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ACCURACY TEST OF DENTAL THREE-DIMENSIONAL OPTICAL SCANNER

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Abstract: *The paper presents the results of accuracy testing of three-dimensional optical scanner that is used in the process of computer integrated fixed dental construction manufacturing in dental medicine. The main purpose of 3d scanning is to acquire information about real object's geometry and transform the collected data into digital form. This enables changes to the digital model inside computer software and considerably shortens the process of construction modelling. Due to the field of use, the scanner user interface is simple and user friendly. Also, the required accuracy of scanning is not high, due to the possibilities of manually adapting the construction at the implantation. The main purpose of the experiment was to establish the achievable accuracy range of dental scanner for usage in quality control in mechanical engineering in general. Paper presents the experiment and results together with explanation of possible causes of deviations. Also, problem and possible solutions that could influence the scanner's accuracy are discussed.*
Key words: *optical scanning, accuracy, dental*

Tačnost testiranja tro-dimenzionalnog optičkog skenera u stomatologiji. *U radu su prikazani rezultati testiranja tačnosti tro-dimenzionalnog optičkog skenera koji se koristi u procesima računarske integracije izrade fiksne dentalne konstrukcije u stomatologiji. Glavna svrha 3D skeniranja je skupljanje informacija o geometriji realnog objekta itransformacija podataka u digitalni oblik. Ovo omogućuje promenu digitalnog modela u računarskom softveru i znatno skraćuje proces modeliranja konstrukcije. Zbog oblasti korišćenja, korisnički interfejs skenera je jednostavan i lako upotrebljiv od strane korisnika. Takođe, zahtevana tačnost skenera nije velika, zbog mogućnosti manuelnog podešavanja konstrukcije prilokom implantacije. Glavna namena eksperimenta je bila uspostavljanje dostignutog raspona tačnosti dentalnog skenera za upotrebu u kontroli kvaliteta generalni u mašinskom inženjerstvu. Rad predstavlja eksperiment i rezultate sa objašnjenjem mogućih uzroka odstupanja. Takođe, razmatraju se problemi i moguća rešenja koja mogu uticati na tačnost skenera.*
Ključne reči: *optičko skeniranje, tačnost, stomatologija*

1. INTRODUCTION

A three-dimensional optical scanner is a device that analyzes real objects or the environment in order to collect data on their form and dimensions. Scanning is performed according to the principle of projecting a fringe pattern of light on the object and recording the deformation of this pattern with a digital camera system. The collected data is used in the scanner software to create a three-dimensional computer model of a scanned object [1].

Test was performed with OrtoSCAN brand dental scanner (Figure 1), which is specialized for easy scanning of dental prosthetics and further digital modeling. The scanning is based on the principle of triangulation of the pattern deformation images from two cameras at a known angle in relation to the direction of projection. Such a scanning principle enables scanning of complex shapes of pocket and groove surfaces, self-calibration and consequently more accurate results. For the projection of a fringe pattern of light, OrtoSCAN scanner uses a white LED projector, which allows greater precision and reliability than laser beam scanning. The sharp lines of the sample are provided based on the optimization of the projector settings and the coordinated settings of the turning of the object and cameras with high resolution [2].

Fig. 1. OrtoScan Optical scanner

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2. EXPERIMENT

The aim of the experiment was to establish the frame of the accuracy of the 3D scanner, since we were interested in how precise it could be used for general measurements in mechanical engineering. It was decided that for the experiment gauge blocks sizes from 10 to 60 mm will be used. Gauge blocks were placed in the scanner plate with the adapted clamping device. The clamping device was adapted to the dimensions of the scanner chamber and was adjustable for different dimensions of the gauge blocks.

Before the start of the scan, the Dental Scanner software communication window offers the option of determining the scope of the measurement. On the screen the status inside of the scanner is shown with a horizontal line that can be moved vertically to determine the lower line of the measuring range. If the horizontal line is in the lower position (0%), the scanning area includes gauge blocks and a large part of the clamping device. In this case, the scanner software algorithm assembled and aligned the data of individual scans based on the overlapping geometry of the gauge block and the clamping device. Measurements where the horizontal line was moved above the clamping device and thus reduced the scanning area to only gauge block, the software algorithm used to align individual scans in a common computer model only by taking into account the geometry of the gauge block (Figure 2).

