Nasal Cavity Perforation by Palatal Implants: False-Positive Records on the Lateral Cephalogram

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Purpose: *Lateral cephalometric films were examined for their validity as a tool for the postoperative evaluation of palatal implant placement.* ***Materials and Methods:*** *Cephalometric and histometric data of 20 partially edentulous human cadaveric maxillae were compared. Lateral cephalograms of the specimens were made, and the palatal complex was pencil traced. In addition, low-dose dental computerized tomography (CT) scans were obtained from every specimen. Based on the CT data, palatal implants (Orthosystem; Institut Straumann, Waldenburg, Switzerland) were placed. Postimplantation, another lateral cephalometric film was recorded. The specimens were prepared for histologic examination. The preoperative tracings were superimposed on the postoperative cephalometric films.* ***Results:*** *Of 20 implants placed, 12 were 4 mm long and 8 were 6 mm long. The distance between the cranial end of the implants and the nasal floor on microscopy ranged from 0.3 to 9.3 mm. Perforation of the nasal floor was absent throughout on intraoperative probing, while 2 implants projected beyond the nasal floor on histologic analysis of the specimens. An analysis of the superimposed pre- and postoperative cephalograms showed 5 implants projecting beyond the nasal floor. Histologically, only 1 of these projecting implants had actually caused perforation of the palatal complex. A comparison between the histometric and the cephalometric data showed that cephalometry, on average, imaged the palatal complex 0.8 mm below the actual anatomic site.* ***Discussion and Conclusions:*** *Twenty percent of palatal implants projecting beyond the nasal floor were false-positive records on the postoperative lateral cephalograms. Despite CT scans, 10% of the implants placed caused fenestration of the nasal cavity by histologic evidence. If the palatal complex was perforated, intraoperative probing with a periodontal probe did not confirm the perforation. Bone perforations up to 1.3 mm did not necessarily result in frank perforation of the nasal mucosa. Two-dimensional images could not be related to actual penetrations into the nasal cavity.* INT J ORAL MAXILLOFAC IMPLANTS 2005;20:267–273

Key words: *computerized tomography, histometry, lateral cephalometry, palatal implants*

Anchorage is one of the most important aspects in orthodontic treatment. It may be defined as the "resistance to unwanted tooth movement."[1] Extra- and intraoral anchorage aids (eg, headgear, Delaire masks, Nance appliances, maxillomandibular or intra-arch elastics) have been used to increase this resistance. Nevertheless, loss of anchorage is often seen with these types of anchorage aids.[2–6] Osseointegrated implants have been described as an alternative that provides maximum anchorage.[7–12] Apart from the combined orthodontic and subsequent prosthodontic use of implants,[13–15] the use of temporary implants for exclusively orthodontic purposes has become increasingly common.[16–19]

For orthodontic treatment in the maxilla, the hard palate has been reported to be a useful implant site.[20–27] However, the limited vertical bone volume and the presence of the palatal suture continue to be points of controversy. Bernhart and coworkers[26] found the paramedian region of the palate to be a useful candidate site for implants, particularly in young patients during active growth. By contrast, Wehrbein and associates[25] reported the area around

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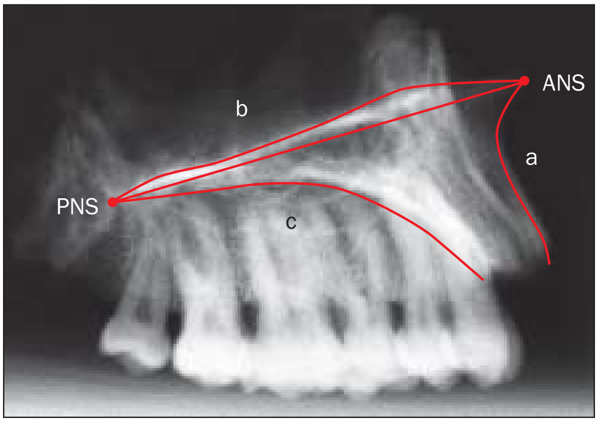


Fig 1 Preoperative lateral cephalogram of a cadaveric maxilla. ANS, PNS, the anterior aspect of the maxilla *(a)*, the floor of the nasal cavity *(b)*, and the palatal roof *(c)* were marked on translucent acetate paper.

