Introduction

Rigid endoscopes are an indispensable part of the armamentarium of modern surgical practice. The modern Hopkins rod lens endoscopes have many advantages compared to other devices used in the past [1] but still possess the major setbacks of all endoscopes – barrel image distortion. The aim of the study is to outline a methodology for recording, measuring and correcting the optical distortion of different Hopkins rod lens endoscopes with a simple and as easy to apply a protocol, with application in varying medical fields.

Materials and methods

The distortion measuring scaffold created for the aim of the study (Fig. 1a) is made out of two supports mounted on an angular frame. One of the supports holds the endoscope while the other houses a custom made distortion grid with dimensions of 4 by 4 cm (20x20 squares 2mm each) (Fig. 1b) of which the endoscopic images for calibration were obtained.

![Figure 1](image1.png)

(a) the scaffold with a 70⁰ endoscope mounted and a printout of the calibration grid (b)

For the aim of the study a set of standard ENT Hopkins rod lens endoscopes were used - 0⁰ (Spiggle & Theis Medizintechnik GmbH, Overath, Germany), 30⁰ (Karl Storz, Tuttinglen, Germany), 70⁰ (Karl Storz, Tuttinglen, Germany) and a 90⁰ (Karl Storz, Tuttinglen, Germany). These endoscopes were used in a previous study and chosen as the most appropriate, due to their wide set of clinical and surgical applications. The images were taken using an endoscope compatible Nikon E 4500 digital camera.

The endoscopes were all corrected for viewing angle and distance and pointed perpendicularly at the center calibration spot of the custom made distortion measuring grid attached to the scaffold, with the means to avoid perspective distortion [2]. The distortion rate was determined by measuring the pixel distance between identical points of the superimposed original grid and images of it taken through each endoscope using the Photoshop® CS6™ software engine. The obtained information for the distortion rates of each system was then used for the correction of images obtained with the same optical system, without the need of superimposing and measuring distortion for each correction.

Results

The software measurements of the distorted images showed that barrel distortion is more evident in the outer third of the viewing field (Fig. 2a). The distortion, measured in pixels throughout the viewing field, also provided the proper parameters needed for software correction of any image obtained through the already tested and calibrated endoscopic systems, without the need for individual image calibration. The correction itself was carried out on the same software engine by applying reverse center distortion, with the measured pixel deviation from the barrel distortion, on each individual endoscope, used as a parameter for correction of images taken through it, to proper non-distorted proportions (Fig. 2b).

![Figure 2](image2.png)

(a) the original image (b) corrected image

Figure 2 – The pre and post process endoscopy image of the distortion grid taken through a 70⁰ Karl Storz Hopkins rod lens endoscope - (a) the original image with evident barrel distortion and (b) the digitally corrected image with the now straitened lines and absence of barrel distortion.

The created scaffold itself proved to be a very useful tool for calibration and obtaining of experimental images for varying types of endoscopes. After the parameters were established images of anatomical objects were taken and the same algorithm was applied with satisfying results (Fig. 3).

![Figure 3](image3.png)

(a) original grid (b) corrected grid (c) not corrected live image (d) corrected live image

Figure 3 - (a) original grid image (b) corrected grid (c) not corrected live image (d) corrected live image. The set of images is obtained though a 0⁰ endoscope.

Discussion

The application of the scaffold to hold the endoscope body and the grids gives the opportunity to perform post process anatomical measurements, after the recordings are corrected and measured using the tested algorithm. Wide angle optics such as the ones used, require great computing power in order to obtain a live geometrically correct image, that is why further development on the hardware and software is required to produce a clinically applicable device [3].

Conclusion

This method of correcting the image distortion of the endoscope images is a potential basis for further developing the technique of image correction. It provides an affordable opportunity to easily perform correct anatomical and proportionate measurements using endoscopy [4].

References