Technical note: "Look-ahead" navigation method for K-wire fixation in rhinoplasty

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Objective. The Kirschner wire (K-wire) technique for fixation of rib cartilage grafts to the maxilla is a powerful tool in rhinoplasty. It gives the nose unparalleled anterior projection. However, the technique is challenging because of poor maxillary visualization through the open rhinoplasty approach. Inaccurate K-wire placement can cause dental injury or violation of the nasal/palatal mucosa. This study evaluates the efficacy of a surgical navigation system to guide K-wire placement.
Study design. K-wires were placed, through an open rhinoplasty approach, into the maxilla of 12 fresh cadaver heads by a single surgeon. Six control specimens had K-wires placed without navigation. Six treatment specimens had K-wires placed with the "look-ahead navigation method," in which a surgical navigation device was attached to the K-wire gun. All maxillae were then sectioned to determine the final location of the K-wires.
Results. Four out of five (80%) of the K-wires were successfully placed in the treatment group, although only 3 out of 6 (50%) of the K-wires were successfully placed in the control group. One treatment K-wire was dislodged during the sectioning process and had to be excluded. The average K-wire deviation in the axial plane was less for the treatment group (0.2 ± 0.4 mm) than for the control group (1.8 ± 1.5 mm; $P < .05$).
Conclusion. When surgical navigation is used in K-wired cartilage strut graft placement to maxilla, it can improve the accuracy of K-wire placement. This may result in reduced complications due to errant K-wire placement. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:168-72)**

The K-wire cartilage graft fixation technique is a powerful tool in rhinoplasty.[1] It allows fixation of a rib cartilage graft to the maxilla, thereby providing unparalleled tip projection. It can be applied when aggressive lengthening of the columella is needed (i.e., secondary rhinoplasty, cleft lip nasal deformity, traumatic nasal deformity, and small ethnic noses). However, this method is technically challenging because of poor maxillary visualization through the open rhinoplasty approach. Inaccurate placement can result in dental injury or violation of the oral/nasal cavities.[1] The goal of the present study was to determine whether an inexperienced surgeon (i.e., a resident in training) with only 1 prior K-wire fixation rhinoplasty experience could perform K-wire fixation rhinoplasty more accurately using surgical navigation to guide K-wire placement within the maxilla.

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METHODS

Twelve fresh cadaver heads were obtained from the University of California Davis Donated Body Program. Six heads were randomly selected to undergo preprocedure computerized tomography (CT) scans, necessary for use with surgical navigation. The CT data were transfered to the Tria navigation system (Medtronic-Xomed, Jacksonville, FL). A traditional open rhinoplasty approach was performed on all 12 specimens, with an extended periosteal elevation over the nasal spine and premaxilla. A 0.035-inch threaded K-wire was positioned 3 mm off the midline (to avoid hitting the incisive foramen) and inserted into the nasal spine to simulate cartilage graft placement (Fig. 1). All K-wires were placed by a single surgeon (KK). Six K-wires were placed "blindly" (without surgical navigation) using the palate, nasal floor, and nasal septum as anatomic landmarks. A probe was inserted into the nose, and along the nasal floor to assist in K-wire placement. The K-wire was placed parallel to the probe (Fig. 2). Six K-wires were placed with the look-ahead navigation method. The surgical navigation system requires a "tracking" reference arc to be placed on the forehead of each specimen (Fig. 3) and that each specimen be registered on the navigation computer using surface landmarks (i.e., tragus, lateral canthus, glabella, etc.). Landmarks were localized with a registration