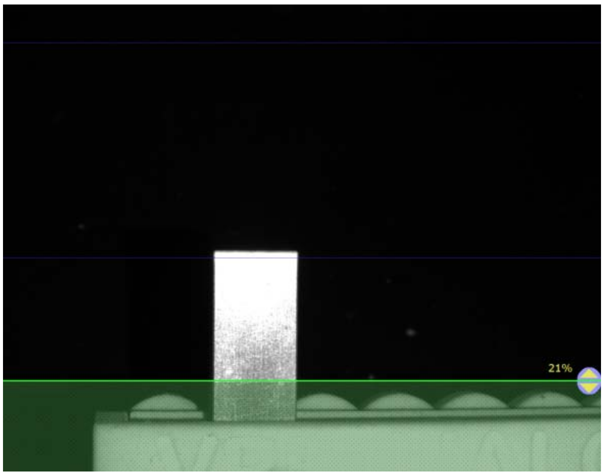

Fig. 2. Measuring range selection

2.1 Data processing

In order to establish deviations, dimension of the scanned 3D model of gauge blocks had to be determined. This was done with GOM Inspect CAQ software package. Each gauge block results were processed according to the protocol shown on Figure 3.

The first step in setting the dimensions is to transfer the STL file to the GOM Inspect software environment. Measurements were made between two planes that determine the nominal measure of the gauge block. One of these planes was used to define a best-fit plane, the other serves to determine the points. The plane, which served as a reference, is generated on the basis of the average values of the total selected area. On the other plane, the same number (9) of points were selected for each of the measurements of the gauge block in and in the same order. The distance between the points and the plane were calculated in the normal direction. Figure 3 shows a 30 mm block, with associated points and distances from the best-fit reference plane. The distance number represents the distance between the both surfaces that determine the nominal value of the gauge block. In the program, the distance marked with the symbol L. (last in each result table), represents the normal distance of individual points from the plane.

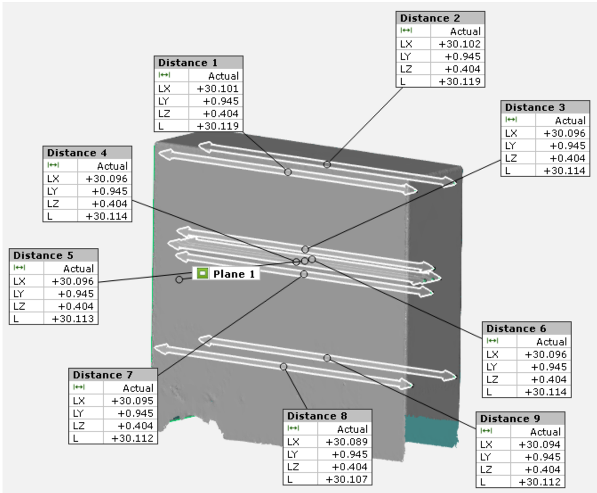

Fig. 3. Processing of measurement results

2.2 Results

The results of the measurements are divided into two sets. The first set represents the results of the measurements that were made when scanning the gauge block with the clamping device, while the second set presents the results generated by scanning only gauge blocks without the included geometry of the clamping device.

The average deviation represents the arithmetic mean of all the results (9 points) of individual measurements. For each of the gauge blocks, 10 consecutive measurements were performed, each of which included a distance analysis of 9 points. Thus, for each gauge block, 90 results were available (deviations from the nominal distance of the gauge block). For each block and each measurement separately, it was necessary to determine the average deviation value and convert the results into a graphic form. Because of the different sizes of the gauge blocks, the results are presented in the form of deviations from the nominal values of the gauge blocks.

Figure 4 represents the results of the average measurement deviations which were obtained with the included clamping device. The most accurate measurement is in the case of a gauge block of size 40 mm, with an average deviation of 0.026 mm. The least accurate results are in the case of a gauge block size of 60 mm, where the average deviation from the nominal value of the gauge block is 0.120 mm (failing our expectation of achieving 0,1mm accuracy).