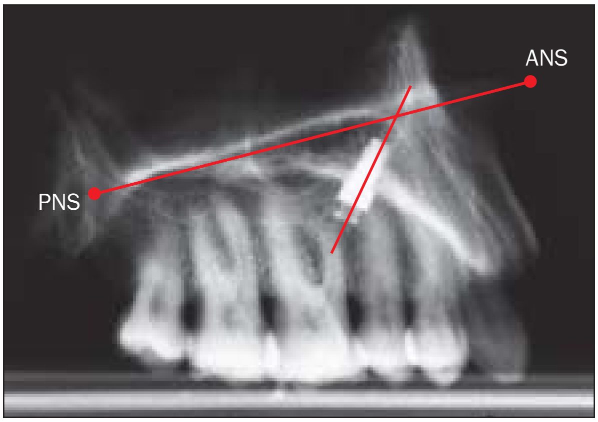


Fig 2 Postoperative lateral cephalogram of a cadaveric maxilla. The preoperative lateral tracing of the ANS/PNS line was superimposed on the palatal plane.

the ossified median palatal suture to be an ideal implant site both in adults and fully grown adolescents. As paramedian palatal implants may penetrate into the inferior nasal cavity, preoperative computerized tomographic (CT) scans are indispensable.[26] Dental CT images the bone volume available for implant placement with a high degree of accuracy.[26] The radiation exposure, which can be a limiting factor of dental CTs, has been substantially reduced without any loss of accuracy by the introduction of low-dose techniques.[28–30]

Wehrbein and coworkers[24,31] found cephalometric films adequate for evaluating the vertical bone volume available around the palatal suture. Cephalometric films have also been described as a postoperative control tool in the clinical setting.[25,31] However, radiologic imaging of palatal implants by postoperative lateral cephalograms is of limited value because intraoperative evidence by probing and clinical evidence may differ from the cephalographic record.[31]

Therefore, the aim of this study was to investigate the validity of lateral cephalometric films as a postoperative control tool after the placement of palatal implants. For this purpose cephalometric data were compared with histometric data obtained from cadavers.

MATERIALS AND METHODS

Twenty partially dentate maxillae of formalin-phenol fixed human cadavers from the Institute of Anatomy, Medical University of Vienna, were examined. The mean age of the deceased was 74.9 years (SD 9.6 years; range, 44 to 86 years). Of these cadaveric specimens, lateral cephalometric films were recorded with the Orthophos CD Multipuls System (Siemens, Bensheim, Germany) at a film–focus distance of 66.8 inches (1.67 m) and 60 kV, 0.9 mA, and 0.2 s exposure (Fig 1). The specimens were mounted with the midsagittal line perpendicular to the support. The film–focus distance and the distance between the focus and the midsagittal line were documented to account for potential magnification.

Two experienced orthodontists (subsequently called observer A and observer B) traced the palatal complex imaged on the lateral cephalograms on transparent acetate paper with a 0.35-mm pencil to assess the maximum vertical bone volume on the preoperative cephalograms. The structural method described by Björk[32] and Björk and Skieller[33] was used for tracing. On the tracings, anterior nasal spine (ANS), posterior nasal spine (PNS), the anterior aspect of the maxilla, the floor of the nasal cavity, and the palatal roof were marked (Fig 1). Repeat tracings were made by each observer after an interval of 1 month.

In addition, dental CT scans were recorded from each specimen to evaluate the maximal vertical bone volume and to identify the optimal implant site in the median palatal region. The site with the largest vertical bone volume was considered to be the best candidate site. Palatal tomography was performed with the Tomoscan SR 6000 System (Philips, Eindhoven, The Netherlands) using the usual low-dose protocol for dental CTs (slice thickness 1.5 mm; table speed 1 mm; fast scan mode, 120 kV, 25 mA, scan time 2 seconds, matrix 512 × 512; scanning plane tilted toward the hard palate). The images obtained were reconstructed with a high-resolution filter. For multiplanar reformatting of the data, a workstation and the Easy Vision R 4 software (Philips) were used.

