Original Article

Comparison of 2.9- *vs.* 3.7-mm flexible distal-chip nasal endoscopes in diagnostic nasal endoscopy

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Background: Nasal endoscopy is a crucial component of sinonasal examination, providing detailed visualization in a challenging region. Advances in digital imaging technology have led to the development of distal-chip nasal endoscopes, overcoming some of the limitations of fibre optic endoscopes. This study aimed to compare the visualisation of the sinonasal cavity, patient comfort, and ease of examination between a 2.9-mm and a 3.7-mm distal-chip flexible nasal endoscope.

Methods: Fifty patients undergoing routine clinical review were included in a single-centre prospective study conducted from January 2021 to December 2021 through the Ear Nose and Throat outpatient clinic at Logan Hospital, Australia. Two consecutive examinations were performed using both endoscope sizes and sinonasal visualization, patient discomfort, and ease of examination were assessed. Differences in site visualisations were tested using the McNemar paired test. Differences between patient discomfort and clinician difficulty scores were tested using the paired *t*-test or the Wilcoxon test.

Results: Image quality and lighting appeared similar between the two endoscopes. Visualisation rates varied across anatomical subsites, with an overall improvement of 3.1% achieved with the 2.9-mm endoscope. The 2.9-mm endoscope outperformed the 3.7-mm endoscope in visualizing the superior turbinate [McNemar's P=0.003, odds ratio (OR) =2.75, 95% confidence interval (CI): 1.29–5.88], sphenoid ostium (McNemar's P=0.025, OR =1.38, 95% CI: 0.76–2.52) and sphenoethmoid recess (McNemar's P=0.05, OR =2.76, 95% CI: 1.18–6.3). The 3.7-mm endoscope showed a trend toward superiority in visualisation in the cribriform fossa (McNemar's P=0.061, OR =3.16, 95% CI: 1.77–5.75). Patient discomfort and clinician difficulty were significantly lower with the 2.9-mm endoscope compared to the 3.7-mm endoscope [Wilcoxon P<0.001, interclass correlation coefficient (ICC) =0.86, 95% CI: 0.79–0.9]. ICCs indicated good reliability for both patient discomfort and clinician difficulty scores. The findings suggest that the narrower 2.9-mm endoscope provides improved visualisation, greater patient comfort, and enhanced ease of examination compared to the traditional 3.7-mm endoscope.

Conclusions: This study highlights the clinical significance of narrow endoscopes in visualizing anatomically restricted regions and their potential impact on early diagnosis, evaluation of olfaction disorders, and diagnostic workup of anterior skull base pathology. The results assist clinicians in selecting the optimal endoscope for their patients' needs, reducing reliance on radiology and minimizing unnecessary interventions. The implementation of distal-chip nasal endoscopes holds promise for improving sinonasal examination and enhancing patient care.

Keywords: Diagnostic nasal endoscopy; distal chip scope; sinonasal visualisation

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Introduction

Nasal endoscopy was first reported by Hirschman using a modified cystoscope in 1921 (1). The 1950's saw the arrival of rigid nasal endoscopy and endoscopic sinus surgery. More recently, flexible nasal endoscopy has become a standard component of sinonasal examination, providing detailed visualisation for what otherwise is a challenging region to examine (2).

Modern digital imaging technology in the form of small multichromatic image sensor chips, can now be placed at the distal end of an endoscope, overcoming some limitations of fibreoptic endoscopes (3). For fibreoptic endoscopes, a decrease in the endoscope diameter necessitates an equivalent reduction in image quality and light transfer capacity (4). Distal chip endoscopes allow decreased endoscope diameter whilst maintaining a high definition image. The fibreoptic endoscope is also restrained by a number of artefacts that limit its diagnostic ability (3,5). The barrelling phenomenon, which warps the image of a fibreoptic endoscope, is markedly reduced with distal chip nasal endoscopes (3). The pixelated moiré pattern is present when coupling a fibreoptic endoscope to a digital camera interface for display on an external monitor (5). This pattern decreases the clarity of the image being viewed and adds to the time needed to defocus the image as a customary way to minimize the effect (5). The moiré effect is obviated with the use of the distal-chip nasal endoscopes as the image is received through the video sensor at the tip of the endoscope and passes digitally to the display monitor for high definition viewing by the clinician (5).

