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First intraoperative experience with three-dimensional (3D) high-definition (HD) nasal endoscopy for lacrimal surgeries

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Abstract The aim of this study is to report our preliminary experiences with regard to safety and feasibility of three-dimensional (3D) endoscopic lacrimal surgeries with a recently launched latest generation 3D endoscope. A 4-mm rigid three-dimensional (3D) endoscope (TIPCAM 1S 3D ORL^{R}, Karl Storz, Tuttlingen, Germany) was used. Fifteen patients who underwent various endoscopic lacrimal procedures by a single surgeon (MJA) were included. The procedures included probing with nasolacrimal intubation, cruciate marsupialization of intranasal cysts for congenital dacryoceles, powered endoscopic dacryocystorhinostomy, post-operative stent removal with ostium granuloma excision. The implementation, visualization, optical performance, ease of tissue handling and complications were noted. Ten surgical observers filled a questionnaire to rate their experiences. Enhanced depth perception was found to be very beneficial intraoperatively. Greater anatomical delineation facilitated improved hand–eye coordination and dexterity. Intraoperative assessment and handling of tissues and surgical manoeuvring were precise and did not require the additional spatial cues that the surgeon derives from a two-dimensional image. These benefits were more appreciated in the complex cases. The setup was easy on previous endoscopic platforms and did not consume any additional time. All the surgical procedures were completed successfully without any complications. The surgical observers unanimously noted enhanced anatomical understanding and surgical learning as compared to the routine 2D planes. Operating in 3D planes enhances depth perception, dexterity and precision. Although initial results are promising, further randomized studies with head-on comparisons between 3D and 2D would help formulate specific guidelines.

Keyword 3D · Endoscope · Lacrimal · TIPCAMR · Dacryocystorhinostomy

Introduction

Endoscopic lacrimal surgeries are constantly evolving with increasing indications [1]. The currently used standard rigid endoscopes are two-dimensional and hence have several limitations. The most significant being lack of depth perception. Endoscopic surgeons operate on tissues which are anatomically three-dimensional, but the operative images are displayed in two dimensions and they need to rely on subjective spatial depth cues to derive the indirect 3D information. The significance of depth perceptions in areas with critical anatomical proximities like the head and neck cannot be overemphasized. Three-dimensional endoscopy is being increasingly used for expanding indications in neurosurgery, gastroenterology, gynaecology and otolaryngology [2–16]. 3D endoscopic studies in these subspecialties have enumerated multiple benefits which include enhanced depth perception and safety, quick surgery, faster recovery, improved morbidity and a good endoscopy learning tool for the inexperienced surgeons [2–13]. The current study aims to assess the utility and feasibility of 3D endoscopy in lacrimal surgeries using the recently launched latest generation 3D endoscopes.

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Materials and methods

Institutional review board approval and patient consent were obtained prior to the surgery. All the procedures were performed by a single surgeon (MJA), who was well versed with the use of standard rigid and continuously variable endoscopes. Initial inspection practice was performed in two cases of bilateral endoscopic guided probing to get comfortable and oriented with use of 3D endoscopes.

The TIPCAM^{R} 1S 3D ORL endoscope

The TIPCAM^{R} 1S 3D ORL (Karl Storz, Tuttlingen, Germany) is a specialized Hopkins telescope; rigid with 4 mm shaft diameter, 18 cm length and available with 0° and 30° angulations (Fig. 1a). The endoscopic system consists of the Image 1S modular platform (Karl Storz, Tuttlingen, Germany), on which the existing endoscopic systems can be expanded (Fig. 1b). The HD 3D display monitor (26 or 32 inch) (Fig. 1c) is provided with multiple video input and output options and has an inbuilt visualization modes namely; clara, clara + chroma and spectra for delineation of tissue structures like vascular structures. The 3D video endoscopic system has a full HD image sensor with a frame rate of 50/60 Hz and resolution of 1920 × 1080 pixels. The camera head is provided with freely programmable buttons (Fig. 1a). The telescope and the camera head are steam and plasma sterilizable. For the viewing, either a fogless, passive 3D polarization glass or a circularly polarized 3D clip on glasses can be used (Fig. 1d). The recording can be performed using the AIDA^{R} 3D software (Karl Storz, Tuttlingen, Germany). The 3D monitor is ideally placed straight in front of the observer at a distance of 2 m.

Fifteen patients who underwent various endoscopic lacrimal procedures by a single surgeon (MJA) were included. The procedures included unilateral or bilateral probing with nasolacrimal intubations for congenital nasolacrimal duct obstructions ($n = 6$), cruciate marsupialization of intranasal cysts for congenital dacryoceles ($n = 2$), powered endoscopic dacryocystorhinostomy ($n = 5$), post-operative stent removal with ostium granuloma excision ($n = 2$). The implementation, visualization, optical performance, ease of tissue handling and complications were noted. After observing these procedures, ten surgical observers (included two consultants and 8 fellows) with previous experiences with the routine 2D, filled a questionnaire (Table 1) to rate their experiences. All these observers had a prior testing of their stereo-acuity to ascertain the normalcy of their stereopsis.