A tangent was drawn in the midsagittal plane along the hard palate on the oral side. The implant site was defined in millimeters from the posterior bony rim of the incisive foramen.[26,34]

Based on these data, implants were placed by strictly following the manufacturer's protocol (Orthosystem, Institut Straumann, Waldenburg, Switzerland). All implants used had a diameter of 3.3 mm; their length (either 4 or 6 mm) was chosen to match the bone volume available and to prevent perforation of the nasal floor. Intraoperatively, the cranial part of the implant site was gently but carefully probed with a periodontal probe (PCP11; Hu-Friedy, Chicago, IL) to rule out nasal floor perforation.

Postimplantation, another lateral cephalogram was recorded with the preoperative settings (Fig 2). Then the implant-bearing cadaveric maxillary specimens were processed with the Exakt cutting and grinding equipment (Exakt Apparatebau, Norderstedt, Germany) described by Donath and Breuner.[35]

After prefixation in buffered formalin solution (4%, pH 7.7) the implant-bearing maxillae were cut with the Exakt Precision Saw (Exakt Apparatebau). The sections were dehydrated in ascending grades of alcohol and infiltrated and embedded in methacrylate-based resin (Technovit 7200 VLC; Heraeus Kulzer, Friedrichsdorf, Germany) cured by exposure to blue light for 24 hours.

Using a cutting and micro-grinding system with grinding disks of ascending coarseness (500, 1,200, and 4,000) 4 undecalcified thin sections were prepared per implant. The orientation of the sections was parallel to the longitudinal implant axis and perpendicular to the midsagittal plane. As the implants were placed perpendicular to the curvature of the palate and precisely in the midsagittal plane, the position of the sectioning plane was defined in all 3 dimensions (Fig 3). For histologic analysis, the specimens were stained with toluidine blue.

A light microscope (Microphot-FXA; Nikon, Tokyo, Japan) with an eyepiece micrometer that had previously been calibrated for the chosen magnification by means of a stage micrometer was used for measuring the smallest distance between the implants and the bony nasal floor along the long implant axis in graduation marks.

The slice running through the longitudinal implant axis was chosen for every measurement. Magnification was 25×. The graduation marks were converted to millimeters, with 1 graduation mark equivalent to 0.0396 mm. The preoperative tracings (2 from each observer) were placed on the postoperative lateral cephalometric films and superimposed on the ANS-PNS line. The distance between the cranial implant end and the contour of the palatal complex was measured along the projection of the longitudinal axis of the implants (Fig 3).

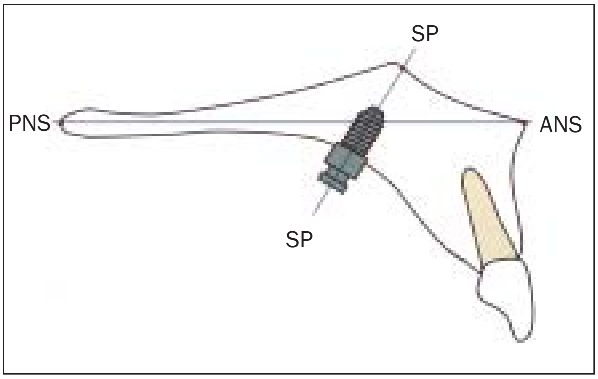


Fig 3 Schematic drawing of an implanted maxilla. Note the palatal complex. The ANS-PNS line is the palatal plane; the SP is the sectioning plane.

The data thus obtained were compared with the histometric data with due consideration of the magnification factor.

Statistical Analysis

Differences between the measured data and between the measured data and the histologic data were assessed by observers A and B. They were expressed as means, SDs, medians, and lowest and highest values. Normally distributed differences were evaluated with the paired *t* test. For all other data, the Wilcoxon nonparametric signed rank test was used. For comparing the mean measurements of observers A and B with the histometric data, which was used as the "gold standard," a Bonferroni-Hohn correction was made. All tests were 2-sided, and $P \leq .05$ was considered significant.