Endoscopic visualisation of the sinonasal cavity is also limited by narrow anatomy and patient tolerance (2,6). The ability to adequately visualise narrow regions, such as the olfactory cleft or sphenoethmoid recess, may aid in early diagnosis and reduce reliance on radiology for identification and surveillance of conditions in these areas (7). Previous studies have demonstrated that narrower endoscopes allow superior visualisation of the nasal cavity and are better tolerated by patients (6,7). Distal-chip nasal endoscopes may visualise regions of the nasal cavity with a narrower calibre device, without loss of diagnostic image resolution or illumination. There is an absence of literature comparing the visualisation outcomes or the patient reported comfort for reduced diameter distal chip flexible nasal endoscopes (FNEs).

This paper compares the extent of visualisation of the sinonasal cavity, patient comfort and assessors ease of examination when using a 2.9-mm distal-chip FNE and the former standard 3.7-mm distal-chip FNE during routine flexible nasal endoscopy. It was hypothesised that with the slim 2.9-mm endoscope; sinonasal cavity visualisation, patient comfort and assessor ease would improve compared to the traditional 3.7-mm endoscope. The results of this study may assist clinicians in selecting an optimal endoscope for their patient's needs. We present this article in accordance with the STROBE reporting checklist (available at https://www.theajo.com/article/view/10.21037/ajo-23-33/rc).

Methods

This was a single-centre prospective study conducted from January 2021 to December 2021 through the Ear Nose and Throat outpatient clinic at Logan Hospital, Australia. The objectives of this study were to identify differences in ability to visualize the nasal cavity, patient comfort and ease of examination when comparing a 2.9-mm diameter distal-chip FNE with a former standard diameter 3.7-mm distal-chip FNE. The primary outcome of this study was the difference in sinonasal visualisation between the two different diameter nasal endoscopes. The secondary outcome measures were the differences in patient discomfort scores and the ease of examination score when comparing the two different diameter nasal endoscopes.

Fifty patients were included with the target population being those over the age of 18 who attend the Otolaryngology Head and Neck Surgery Outpatient Department for routine clinical review over a 2-month period. The sample size of 50 patients was established by a power analysis in a pilot study of 15 patients (α=0.05, β=0.2). Subject selection was based on the first 50 consenting patients seen by the allocated endoscopist in their outpatient clinic after commencement of the study. Patient selection encompassed the full breath of Otolaryngology Head and Neck Surgery presentations. All patients under 18 years of age or those who have previously undergone any form of sinonasal

Table 1 Visualisation based on scope size and reviewer

Scope size	Visualisation, %		
	Reviewer 1	Reviewer 2	Combined
2.9 mm	48.1	44.4	46.3
3.7 mm	47	39.3	43.2
Difference	1.1	5.1	3.1

surgery were excluded. The study employed a repeated measures design, there was no randomisation of subjects into different study arms.

All patients were administered topical anaesthetic/decongestion nasal spray, CoPhenylcaine Forte (ENT Technologies PTL Ltd., Hawthorne, Australia) applied at the recommended dose of 5 sprays per nasal cavity 10 min prior to nasal endoscopy. Each patient then underwent two consecutive FNE examinations of each nasal cavity. All endoscopic examinations were performed by the same clinician and recorded for later sinonasal visualization scoring. The Karl Storz 2.9-mm (outer diameter) CMOS video rhino-laryngoscope was used first on the right nasal cavity followed by the Karl Storz 3.7-mm (outer diameter) CMOS video rhino-laryngoscope, the order was reversed for the left nasal cavity examinations. The appearance of each scope was similar but not identical and as such patient blinding was not possible. The clinician was not blinded to the scope diameter, the patient population was not informed of which scope was being used during each examination. At completion of each examination a comfort level was recorded by the patient on a standardised visual analog scale (VAS) with a scale of 0–10 (0 indicating no pain and 10 indicating the worst pain they have experienced) and a clinician ease of examination was recorded by the clinician, on a scale of 1–5 (1 being very easy and 5 being very difficult). There was a total of four video files per patient, two endoscopies per nasal cavities.