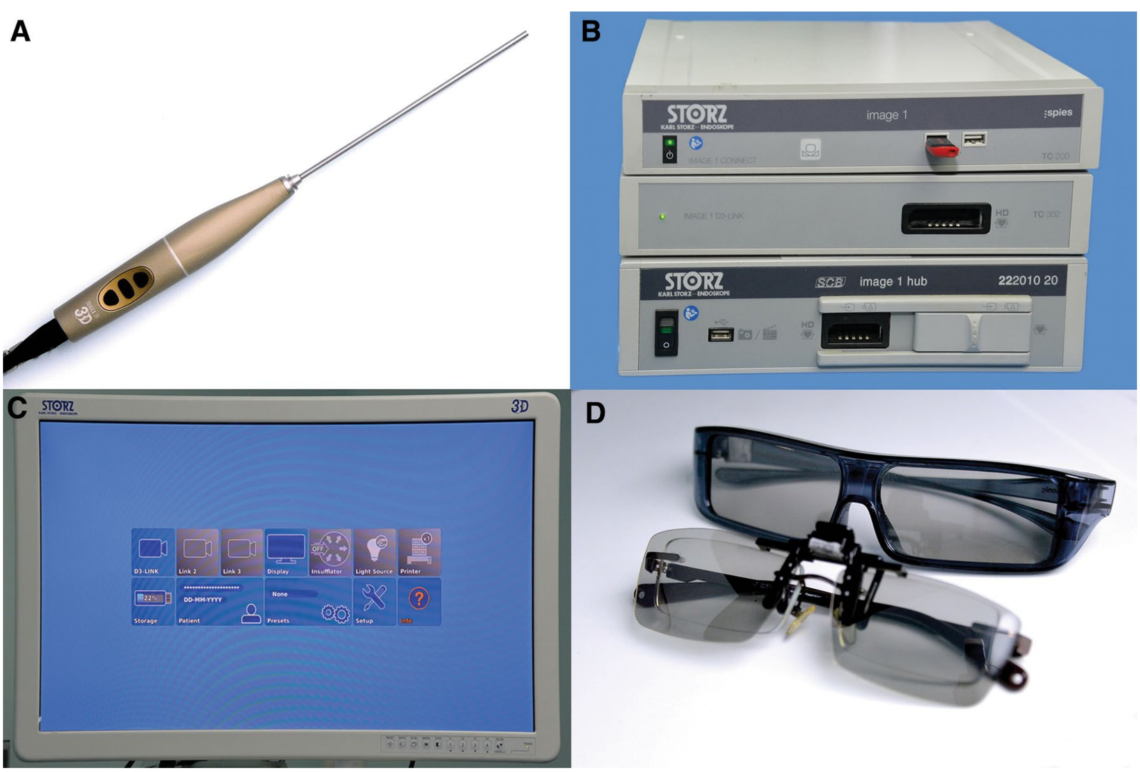

Fig. 1 The 3D endoscope: external photography showing the TIPCAM^{R} 1S 3D ORL telescope. Note the programmable buttons on the camera head (**a**). The platform for the 3D endoscopy system (**b**), the 3D HD monitor with numerous visualization options (**c**) and the 3D fogging glasses and the clip on variants (**d**)

Table 1 Subjective experience with 3D in comparison to 2D

Grade guidelines: please rate the answers in the following terms:
W—worse
E—equal
B1—up to 25% better
B2—25–50% better
B3—50–75% better
B4—75–100% better
1. How different was the anatomical delineation of tissues?
2. How would you rate the depth perception during tissue handling?
3. How would you rate the overall surgical learning experience?

Results

Enhanced depth perception was found to be very beneficial intraoperatively. Greater anatomical delineation facilitated improved hand–eye coordination and dexterity. Intraoperative assessment and handling of tissues and surgical manoeuvring were precise and did not require the additional spatial cues that the surgeon derives from a two-dimensional image. Image separation of intraoperative pictures can provide a clue to the extent of enhanced depth perception (Fig. 2a–d). The malleability of the surgical wounds created was better understood. All these benefits were more appreciated in the complex cases like that of cruciate marsupialization for congenital dacryoceles ($n=2$) or for post-facial trauma setting of powered endoscopic DCR ($n=2$). The setup was easy on previous endoscopic platforms and did not consume any additional time. Intraoperatively, there was a sudden loss of 3D on four occasions and happened secondary to smearing of the telescope mirror with blood or secretions. This could be immediately rectified with simple cleaning of the lens as is routinely done during endoscopic surgeries. All the surgical procedures were completed successfully without any complications. The stereo-acuity of the observers was tested with Randot's graded circle test and all were found to have normal stereopsis (20–30 s of an arc). The observers unanimously graded anatomical delineation and enhanced depth perception as B4 (75–100% better as compared to 2D) and graded the overall surgical learning experience B3 (50–75% better as compared to 2D) and beyond.

Discussion

The current study reports the utility of latest generation 3D HD endoscopes while performing lacrimal procedures.