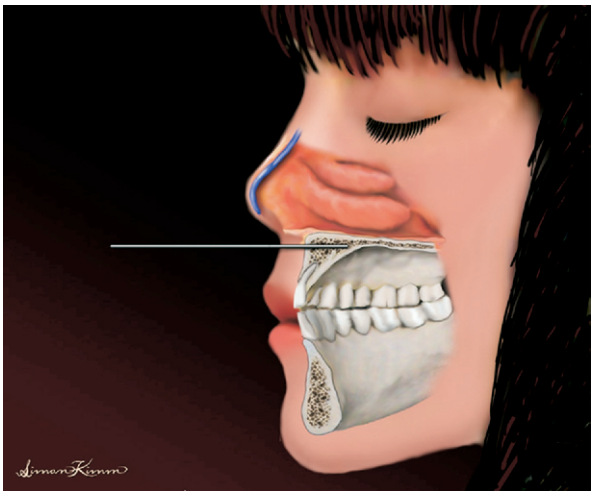

Fig. 1. Illustration of a parasagittal cut through the palate demonstrating accurate placement of a K-wire. Note that the K-wire placement avoids the dental roots and maintains a position within the thick anterior portion of the palatal bone.

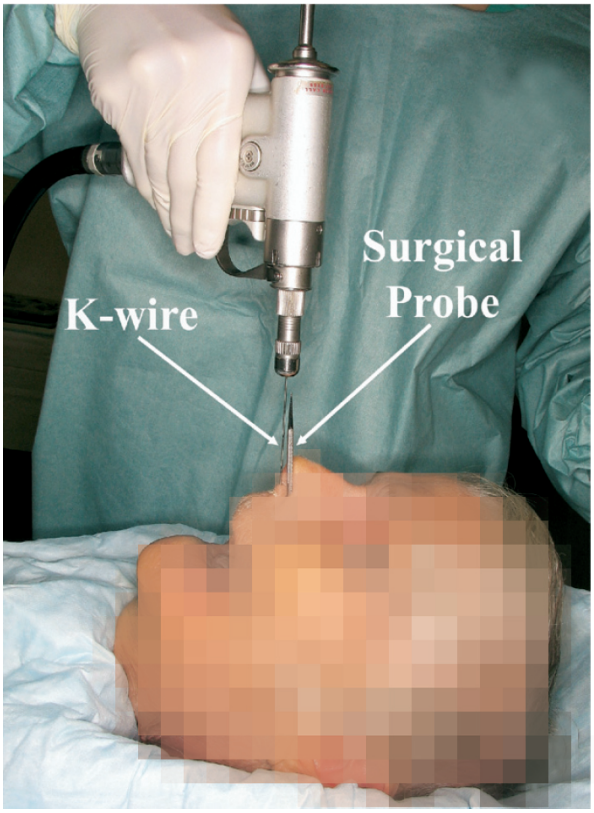

Fig. 2. Photograph of "blind" placement of a K-wire through an open rhinoplasty approach. The K-wire was aligned parallel to a probe resting along the nasal floor.

probe (Fig. 3). A reference arc was then attached to the K-wire gun (Fig. 4). The registration process took approximately 15 minutes per specimen. Once accomplished, the surgeon can view coronal, axial, and sagittal CT reconstructions of the specimen on a computer monitor (Fig. 5). The tip of the K-wire is depicted on the screen, and hash marks show the projected course of the K-wire at any predetermined distance. The look-ahead mode was set to 15 mm (i.e., each 3 hash marks representing 5 mm). After viewing the anticipated K-wire insertion path on the monitor, each of 6 K-wires were inserted.

Each premaxilla was then carefully drilled out to determine the final tip location in the sagittal and axial planes. In the sagittal plane, the results were rated as either successful (K-wire not violating nasal/palatal mucosa) or unsuccessful (K-wire violating nasal/palatal mucosa). In the axial plane, the final tip position was compared to the entry point and the difference recorded in millimeters. The K-wire penetration depth and thickness of maxillary bone at the K-wire tip were also recorded in millimeters.

Fig. 3. Photograph of registration process. The reference arc is placed on the specimen and the registration probe is used to identify anatomic landmarks.

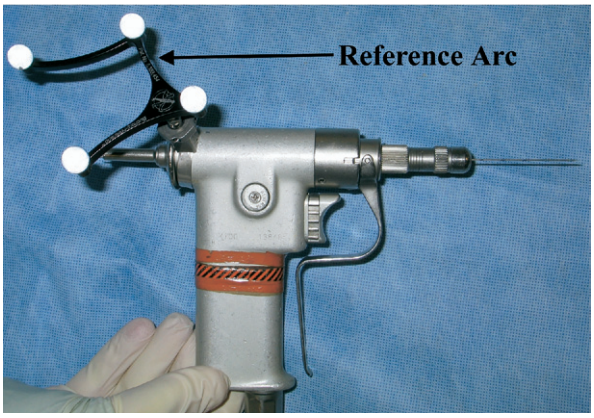

Fig. 4. The K-wire gun with reference arc attached.