The 200 randomised and deidentified video files were reviewed separately by two Otolaryngologist Head and Neck Surgeons (not involved in the patient's care) for scoring with the endoscopic sinonasal visualisation scoring system. This scoring system allocates 21 marks for 21 discrete anatomical sites and 1 mark for sinonasal pathology (pus, polyps, masses or other) visualized in the sinonasal cavity and was a modification of a scoring system in a study by Lal (see *Table 1*) (6). The 9,600 anatomical subsites from the 200 video files were scored as either satisfactorily visualised or unsatisfactorily visualized.

Categorical variables were described using frequencies and percentages. Continuous variables were described either using mean ± standard deviation (SD) when a variable was normally distributed, or median and interquartile range (IQR) when normality was not met. Normality was assessed using the Shapiro-Wilks test.

Differences in proportions between the site visualisations were tested using the McNemar paired test. For assessing differences between patient discomfort ratings and clinician difficulty scores either the paired *t*-test was used for comparing normal continuous variables or the Wilcoxon test for was used for non-parametric continuous variables. The interclass correlation coefficient (ICC) estimates and their 95% confidence intervals (CI) were calculated based on a mean-rating (k=2), consistency, 2-way mixed-effects model. The ICC estimate values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 are indicative of poor, moderate, good, and excellent reliability, respectively (8).

When analyzing for inter-interpreter reliability the binary categorical variables of interest: a Cohen's Kappa estimate was performed. The judgement for the estimated Kappa about the extent of agreement is given by Landis (8). Further analysis to explore inter-interpreter differences was not established.

The analyses were preformed using the R software version R version 4.0.2 (2020-06-22) and developed in RStudio 2021.9.1.372.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of the Central Queensland Hospital and Health Service (EC00173). Written informed consent to participate in the study was obtained from each patient prior to commencement of the study.

Results

The recruited patients included 28 females (56%) and 22 males (44%) with a median age of the study population was 39.5 years (IQR, 31–60 years). The two reviewers achieved a 45% visualisation rate across all 9,600 anatomical subsites reviewed. Visualisation rates vary substantially from site to site.

There was an overall agreement of 79% between the two reviewers. Reviewer 1 gained a 1.1% improved visualisation (McNemar's test P<0.001) across all 9,600 anatomical subsites reviewed from the 2.9-mm scope compared to the 3.7-mm

Table 2 Visualisation based on scope size

Anatomical structure	Visualisation, %			
	2.9-mm scope	3.7-mm scope	Difference	P value
Superior turbinate	83	70.50	12.50	0.003
Sphenoid ostium	43	31.70	11.30	0.025
Sphenoethmoid recess	85.50	78.10	7.40	0.05
Cribriform fossa	51.50	43.90	7.60	0.061
Sphenoid antrum	4	0.50	3.50	0.114
Nasal septal deviation	50.50	43.40	7.10	0.161
Hasner's valve	50	43.40	6.60	0.166
Bulla ethmoidalis	16	10.70	5.30	0.233
Suprabular recess	4.50	2.10	2.40	0.267
Fossa of Rosenmuller	93	90.30	2.70	0.404
Choana	96.50	94.40	2.10	0.423
Nasal vault	94.50	92.40	2.10	0.479
Eustachian tube	94.50	92.40	2.10	0.479
Hiatus semilunaris	18.50	14.80	3.70	0.511
Maxillary ostium	2	1	1.00	0.617
Nasal floor	98	96.90	1.10	0.683
Nasal pathology	25	23	2.00	0.784
Retrobullar recess	5.50	4.10	1.40	0.814
Middle turbinate	92	90.80	1.20	0.838
Vertical portion of uncinate	46.50	46.40	0.10	1.0
Maxillary antrum	2.50	2	0.50	1.0
Frontal recess	1	1	0.00	1.0
Accessory maxillary ostium	11.50	12.20	–0.70	0.855
Horizontal portion of uncinate	44	46.90	–2.90	0.32