RESULTS

Of the 20 implants placed in the partially dentate maxillae of formalin-phenol fixed human cadavers on the basis of the preoperative CT data, 12 were 4 mm long and 8 were 6 mm long (Table 1). The shortest distance between the cranial implant end and the nasal floor (0.3 mm) was found in sample 6 (implant length 6 mm), while the largest distance of the whole series (9.3 mm) was found in sample 7 (implant length 6 mm). Gentle but meticulous intraoperative probing with a periodontal probe failed to detect any nasal floor perforations. On histologic examination following light microscopy, 2 implants were found to project beyond the nasal floor: sample 3, a 6-mm implant that projected 1 mm beyond the nasal floor, and sample 11, a 4-mm implant that pro-

Table 1 Implant Length and Distance Between Cranial Implant End and the Nasal Floor on Histomorphometric Examination

Sample	Implant length (mm)	Distance from cranial implant end to nasal floor GM	mm
1	4	25	1.0
2	6	154	6.1
3	6	−26	−1.0
4	4	12	0.5
5	6	110	4.4
6	6	8	0.3
7	6	235	9.3
8	4	45	1.8
9	4	10	0.4
10	4	21	0.8
11	4	−33	−1.3
12	4	169	6.7
13	6	142	5.6
14	4	11	0.4
15	4	95	3.7
16	4	30	1.2
17	4	180	7.1
18	4	135	5.3
19	6	20	0.8
20	6	73	2.9
Mean		70.8	2.8

GM = graduation marks.
Negative distance indicates that the implants projected beyond the nasal floor.

jected 1.3 mm beyond the nasal floor (Table 1). The mean distance between the implants and the nasal floor above them was 2.8 mm.

On analysis of the cephalometric data (Table 2) obtained by superimposing the preoperative tracings of the palatal complex on the postoperative cephalometric films of the implant-bearing maxillae, 5 implants were found to project into the nasal cavity by between −0.25 and −2.75 mm. Observer A detected 3 projections (samples 7, 8, and 11), while observer B found 5 (samples 7, 8, 10, 11, and 16). Of these, only 1 (sample 11) was confirmed histologically (Tables 1 and 2). In sample 3 (6-mm implant) the cephalometric data of both observers failed to show any projection beyond the palatal complex; however, the histologic evidence showed that the implant had been placed 1 mm above the nasal floor (Tables 1 and 2).

When accounting for the magnification factor, which was found to be 6.7%, the highest mean projection above the palatal complex was 2.75 mm (sample 11) by cephalometric evidence (Table 2) versus 1.3 mm (sample 11) by histologic evidence (Table 1). An evaluation of intraobserver agreement showed that only 4 of the 20 repeat measurements made by observer A agreed with the original data, versus 7 of 20 made by observer B. For both observers, the largest difference between original and repeat measurements was 1.5 mm (Table 2).

An evaluation of interobserver agreement showed that observer A located the cranial border of the palatal complex (floor of the nasal cavity) at a higher level than observer B (mean difference 0.42 mm, median difference 0.25 mm; $P = .0065$, Wilcoxon signed rank test). The largest interobserver difference was 3 mm.

A comparison of the histometric data (the gold standard) with the mean cephalometric data (Table 3) showed that observer A located the palatal complex on cephalometric tracings at a site lower than that indicated by the gold standard (mean difference, −1.00 ± 3.92 mm). Eight of his tracings were below the gold standard (largest difference, 9.39 mm) and 12 were above it (largest difference, 6.83 mm). For examiner B the difference was −0.61 ± 4.03 mm. Again, 8 tracings were below the gold standard (largest difference, 9.39 mm) and 12 were above it (largest difference, 6.60 mm).

DISCUSSION

Endosseous implants are stable and provide ideal bony anchorage for orthodontic treatment.[36] In the maxilla, implants placed in the midsagittal region of the hard palate have been used for orthodontic anchorage by several investigators.[21–23,25,31]

Lateral cephalograms have been used to evaluate vertical bone volume preoperatively and to check the position of the implants postoperatively.[24,31,36] CT has been reported to produce precise information on vertical bone volume preoperatively.[26] In a CT study by Bernhart and associates,[26] age did not correlate with the vertical bone volume available in the hard palate. The mean age of the cadavers examined in their study was 74.9 years. The placement of palatal implants was prompted by the reduced number of teeth in the specimens evaluated.[36]

Preoperative lateral cephalograms were used to define the palatal complex before implant placement. For this purpose the palatal complex was pencil-traced on the cephalograms by both observers to rule out any interference by the implant during tracing the palatal complex on postoperative lateral cephalometric films. The superimposition of pre- and postoperative lateral cephalometric films enabled adequate evaluation of the relationship between the cranial end of the implant and the palatal complex.