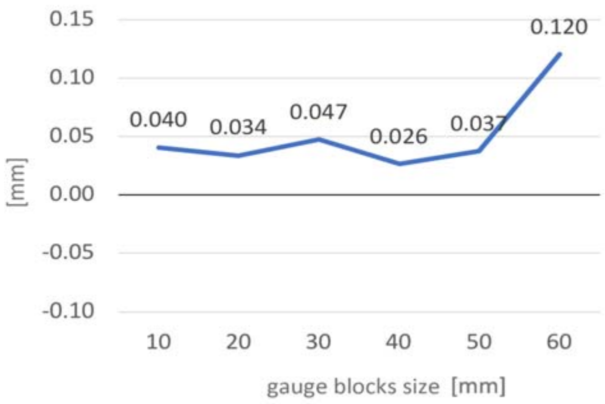

Fig. 4. Average deviations of measurements with included clamping device geometry.

Figure 5 represents the results of average deviations of measurements, where the clamping device was not included in the scope of the scanned geometry. The minimum average deviations from the nominal values of the gauge block were found in the analysis of the results of a gauge block of size 10 mm, with an average deviation of -0.010 mm. The maximum average deviation occurs at gauge block of size 50 mm and are -0.061 mm. The expected accuracy of 0,1 mm was thus achieved in the case of measurements were clamping device was not included in the scanning range.

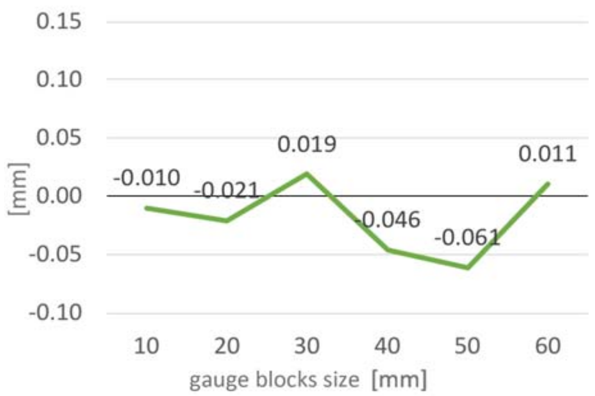

Fig. 5. Average deviations of measurements without included clamping device geometry.

A standard deviation is a statistical indicator by which it is possible to measure the dispersion of the value contained within a population (or a set of data). [3].

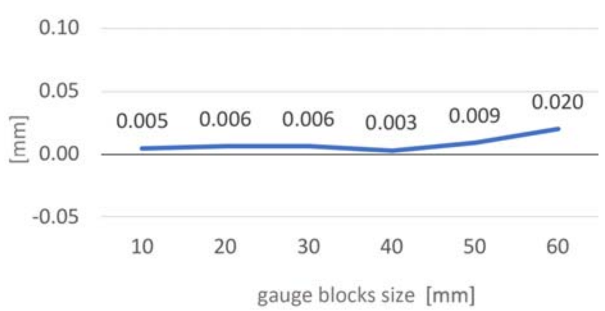

Fig. 6. Standard deviation in measurements with included clamping device geometry.

The standard deviation of measurements, where the clamping device is included in the scanning range, is shown in Figure 6. The most dispersed data is in the case of a gauge block of size 60 mm, because the standard deviation is 0.020 mm and in comparison, with the other results it stands out. Gauge block size 40 mm scanning represents the most concentrated measurement results, because the standard deviation is only 0.003 mm.

The standard deviations of measurements, where the clamping device was not included in the scanning range, are presented in the Figure 7. The highest standard deviation was obtained at gauge block size 20 mm and is 0.016 mm. The minimum spread of data is in the results of a 40 mm gauge block, with the standard deviation of 0.004 mm. Total range of standard deviation in the case of second set of measurements, where the clamping device was not included in the scanning range is 0.012 mm.

Fig. 7. Average deviations in measurements without clamping device geometry.

Figures 8 and 9 represent the maximal and minimal values of the measurements of each point according to the measurement procedure described in the previous chapter. As in the case of the previous results, here too are (due to different sizes of gauge blocks) the results given in the form of deviations from the nominal values of the gauge blocks.