scope, whereas reviewer 2 gained a 5.1% benefit (P<0.001). The slim 2.9-mm diameter endoscope showed a combined increased visualisation rates of 3.1% (P<0.001) over the traditional diameter 3.7-mm endoscope (see *Table 1*).

The 2.9-mm endoscope was superior in visualising the superior turbinate, sphenoid ostium, and sphenoethmoid recess. The superior turbinate [P=0.003, odds ratio (OR) =2.75, 95% CI: 1.29–5.88], sphenoid ostium (P=0.025, OR =1.38, 95% CI: 0.76–2.52) and sphenoethmoid recess (P=0.05, OR =2.76, 95% CI: 1.18–6.3) reached statistical significance applying a McNemar's method, with the cribriform recess (P=0.061, OR =3.16, 95% CI: 1.77–5.75) approaching significance. The 3.7-mm endoscope was superior in visualisation of only 2 anatomical sites, the accessory maxillary ostium and the horizontal portion of uncinate (neither reached statistical significance). Visualisation scores based on endoscope diameter can be seen in *Table 2*.

The 2.9-mm diameter endoscope was on average 2 discomfort ratings lower (median 3, 3.2±1.75) than the 3.7-mm endoscope (median 5, 4.8±2.13) on a scale of 1–10 (see *Table 3*). There was a significant difference between the discomfort felt with the 2.9-mm and 3.7-mm endoscopes (Wilcoxon signed rank test with continuity correction

Table 3 Patient discomfort and ease of examination based on scope size

Scope	Patient discomfort rating [0–10]		Ease of examination rating [1–5]	
	Mean ± standard deviation	Median [interquartile range]	Mean ± standard deviation	Median [interquartile range]
2.9 mm	3.2±1.75	3 [2–4]	1.9±1.07	2 [1–2]
3.7 mm	4.8±2.13	5 [3–6.25]	2.9±1.14	3 [2–4]
Difference	1.6	2	1	1

P<0.001). There was an ICC of 0.86 with a 95% CI (0.79–0.90) indicating a good correlation.

There was similarly a significant difference in clinician ease of examination with the 2.9-mm scope compared to the 3.7-mm endoscope. The 2.9-mm diameter scope was on average 1 difficulty rating lower (median 2, 1.9±1.07) than the 3.7-mm scope (median 3, 2.9±1.14) on a scale of 1–5 (Wilcoxon signed rank test with continuity correction, P<0.001). There was an ICC of 0.84 with a 95% CI (0.76–0.89) indicating a good correlation (see *Table 3*).

The patient discomfort related to ease of examination for both the 2.9-mm and 3.7-mm endoscopes were statistically significantly (linear regression P=0.05 and P<0.001 respectively). Whilst statistically significant, the amount of variation in the data for the 2.9-mm endoscope showed little or no correlation (r^2=0.03) and a weak correlation for the 3.7-mm endoscope (r^2=0.15), with the 3.7-mm scope having the more pronounced relationship.

Discussion

Flexible nasal endoscopy has become standard of care in the assessment of the nasal cavity. Development of the distal chip FNE has overcome the optical limitations of fibreoptic nasal endoscopes such that image quality from narrower endoscopes mirrors that of traditional diameter counterparts. To our knowledge, this study is the first to explore whether a narrower diameter distal chip FNE can outperform a traditional diameter distal chip FNE in its capacity to visualise the nasal cavity, to limit patient discomfort and increase the clinician's ease of use.