In the present study, 18 of 20 palatal implants (90% of the specimens) were successfully placed without fenestration of the bone by histologic evidence (Fig 4). The mean distance between the cranial

Table 2 Distance (in mm) Between Cranial Implant End and the Nasal Floor on Superimposition of Preoperative Tracings on Postoperative Cephalograms

	Measurements					
	Observer A			Observer B		
Sample	First	Second	Mean	First	Second	Mean
1	1.5	1.5	1.50	1.5	0.5	1.00
2	7.5	7.0	7.25	7.0	7.0	7.00
3	1.0	0.0	0.50	0.0	0.0	0.00
4	1.5	1.0	1.25	1.0	1.0	1.00
5	4.0	3.5	3.75	4.0	4.0	4.00
6	3.0	2.5	2.75	2.0	2.0	2.00
7	−1.0	−0.5	−0.75	−0.5	−1.0	−0.75
8	−0.5	−1.0	−0.75	−1.0	−0.8	−0.90
9	1.0	1.5	1.25	1.0	1.0	1.00
10	0.0	0.0	0.00	−0.5	0.0	−0.25
11	−3.5	−2.0	−2.75	−3.0	−2.5	−2.75
12	14.0	14.0	14.00	14.0	13.0	13.50
13	6.0	4.5	5.25	5.0	4.5	4.75
14	7.5	8.0	7.75	8.0	7.0	7.50
15	8.0	7.5	7.75	8.0	8.5	8.25
16	1.0	0.0	0.50	−2.0	−0.5	−1.25
17	8.5	8.5	8.50	8.5	9.0	8.75
18	4.5	5.0	4.75	1.5	2.0	1.75
19	7.5	8.0	7.75	8.0	7.0	7.50
20	7.5	7.0	7.25	7.0	7.0	7.50

Negative distance indicates that the implants projected beyond the nasal floor.

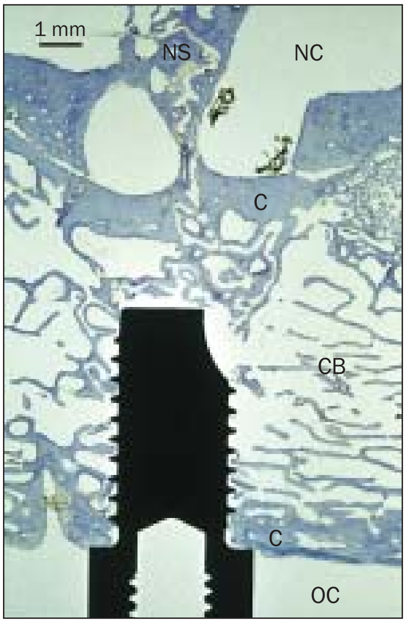
Table 3 Comparison of Each Observer's Measurement to the Histomorphometric Measurement

	Observer A	Observer B
Mean difference	−1.00	−0.61
SD	3.92	4.03
Median difference	−0.76	−0.52
Maximum difference below the gold standard	−9.39	−9.39
Maximum difference above the gold standard	6.83	6.60
t test	*P* = .23 (.46)	*P* = .47 (.47)
Signed rank test	*P* = .14 (.28)	*P* = .43 (.43)

Bonferroni-Hohn corrected *P* values are given in parentheses.

end of the implants and the palatal complex was 2.8 mm. The remaining 2 implants (samples 3 and 11) penetrated the bone despite guidance by preoperative CT data, as shown by the histologic evidence. Although intraoperative probing failed to detect any fenestration, the histologic analysis postimplantation showed the implants to project beyond the palatal complex by 1 mm and 1.3 mm, respectively. The fenestrations observed may have been the result of problems with the transfer of the CT data to the operative site. As recommended by the manufacturer's protocol, a transgingival approach was used without exposure of the incisive foramen. Intraoperatively, the foramen was only identifiable by palpation. As the posterior margin of the incisive foramen was used as a reference point for the CT data,[26] the implants may not have been placed exactly at the intended site, causing a perforation.