The accuracy range of measurements with the clamping device geometry included is shown in Figure 8.

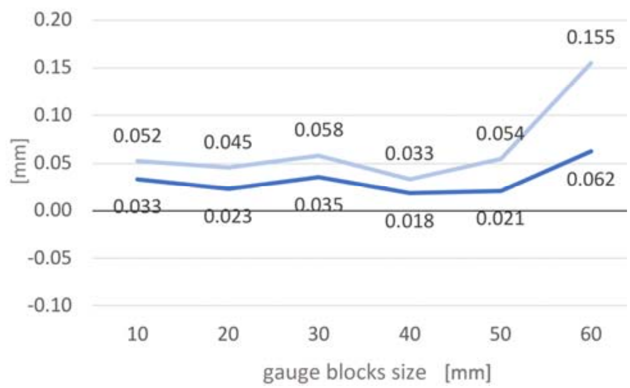

Fig. 8. Accuracy range of measurements, which has included clamping device geometry.

The maximal measured value of the deviation is 0.115 mm in the case of a gauge block size 60 mm, and remarkably stands out in comparison with the other values. The minimum deviation value occurs at 40 mm gauge block and is 0.018 mm. The range of measurement accuracy is therefore between 0.155 mm and 0.018 mm, what is together 0.137 mm. The results of the gauge block of size 60 mm have a widest range of 0.093 mm, the minimum range occurs in the results of a 40 mm block and is 0.015 mm.

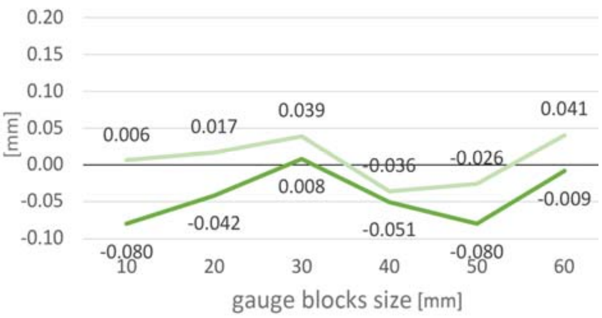

Fig. 9. Average deviations in measurements without clamping device geometry.

The range of the accuracy of second set of measurements, where the clamping device was not included in the scanning range, is shown on Figure 9. The maximum value of the deviation occurs in a gauge block of size 60 mm and is 0.041 mm. The minimum value was measured with a gauge block of sizes 10 and 50 mm, with both deviation results at -0,080 mm. The total accuracy range is 0.121 mm. The maximum range of measurements of a single block is found in the results of a gauge block of size 10 mm at 0.086 mm, and the smallest in the results of measurements of a gauge block of size 40 mm at 0.015 mm.

3.CONCLUSION

The results of the described experiment present the achievable accuracy range that can be expected of OrtoScan optical scanner.

Most of the measurement results are within the expected accuracy of 0.1 mm deviations from the nominal values of the gauge blocks. Bigger deviations in measurements occurred in gauge block of size 60 mm. The reason for such deviations is probably that the size of 60 mm block is already at the limits of the scanner's measuring volume. Particularly interesting are the differences between the results of the scans with and without the clamping device geometry data being processed or not. It can be observed that in cases without clamping device geometry, smaller values of measurements of gauge blocks were obtained, which are also closer to the nominal value of gauge block size. In the results of the measurements with the clamping device geometry included, the narrower scattering of results was achieved and also the narrower range of highest and lowest measured values. For this reason, we can conclude that the scanning accuracy is not affected only by the scanning method, but also by the method of data processing at the assembly of individual scans in the common 3D geometry. It can be assumed that a better repeatability of the measurements is due to the fact that in cases of including the clamping device geometry there was more data available to the assembling algorithm. Also, the shape of the geometry could have an influence on the accuracy. The clamping device has a much more complex geometry than the guage block itself. That could also contribute tu less scattering of data when such a geometry is assembled from individual scans into a common three-dimensional geometry.

More positive deviations from the nominal value are probably due to the application of the coating layer due to the glossy surfaces of metal blocks in order to be able to obtain the gauge block geometry by fringe pattern scanning.

4. REFERENCES

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