The effect of diameter on the ability to visualise the nasal anatomical subsites was relatively small, giving only a 3% overall improvement when using the 2.9-mm scope. As would be expected the anatomical regions where there was a statistically significant improvement in visualisation with the 2.9-mm endoscope were the anatomically restricted regions of the superior turbinate (P=0.003), sphenoid ostium (P=0.025), sphenoethmoid recess (P=0.05) and the cribriform fossa (P=0.061) which approached significance. A similar finding was described by Neel *et al.* who reported superior visualisation in the sphenoethmoid recess, superior turbinate, sphenoid ostium and olfactory cleft with a 3-mm rigid endoscope when compared to a 4-mm rigid nasal endoscope (6). Aside from routine sinonasal endoscopic assessment, there are clinical situations where visual examination of the above stated difficult to visualise regions is of clinical importance. A narrow endoscope with its improved ability to adequately visualise regions along the skull base positions it well to contribute to the diagnostic workup of anterior cranial skull base cerebrospinal fluid (CSF) leaks (9). Endoscopic visualisation of the narrow pathway leading to the olfactory mucosa can aid in the evaluation of conductive versus sensory/neural disordered olfaction (10,11). Thorough visualisation of the olfactory fossa and other difficult to visualise regions can aid in the early diagnosis of malignant sinonasal pathology. An example would be sinonasal adenocarcinoma, often the diagnosis is delayed due to having early asymptomatic growth. Screening programs have been developed for woodworkers who are at elevated risk of sinonasal adenocarcinoma. Having the capacity to directly visualise the narrow mucosal regions and aid radiological differentiation of inflammatory or tumoral opacification in these regions may mitigate unnecessary biopsies, repeat imaging or uncomfortable manipulation of the middle turbinate and septum during awake nasal endoscopy with wider endoscopes (7).

In this study, the inability to show statistical differences in visualisation in the majority of sinonasal regions assessed can be explained by grouping the regions into two distinctly different subgroups. The first group is made up of those regions that are considered anatomically capacious, allowing trouble-free access with all standard endoscope sizes. All anatomical subsites that displayed a >90% visualisation rate with either endoscope size would be included in this first group. These regions are: the middle turbinate, nasal floor, choana, vault, fossa of Rosenmuller and eustachian tube orifice. These regions had no statistically significant

differences with differing scope diameter (*Table 2*). The second group is made up of those regions that may be considered anatomically constrained. These regions are shielded by the middle turbinate or other structures which preclude ready access with the endoscope. All anatomical subsites that displayed a <10% visualisation rate with either endoscope size would be included in this second group. These regions are: the frontal recess, maxillary ostium, maxillary antrum, suprabullar and retrobullar recess. The 2.9-mm endoscope still outperformed the 3.7-mm endoscope in all the group 2 subsites aside from the frontal recess (equivalent), yet due to the small percentage of visualisations in these regions statistical significance was not achieved. In 20 of the 22 sinonasal sites reviewed the 2.9-mm endoscope outperformed the 3.7-mm endoscope. The horizontal portion of uncinate and the accessory maxillary ostium were visualised more frequently with the 3.7-mm endoscope, but neither approached statistical significance. This is thought to be related to chance as the difference in visualisation between the two endoscopes was minimal.