To compound the difficulty of implant placement, the transgingival approach provides at best a limited view of the bony palatal roof. As a result, the implant axis may have deviated from the normal line of the



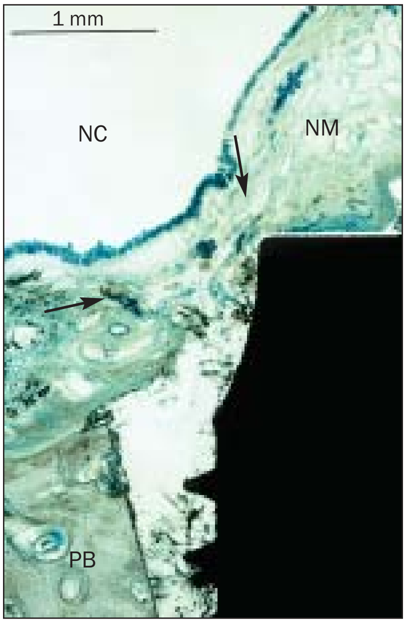


Fig 4 *(Left)* Histologic specimen showing an implant without bone fenestration (toluidine blue). NS = nasal septum, NC = nasal cavity, C = cortex, CB = cancellous bone, OC = oral cavity.

Fig 5 *(Right)* Histologic specimen showing bone fenestration *(arrows)*. NM = nasal mucosa, PB = palatal bone, NC = nasal cavity. The implant was also displaced approximately 0.5 mm from the wall of the bur hole because of insufficient bone mass at the implant site (toluidine blue).

palatal roof. Per CT protocol, the largest vertical bone volume is measured along the normal line of the palatal roof.

On the histologic sections both implants causing fenestrations projected into the nasal septum. This prevented the detection of perforations by clinical probing of the implant site. Significantly, both fenestrations were located at the periphery of the bur holes. The small diameter of the bur holes (2.8 mm) may thus have been another factor explaining why intraoperative probing was uninformative (Fig 5).

Neither of the 2 fenestrations completely pierced the nasal mucosa, and its thickness prevented an open communication with the nasal cavity in our study. Similar results were also reported by Wehrbein and associates.[31]

Unlike the histologic data, the cephalometric data varied widely. By cephalometric evidence, the palatal complex was located 0.8 mm below the histologically evaluated site on average (mean smallest difference 0.61 mm for observer B, mean largest difference 1 mm for observer A). This suggests that the safety margin of 2 mm recommended by Wehrbein and coworkers[31] would be sufficient for preoperative planning. Based on clinical and radiologic data of 12 patients and 3 wire-marked skulls, Wehrbein and coworkers showed that the highest point in the bony border of the palatal complex seen radiologically largely corresponded to the anatomic structure of the nasal floor rather than the nasal septum, which is located midsagittally. They concluded that at least 2 mm more bone was available vertically in the anterior and mid-third of the hard palate than indicated by lateral cephalometry. Intraoperative probing of the 12 patients failed to detect any perforation; 5 palatal implants projected into the nasal cavity on postoperative cephalometric films.

In the present study the superimposition of the preoperative tracings on the postoperative cephalograms also showed that 5 implants projected into the nasal cavity (3 detected by observer A and 5 by observer B). However, only 1 fenestration (sample 11; 1.3 mm) seen by both observers was confirmed histologically. The remaining 4 (ie, 20% of the implants placed) were projection-related artifacts caused by the low palatal complex inappropriately suggested by the lateral cephalometric films. This agrees well with reports in the literature.[31] It is also remarkable that the second fenestration found by histologic evidence (sample 3; 1 mm) was not seen on the lateral cephalometric film.

Both histologically verified fenestrations stayed well below the extra 2 mm in vertical bone height, albeit invisible on lateral cephalometric films.[31] Still, it is important to remember the tremendous discrepancies found between cephalometric and histometric data, with cephalometric data ranging from –9.4 to +6.8 mm.

CONCLUSIONS

The results of this cadaver investigation indicated:

1. Lateral cephalometric films did not show the true relationship between the cranial implant end and the cranial border of the palatal complex (20% false-positive records).

2. Despite CT scans, 10% of the implants placed caused fenestration of the nasal cavity when a transgingival approach was used.
3. In cases where the palatal complex was perforated, intraoperative probing with a periodontal probe did not confirm the perforation.
4. Fenestration heights of less than 1.3 mm in the region of the median palatal suture could not be detected by intraoperative probing.
5. Fenestration heights of 1.3 mm were not necessarily associated with perforation of the nasal mucosa.
6. Two-dimensional images could not be related to actual penetrations into the nasal cavity.

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