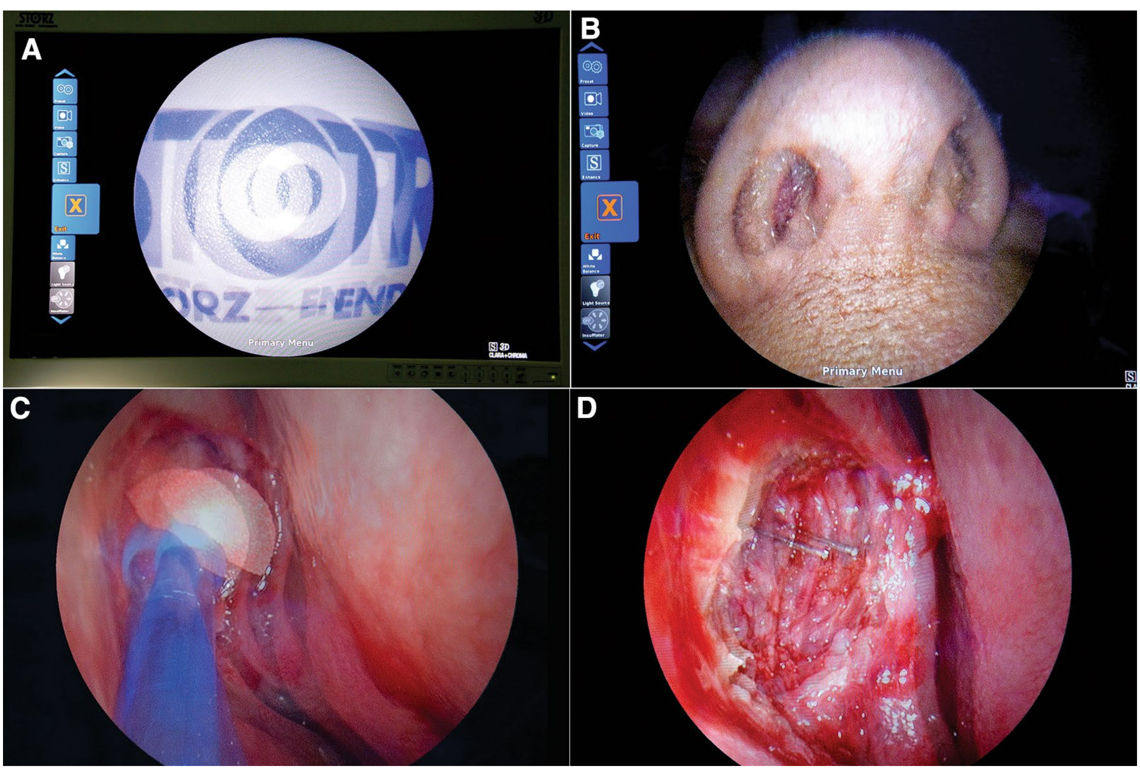

Fig. 2 Intraoperative 3D imaging: external photograph of the 3D monitor screen. Note the image separation by the right and the left lenses (**a**). Endoscopic pictures showing the external nares (**b**), application of MMC-soaked Merocel sponge (**c**) and during the intubation (**d**). Note the well separated two images of the single bodkin taken by the two different lenses that gives the much needed depth perception

Although 3D endoscopy has its own set of limitations, enhanced depth perception and better anatomical delineation are big advantages for surgeons working in and around tissues with critical proximities and in more complex scenarios.

Although there is not much of literature on the use of 3D endoscopy in otolaryngology, its utility is widely studied in laparoscopic and neurosurgical studies. A meta-analysis [14] of 2D versus 3D laparoscopic surgery included 21 published trials and found that 3D surgeries were superior to 2D in terms of surgical time ($P<0.00001$), blood loss ($P<0.01$), peri-operative complications ($P<0.04$) and hospital stay ($P<0.03$). However, they demonstrated similar efficacy on the secondary end-points that were studied. Fergo et al. [15] studied 13 randomized clinical trials comparing 3D versus 2D laparoscopy for abdominal surgeries. They found that 69% (9/13) of them showed superiority of 3D in terms of reduction of time and 77% (10/13) showed significant reduction in error. However Sakata et al. [16] reviewed the variations in studies which evaluated three generations of 3D endoscopic systems used for laparoscopy and concluded that individual performance in 3D is determined by multiple factors. One of the major limitations of these studies was the failure to check the stereo-acuity of the participants. They also stressed the need for evolving objective measures of performance.

The 3D endoscopes have certain limitations. In very narrow areas, the 3D effect may occasionally be lost. Smearing of any of the aperture lens can lead to a sudden loss of 3D, which can be very quickly resolved with a routine lens cleaning. It is desirable to have option of more angulated 3D telescopes (45°–90°) or having a continuously variable 3D telescope. In addition, the cost involved needs to be taken into consideration. Although the learning curve is short for experienced endoscopists, it may take few cases for the inexperienced before getting comfortable with the use of 3D endoscopes.

In conclusion, the preliminary experiences of 3D endoscopy in lacrimal surgeries appear to be promising. Their potential needs to be explored with further studies comparing their benefits over the regular 2D systems that may help in formulating appropriate guidelines.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Financial disclosure No financial disclosure.

Ethical approval All the procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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