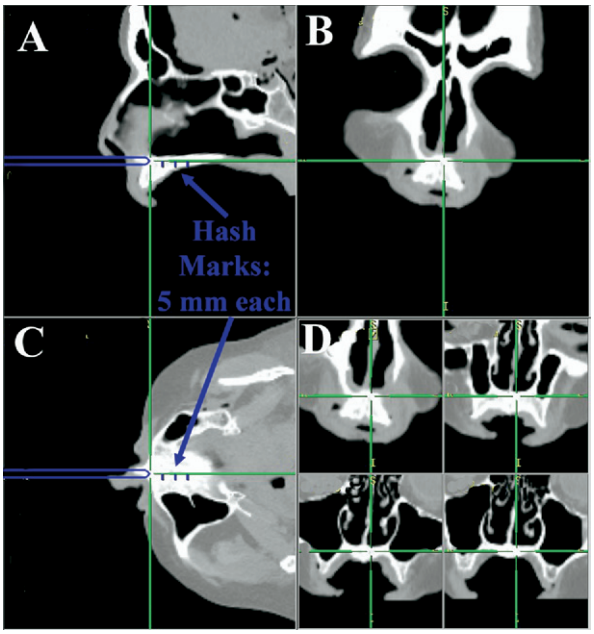

Fig. 5. "Look-ahead" navigation view seen by the surgeon. **A**, sagittal view, note the 5-mm hash marks that identify the projected course of the K-wire; **B**, coronal view; **C**, axial view; **D**, sequential coronal views (one for each hash mark seen in the axial and sagittal views).

RESULTS

Control group ("Blind" Placement) (Tables 1 and 2)

Three of 6 K-wires were successfully placed. One of these 3 K-wires violated the maxillary bone but not the mucosa, so it was still rated as successful. The tip of 3 K-wires violated the mucosa (2 oral, 1 nasal) and were recorded as unsuccessful. The average K-wire tip deviation in the axial plane was 1.8 ± 1.5 mm. The average depth of penetration was 11.7 ± 6.1 mm. The average maxillary bone thickness at the final tip location was 5.6 ± 3.0 mm.

Treatment group (Tables 1 and 2)

Four of 5 K-wires were successfully placed. One K-wire was dislodged during the sectioning process and was excluded. The tip of 1 K-wire violated the nasal cavity and was recorded as unsuccessful. The average K-wire tip deviation in the axial plane was 0.2 ± 0.4 mm. The average depth of penetration was 7.6 ± 1.9 mm. The average maxillary bone thickness at the final tip location was 7.4 ± 1.8 mm.

The overall success rates were 50% for the control group (standard error 20.4%), and 80% for the treatment group (standard error 17.9%).

DISCUSSION

Increasing and maintaining nasal tip projection is a challenging goal in rhinoplasty. Many techniques have been described, including columellar struts, onlay grafts, and lower lateral cartilage fixation sutures.[2-4] Unfortunately, these techniques may not be adequate in certain circumstances, such as cleft nasal deformity, secondary rhinoplasty, and traumatic nasal deformities. In these cases, Gunter et al. described the use of a rib cartilage graft, fixated with a K-wire "tent pole" strut, to maintain tip projection (Fig. 6).[1] The use of a K-wire serves 2 purposes: to decrease the chance of cartilage warping and to fixate the graft to the maxilla. Carving costal cartilage requires that a portion of the perichondrium be removed and that the 3-dimensional configuration is altered. This usually results in warping of the graft. Symmetric carving will reduce the risk, but warping can still occur as late as 8-10 days postoperatively.[1,5] The K-wire is also used to rigidly fixate the columellar graft on the maxillary crest/nasal spine. This "tent pole" configuration can be critical to avoid contracture of the soft tissue envelop and maintain postoperative projection. Gunter et al.'s technique involved a hole drilled in the maxilla before insertion of the "K-wire/cartilage graft" construct. The current technique is similar, but the K-wire/cartilage graft construct is drilled directly into the maxilla as a single unit. No predrilling is involved. We feel that single-unit technique approximates the graft directly onto the maxilla more firmly, and provides greater stability with less bone penetration.