Analysis of the visualisation scores reported by each of the 2 reviewers identified some notable disparities. Reviewer 1 reported a 3.7% increase in visualisation rate for the 2.9-mm endoscope and 7.7% increased visualisation rate for the 3.7-mm endoscope compared to reviewer 2 (*Table 1*). Additionally, reviewer 1's scores noted fewer visualisation differences between the two different sized endoscopes, with a rate of 1.1% compared to reviewer 2's 5.1% difference (*Table 1*). An analysis was not established to further explore the inter-interpreter reliability. The differing results do highlight that each clinician's interpretation of what is defined as adequate visualisation of a sinonasal subsite is different. The trend continues to support better visualisation with the narrower endoscope with a statistically significant combined improvement in visualisation of 3.1% ($P<0.001$) for the 2.9-mm compared to the 3.7-mm endoscope (*Table 1*). The hierarchical nature of the study, the large number of replicates (sample size of 9,600 visualisation sites), may have produced overly optimistic P values. This tendency to overly optimistic P values warrants consideration when determining if this statistically significant improvement is clinically significant.

A clinician is unlikely to use more than one FNE in the examination of the sinonasal cavity. The result of this study supports the decision to use a narrower 2.9-mm diameter endoscope as the endoscope of choice when optimal visualisation is the primary objective.

Both comfort and ease of examination were outcomes reviewed in this study. The ability to achieve optimal visualisation during nasal endoscopic examination is contingent on the patient tolerating the procedure and not aborting the examination early due to discomfort, as well as the clinician's comfort in navigating the narrowest regions of the nose without inflicting pain. A considerable number of patients have a phobia of a nasal endoscopic examination with pain being a factor contributing to early termination of examination, with associated insufficient examination and limited diagnostic capacity (12). The influence of endoscope size was significant with regards to patient discomfort and the clinician ease of use with the narrower 2.9-mm endoscope outperforming the 3.7-mm endoscope in both categories. The 2.9-mm endoscope displayed a 20% improved comfort level on a 10-point VAS pain scale, with the median discomfort score of 3 for the narrower scope and 5 for the traditional diameter scope. This discomfort score was a global score and did not reflect pain at different anatomical subsites. Further stratification of pain under these conditions would be insightful but difficult to acquire as it would require real-time reporting by the patient of their perceived pain as the endoscope passed through different regions of the nose. There was no correlation between discomfort during endoscopy and clinical ease of use for the 2.9-mm scope and a weak correlation for the 3.7-mm scope, reflecting that as the clinical found cases challenging to scope with the 3.7-mm endoscope the patient respectively reported these examinations more painful.

The results of this study support the decision to use a narrower 2.9-mm diameter endoscope to reduce patient discomfort during endoscopy, which would also be anticipated to correlate with improved visualisation and patient satisfaction.

These analyses are largely exploratory and caution should be taken when interpreting results due to a small sample size. The results would need to be validated on a larger cohort. Further investigations could be improved with a larger patient cohort, a larger range of endoscope diameters and an increased number of reviewers to allow robust analysis of inter-interpreter differences (better reflecting expected differences between clinicians in the community). This study was designed to explore the routine sinonasal endoscopic examination of patients who have not undergone sinonasal surgery, further studies designed to look at visual access and patient discomfort in the surgically treated patients have been explored in the setting of rigid nasal endoscopy.

Conclusions

The previous limitations of reduced image quality with narrow diameter fiberoptic nasal endoscopes have largely been overcome with the advent of distal-chip FNEs. This study identified improved sinonasal visualisation, patient comfort and ease of endoscopy for the clinician with a narrower 2.9-mm when compared with a former standard 3.7-mm distal-chip FNE. The 2.9-mm endoscope was superior in visualisation of the superior turbinate, sphenoid ostium, and the sphenoethmoid recess compared to the 3.7-mm endoscope. There was a 20% improvement in patient reported discomfort and a 20% improvement in clinical reported ease of use with use of the narrower 2.9-mm endoscope. This study identifies advantages in the use of smaller calibre endoscopes when image quality is preserved.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://www.theajo.com/article/view/10.21037/10.21037/ajo-23-33/rc

Data Sharing Statement: Available at https://www.theajo.com/article/view/10.21037/ajo-23-33/dss

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of the Central Queensland Hospital and Health Service (EC00173) and informed consent was taken from all individual participants.

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