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ORIGINAL STUDY

Rigid chip-on-the-tip endoscope for rhinosurgery and diagnosis

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ABSTRACT

BACKGROUND. The rigid endoscope developed by Karl Storz in 1961 led to a great advance in diagnosis and surgery and nowadays it is the gold standard in routine ENT practice. In addition, the development of video cameras has enhanced the surgical abilities as well as teaching opportunities in endoscopic sinus surgery.

OBJECTIVE. We developed a new prototype endoscope using the "chip-on-the-tip" technology. The aim of our non-clinical study was to observe and discuss the experimental data collected from laboratory tests on plastic models.

MATERIAL AND METHODS. The prototype rigid chip-on-the-tip endoscope has two parts - inner and outer. The inner part includes the chip-on-the-tip camera, light source and the cable. The outer part is a metal tube ending with a 0-degree lens. We performed laboratory tests of the rigid chip-on-the-tip endoscope for rhinosurgery and diagnosis.

RESULTS. We have observed technical parameters of the rigid chip-on-the-tip in order to compare them to conventional endoscopes connected with camera head units that are standard equipment for rhinosurgery and diagnosis.

CONCLUSION. Its advantages compared to the conventional Hopkins endoscope, connected to a standard camera head, are the smaller size, weight and the necessity of only one cable instead of two, allowing easy handling.

KEYWORDS: endoscopic sinus surgery, sinus, rhinosurgery, chip-on-the-tip, rigid endoscope.

INTRODUCTION

Functional endoscopic sinus techniques revolutionized rhinosurgery over the past 30 years. Karl Storz developed the rigid endoscope primarily for urology and later used it in other medical fields, including ENT[1]. This allowed the progress in diagnosis and surgery of the nose, paranasal cavities and skull base surgery[2-7].

The later advance in video technology made possible the visualization of structures on screen with huge magnification and high definition resolution[5,8].

In 2016, a 3D endoscope was introduced[9], however it is not routinely used for FESS (functional endoscopic sinus surgery). Another new development used for endoscopes is the "chip-on-the-tip technology".

The "chip-on-the-tip technology" consists in a distal sensor endoscope that is able to meet the requirements of the smallest endoscopes. The distal sensor technology improves (semiconductor manufacturing concerning CCD - charged-coupled device - and CMOS - complementary metal–oxide–semiconductor)[10] and endoscopes that employ this technology have all the requirements to match the size of contemporary 4mm conventional Hopkins endoscopes. Distal sensor endoscopes are already superior to flexible fiber-optic endoscopes in terms of weight and picture quality[11].

In abdominal surgery, as well as thoracic surgery, the chip-on-the-tip endoscopes are widely spread[12]. The modern flexible endoscopes made with "chip-on-the-tip technology" allow perfect visualization and simplify the equipment[13].

We present a prototype of a rigid endoscope for diagnosis and rhinosurgery. The aim of this article

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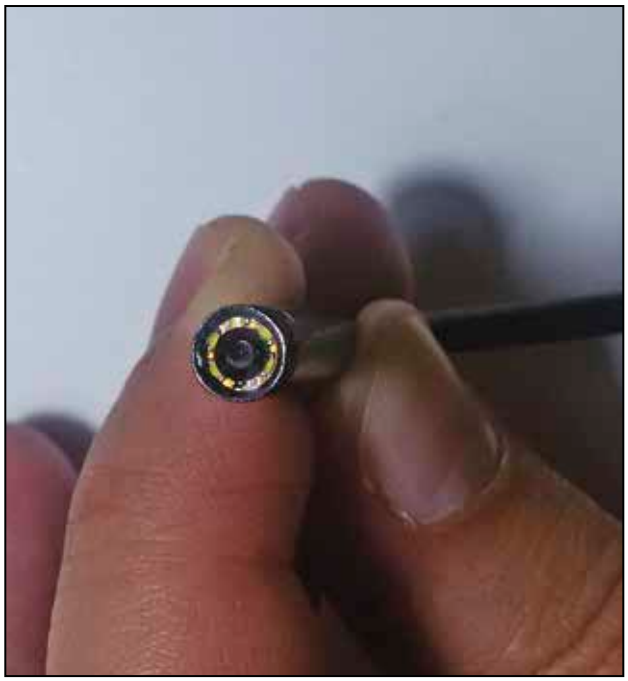

Figure 1 The inner part of the rigid chip-on-the-tip endoscope, consisting of chip-on-the-tip low-cost camera with 6 micro LEDs for illumination.