Although the K-wire fixation technique is extremely stable, insertion of the K-wire is challenging. Visualization of the nasal spine and premaxilla is limited by the open rhinoplasty incision. Errant placement of the K-wire can result in dental injury or violation of the nasal/oral mucosa (Fig. 7). Inadequate penetration of the K-wire (in an effort to avoid injury) may lead to instability of the K-wire/cartilage graft construct and subsequent soft tissue contracture. Gunter et al. published a series of 19 K-wire fixation rhinoplasties, and reported 1 dental injury necessitating a root canal.[1] This complication highlights the need for accurate K-wire placement, and the potential for complications even in the hands of an accomplished rhinoplasty surgeon.

Over the last 10 years, computer-aided surgical navigation systems have been developed to increase surgical accuracy. The current systems are accurate to within approximately 1-2 mm. Unfortunately, navigation has been limited primarily to use in functional endoscopic sinus surgery and neurosurgery. However, newer applications are slowly emerging. The present study evaluated the use of a Medtronic-Xomed surgical navigation system in the "look-ahead" navigation mode to

Table I. Results for control and treatment groups

Group	*Sample*	*K-wire length, mm*	*Maxillary bone thickness, mm*	*Left-right deviation in maxilla, mm*	*Result*
Control group ("blind" placement)	1	18	3	4	Unsuccessful
	2	16	8	1	Successful
	3	5	9	−1	Successful
	4	17	2	0	Unsuccessful
	5	9	4	3	Unsuccessful
	6	5	8	−2	Successful
Test group (navigation)	7	7	8	0	Successful
	8	7	5	0	Successful
	9*	NA*	NA*	NA*	NA*
	10	5	10	−1	Successful
	11	10	7	0	Unsuccessful
	12	9	7	0	Successful

*The K-wire was dislodged during the sectioning process. Therefore, the specimen was excluded.

Table II. Comparison of K-wire position in control and treatment groups

	Control group		*Treatment group*		
	Average	*SD*	*Average*	*SD*	*Confidence level, P*
Number of samples	6		5		
Length, mm	11.7	6.1	7.6	1.9	>.05
Thickness, mm	5.6	3.0	7.4	1.8	>.05
Left-right deviation, mm	1.8	1.5	0.2	0.4	<.05

Fig. 6. Illustration of the K-wire rhinoplasty technique. A K-wire is inserted through the cartilage graft (*red*) and into the palatal bone for stability.

increase accuracy of K-wire placement during rhinoplasty.

The results of the study indicated that the look-ahead navigation method is more accurate than the "blind" technique for K-wire placement. Looking at K-wire placement in the axial plane (i.e., lateral deviation within the palatal bone), the average deviation for the control group was 1.8 ± 1.5 mm. The average deviation for the treatment group was 0.2 ± 0.4 mm. Although the total numbers are small, there was a statistically significant difference ($P < .05$). This implies that the surgeon is less likely to stray off course when using navigation as opposed to a blind technique.

Four of 5 K-wires (80%) remained within the maxillary bone in the treatment group, whereas only 3 of 6 K-wires (50%) remained within the maxillary bone in the control group (1 of the successful control K-wires actually passed through the maxillary bone but did not violate the oral mucosa—while this was rated as successful in the study, it was very close to violating the mucosa, and the clinical implication for such placement is unclear). Factors that influence successful K-wire placement in the midsagittal plane include the depth of K-wire penetration (i.e., less penetration would result in reduced likelihood of mucosal violation) and the bone thickness at the tip of the K-wire (i.e., it should be easier to maintain the K-wire within thicker bone). The average depth of K-wire penetration for the control group was 11.7 ± 6.1 mm and for the treatment group 7.6 ± 1.9 mm (Table 2). The average palatal bone thickness at deepest K-wire penetration for the control group was 5.6 ± 3.0 mm and for the treatment group 7.4 ± 1.8 mm (Table 2). Analysis of this data reveals no significant difference in the depth of penetration or

