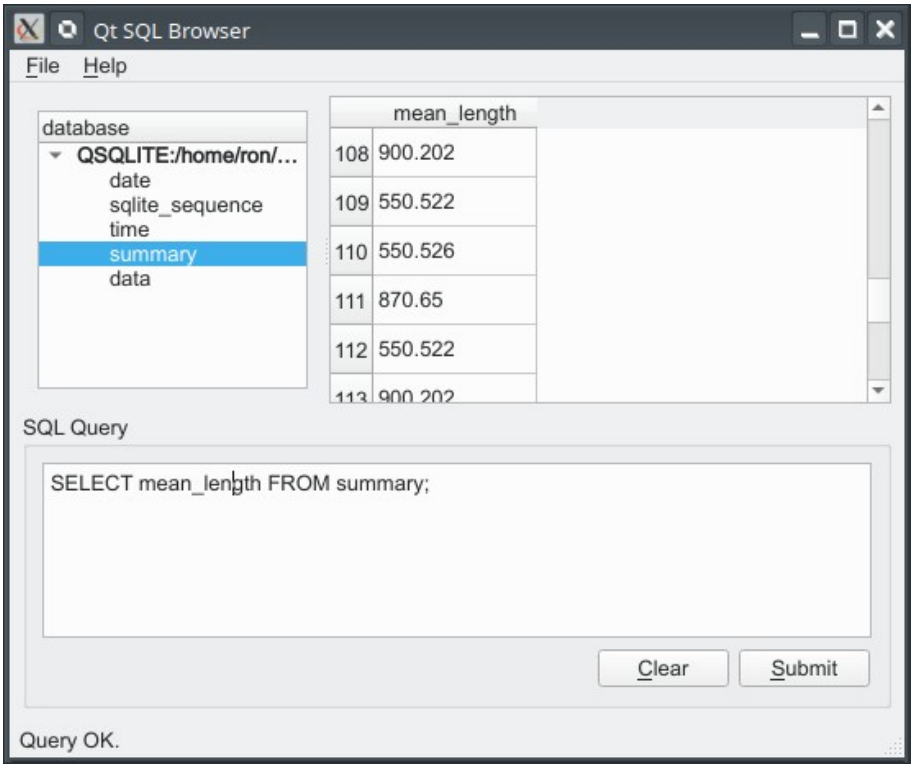

Illustration 8: Example showing the average ballbar lengths from the summary table data.

Database Dialog

Illustration 9 shows the database dialog from the *Ballbar Viewer* utility. The data entries are shown by the year, month, and day for the first level and hour, min, and seconds for the second.

It is believed that users will want to look for results from a specific date first and then consider a specific time.

Options to search for a specific date may be added in the future if the need makes sense. Using the current configuration of separating dates and times should make this unnecessary for most users.

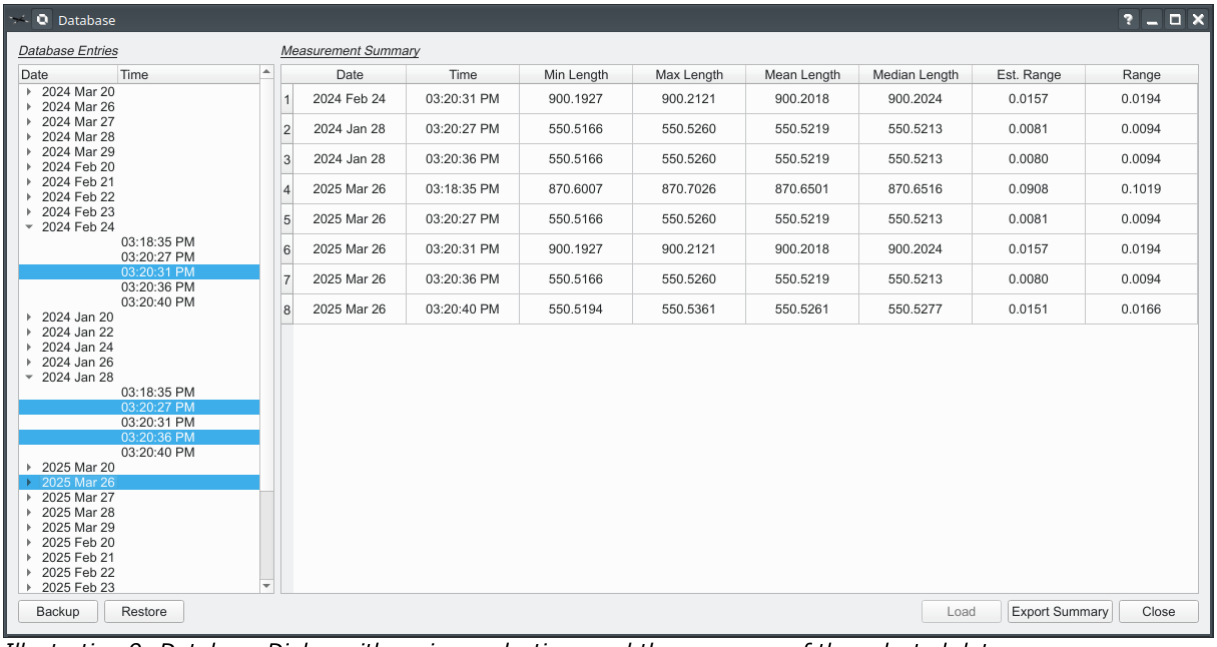

Illustration 9: Database Dialog with various selections and the summary of the selected data.

Table 7: Database Dialog Options

Option	*Description*
Backup	Create a text file backup containing the entire contents of the database. The extension of the file is '.backup'.
Restore	Import the previously created backup file.
Load	Load the selected ballbar measurement data from the database and display it in the *Ballbar Viewer* utility. This function will be disabled if more than one measurement is selected.
Export Summary	Create a CSV file from the Measurement Summary data. This file can be opened with any spreadsheet program.
Close	Close the database utility.

Adding Measurements To The Database

Measurements can be added to the database with the *Save To Database* option from the File Menu or clicking on the related toolbar button from the *Ballbar Viewer* utility. This option is active when new data is imported and will remain active until new data is added.

The date and time associated with each measurement entry is from the date and time the data is added to the database and not the imported file date and time.

Revision History

Date	*Version*	*Changes*
Nov 6, 2016	1.0	New Program
Nov 7, 2016	1.1	Bug fix. OpenGL Z clipping for some input data. Added machine volume information. Improved ability to select ball bar measurements from model.
Nov 28, 2016	1.2	Additional improvements to ballbar selection. Changed selection display from a floating dialog to a text line at the top of the model view window. Added the option to show the selected ballbar when viewing data.
Dec 14, 2016	2.0	Switched to newer OpenGL base class. Added option to detect minimum usable OpenGL version and disable sections of the program that are not compatible.
Jan 15, 2022	3.0	Rewrite of user interface. Tolerance interpretation using median value (not average).
May 21, 2022	3.1	Added sub tolerance and transparency option. Improved bar selection sensitivity. Removed mean and median results from measurement display. Changed text to Tolerance With Limit from Limited Tolerance.
Apr 16, 2024	4.0	Updated measurement and tolerance displays. Made transparent ball bar rendering more transparent. Improved transparent ball bar rendering. Changed sub tolerance to actual value from percentage. Removed drawing of probe offsets except for selected items.
Mar 31, 2025	5.0	Added machine dimensions. Added database option along with suitable features.