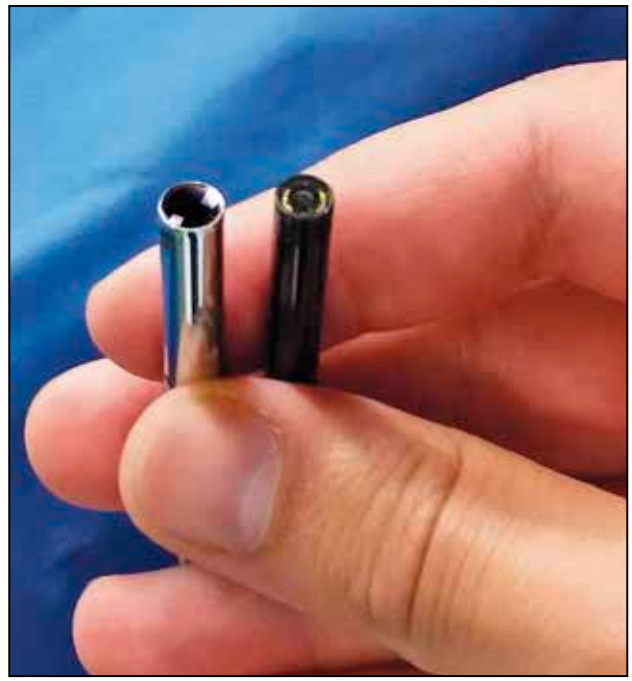

Figure 2 Inner and outer part of the prototype endoscope. The outer part is a metal tube, ending with a 0° lens.

is to test the advantages or disadvantages of this technology and the possibilities to become standard in the routine ENT practice.

MATERIAL AND METHODS

The prototype rigid chip-on-the-tip endoscope has the following features: the inner and the outer part. The inner part is a chip on the tip camera with 6 micro LEDs at the top (Figure 1).

The distal sensor used for the prototype is Complementary metal–oxide–semiconductor (CMOS). We have chosen this technology because of the low price and wide assortment of analogue modes. In addition to that, according to most of the future trends for camera producers, the CMOS technology would be further developed[10].

The outer part is a steel tube with a 0-degree lens at the top (Figure 2).

The whole system was connected directly to the PC and no conventional light source was used (Figure 3).

Only a single cable is needed for the prototype endoscope, to provide both connections for the camera and electricity for the LED light, both on the top of the device.

For the inner part, we have used a low-cost flexible chip-on-the-tip endoscope with the following parameters: 2 in 1 USB Inspection Camera; Lens Diameter: 5.5mm; Resolution 640*480; Sensor

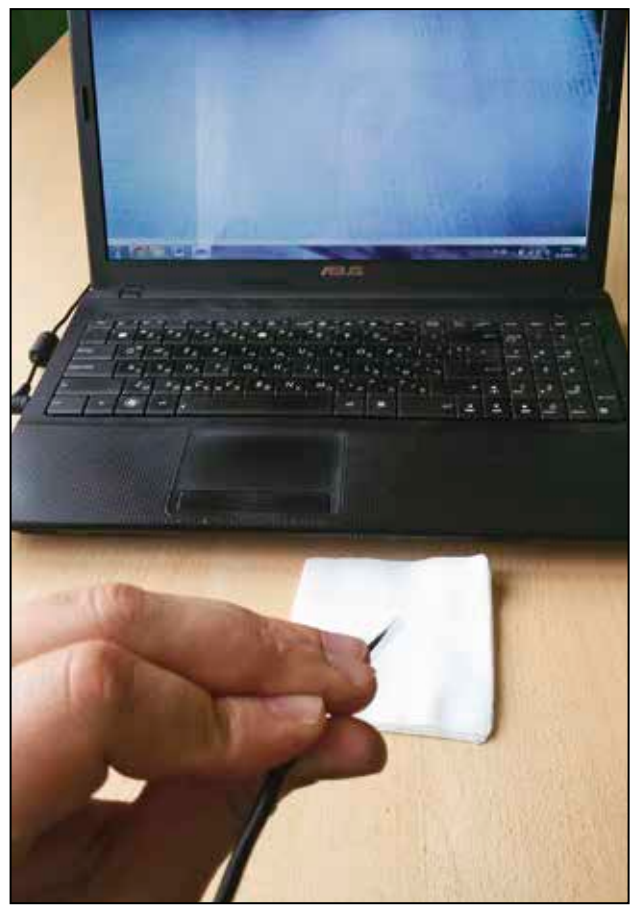

Figure 3 The whole system connected directly to the PC; no conventional light source was used.

Figure 4 Sample images taken with the prototype rigid chip-on-the-tip endoscope on a plastic model of cadaver.

Size: 1/9 inch; Frame Rate: 30fps; View Angle: 66 degree; Operating Temperature: 0 degrees to 60 degrees; Waterproof level: IP67 (**IP** –International Protection is a standard drawn up by the International Electrotechnical Commission; **6** –resistance to dust; **7** – water resistance).

To examine the performance of the prototype rigid chip-on-the-tip endoscope, we made a test on a plastic cadaver (Figure 4) and also performed physical tests (weight, light, temperature, picture quality), and compared them with the conventional Hopkins endoscopes connected to camera heads.

This was the first test of the rigid chip-on-the-tip endoscope for rhinosurgery and diagnosis. That is why we performed only a physical laboratory test. We performed a comparative study of the prototype endoscope with the conventional rigid Hopkins endoscopes connected to camera heads.

The observed parameters were weight, heat at the top of the endoscope, size, picture quality, costs and ergonomics.

The weight was measured by digital scale with sensitivity of 0.1g.

For measuring the temperature at the tip of the rigid chip-on-the-tip endoscope for rhinosurgery and diagnosis we used an infrared non-contact thermometer with accuracy of ±2°C.

The temperature at the tip was measured after 60 seconds and compared to the temperature of standard rigid endoscopes.

RESULTS

We have compared the prototype rigid chip-on-the-tip endoscope with the conventional rigid Hopkins 4 mm 0 degree endoscope connected to a camera head. Although we have used low-cost materials and camera, the following parameters mentioned in the table are very promising (Table 1).

The well-distributed weight of just 20 grams of

Table 1
Chip-on-the-tip endoscope versus conventional rigid endoscope

	Prototype	Conventional rigid Hopkins 4 mm 0 degree endoscope connected to a camera head
Weight	20 g	< 280 g
Heat*	60 °C*	44.3 °C; 65.8 °C and 91.4 °C **
Size	No camera head attached to the endoscope	39x49x114 mm
Picture (Pixel Output Signal H x V)	640 x 480	1920 x 1080
Cost	< 100$	> 10 000$

*Heat at the top of the endoscope according to technical characteristics.
** At 33%, 66% and 100% power levels of xenon light source[14].

the tested prototype makes it much easier to handle compared to the high center mass of the camera head (280 grams) connected to the conventional rigid Hopkins endoscope. These observations objectify the ergonomic advantaged of the rigid chip-on-the-tip endoscope.

DISCUSSIONS

The recent development in semiconductor manufacturing concerning CCD and CMOS has the tendency of improve image quality and reduce costs[10].

The "chip-on-the-tip technology" has many advantages in the field of flexible endoscopy in the ENT practice and multiple studies have shown its benefits[15-17].

Nowadays, the chip-on-the-tip technology is widely used for rigid endoscopes in the field of laparoscopic and thoracic surgery[12].

The greatest advantage of the rigid chip-on-the-tip technology compared to conventional Hopkins endoscopes connected to camera heads is the picture quality.

The Hopkins endoscopes, widely used in the ENT practice, composed of lenses (including rod lenses) combined with the camera head, have greater chromatic aberration compared to the rigid chip-on-the-tip endoscopes because the rigid chip-on-the-tip endoscopes use a smaller number of lenses. This is the reason why the rigid chip-on-the-tip technology has a more realistic visualization with smaller chromatic aberration[18].

The experiment was funded by the first author himself and costs are less than 100$. Despite the low costs, it has many other advantages compared to the rigid Hopkins endoscope connected to a camera head for rhinosurgery; namely, the weight is approximately 10 times less than the conventional rigid Hopkins endoscopes on the market. The outer part of the rigid chip-on-the-tip endoscope is fully autoclavable, the system is mobile, easy to handle and with a smaller size of the endoscope and accompanying equipment. The inner part is very durable like the flexible chip on the endoscopes, compared to the rigid Hopkins endoscope and camera. Moreover, no camera needs to be attached to the endoscope, providing more space for manipulating instruments, particularly in a four-hand technique.

The prototype's quality of the picture was fairly low compared to standard endoscopes (Figure 4). The reason is because it is a low-cost experiment made with a cheap CMOS chip. The nowadays rigid and flexible chip-on-the-tip endoscopes use more often more expensive CCD chips. There are already affordable 2 mm CCD chips, hence the authors' opinion that it is a question of time when the conventional rigid endoscopes in the ENT practice will be replaced by rigid chip-on-the-tip endoscopes.

The video quality is still insufficient for surgery because the CMOS chip used in this experiment is low-cost product, but it can still be used for anatomy demonstration purposes. We suggest that such an endoscope would provide low-income countries with the opportunity to have at least better diagnostic possibilities.

CONCLUSIONS

In conclusion, we would like to state once again some of the advantages of the rigid chip-on-the-tip endoscope.

All parameters (weight, heat at the top of the endoscope, size, picture quality, costs and ergonomics) of this prototype chip-on-the-tip rigid endoscope compared to the nowadays equipment for FESS surgery show the advantages of the "chip-on-the-tip technology".

The picture quality of the prototype is still insufficient for surgery because of the low-cost chip used for the prototype, but can be used for anatomical demonstrations. However, on the market there are already affordable CCD and CMOS 2mm chips which could be integrated into the rigid chip-on-the-tip rhinoscope.

Nowadays, the "chip-on-the-tip technology" is used in the laparoscopic and thoracic surgery. In the field of flexible endoscopes it is already the gold standard. It has many advantages and our vision is that soon the rigid chip-on-the-tip technology would be standard in rhinology.

Conflict of interest: The authors have no conflict of interest.

Contribution of authors: All authors have equally contributed to this work.

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REFERENCES

1. Berci G. Professor Harold H. Hopkins – personal reflections. Surg Endosc. 1995;9:667-8. Available from: https://vdocuments.mx/professor-harold-h-hopkins.html.
2. Messerklinger W. Endoscopy of the nose. Urban &Schwarzenberg; 1978.
3. Stammberger H, Posawetz W. Functional endoscopic sinus surgery. Concept, indications and results of the Messerklinger technique. Eur Arch Otorhinolaryngol. 1990;247(2):63-76.
4. Draf W. Endoscopy of the paranasal sinuses: technique, typical findings, therapeutic possibilities. Springer – Verlag; 1983.
5. Yanagisawa E. The use of video in ENT endoscopy: its value in teaching. Ear Nose Throat J. 1994;73(10):754-63.
6. Tasman AJ, Stammberger H. Video-endoscope versus endoscope for paranasal sinus surgery: influence on stereoacuity. Am J Rhinol. 1998;12(6):389-92.
7. Weber RK, Hosemann W. Comprehensive review on endonasal endoscopic sinus surgery. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2015;14:Doc08. DOI: 10.3205/cto000123. eCollection 2015.
8. Tasman AJ, Feldhusen F, Kolling GH, Hosemann W. Video-endoscope versus endoscope for paranasal sinus surgery: influence on visual acuity and color discrimination. Am J Rhinol. 1999;13(1):7-10.
9. Albrecht T, Baumann I, Plinkert PK, Simon C, Sertel S. Three-dimensional endoscopic visualization in functional endoscopic sinus surgery. Eur Arch Otorhinolaryngol. 2016;273(11):3753-8. Epub 2016 Apr 19.
10. Sherry H, Grzyb J, Zhao Y, Al Hadi R, Cathelin A, Kaiser A, et al. A 1kpixel CMOS camera chip for 25fps real-time terahertz imaging applications. 2012 IEEE International Soli-State Circuits Conference, San Francisco, CA; 2012. P. 252-4. DOI: 10.1109/ISSCC.2012.6177011. Available from: https://ieeexplore.ieee.org/document/6176997/.
11. Okhunov Z, Hruby GW, Mirabile G, Marruffo F, Lehman DS, Benson MC, et al. Prospective comparison of flexible fiberoptic and digital cystoscopes. Urology. 2009;74(2):427–30. DOI: 10.1016/j.urology.2009.01.007. Epub 2009 Jun 6.
12. Dhumane PW, Diana M, Leroy J, Marescaux J. Minimally invasive single-site surgery for the digestive system: A technological review. J Minim Access Surg. 2011;7(1):40-51. DOI: 10.4103/0972-9941.72381.
13. Swanstrom LL, Soper NJ. (eds) Mastery of Endoscopic and Laparoscopic Surgery. LWW, Wolters Kluwer Health; 2013.
14. Tomazic PV, Hammer GP, Gerstenberger C, Koele W, Stammberger H. Heat development at nasal endoscopes' tips: danger of tissue damage? A laboratory study. Laryngoscope. 2012;122(8):1670–3. DOI: 10.1002/lary.23339. Epub 2012 May 3.
15. Kawaida M, Fukuda H, Kohno N. Clinical Experience with a New Type of Rhino-Larynx Electronic Endoscope PENTAX VNL-1530. Diagn Ther Endosc. 1994;1(1):57–62.
16. Schröck A, Stuhrrmann N, Schade G. Flexible 'chip-on-the-tip' endoscopy for larynx diagnostics. HNO. 2008;56(12):1239–42. DOI: 10.1007/s00106-008-1783-1.
17. Eller R, Ginsburg M, Lurie D, Heman-Ackah Y, Lyons K, Sataloff R. Flexible laryngoscopy: a comparison of fiber optic and distal chip technologies-part 2: laryngopharyngeal reflux. J Voice. 2009;23(3):389–95. DOI: 10.1016/j.voice.2007.10.007. Epub 2009 Jan 29.
18. Helferty JP, Zhang C, McLennan G, Higgins WE. Videoendoscopic distortion correction and its application to virtual guidance of endoscopy. IEEE Trans Med Imaging. 2001;20(7):605-17.