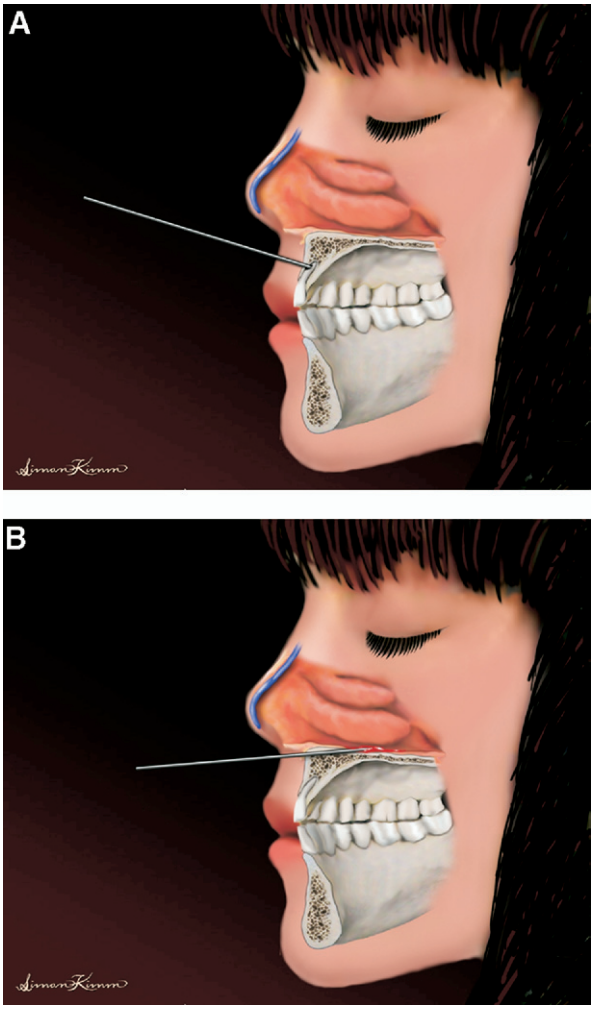

Fig. 7. Illustrations of errant K-wire placement. **A**, dental injury; **B**, violation of the nasal mucosa.

the thickness of the palatal bone for either group ($P > .05$). However, further analysis of the data reveals that the 3 K-wires that violated mucosa in the control group had the thinnest palatal bone (2, 3, and 4 mm), and that 2 of the 3 had the greatest depth of penetration (17 and 18 mm). The single K-wire that violated mucosa in the treatment group had the deepest penetration (10 mm) and the second thinnest bone (7 mm). This is consistent with the intuitive assumption that the thinner the bone and the deeper the penetration, the more likely that the K-wire will violate the mucosa.

Therefore, it is not only important to know that the K-wire is being placed in a true parasagittal plane just off the midline, but also that the K-wire penetration is stopped before the palatal bone becomes too thin. The surgical navigation system in the look-ahead mode allows the surgeon to more accurately accomplish this task. It improves the chances that the K-wire will enter the thickest area of the premaxilla. It also assists in alignment of the K-wire in a true parasagittal plane. Finally, it helps the surgeon stop insertion of the K-wire before significant thinning of the palatal bone.

Most surgical navigation systems allow for attachment of a reference arc to varied types of instrumentation. The reference arcs are relatively small and easily attached in an unobtrusive location (Fig. 5). We found no difference in the ease of K-wire placement with or without the reference arc in place. However, it is important that the surgeon use the surgical navigation system to confirm the ideal entry position and angle of attack just before firing the K-wire. Any delay in placing the K-wire offers greater opportunity for undetected motion of the K-wire gun, bending of the K-wire, and an increased probability that the final placement will be errant.

Navigation also adds cost and time to the surgery. The average cost of a facial CT is $350 (without radiologist reading), and the average setup time for an experienced surgeon is 15 minutes. However, this increased cost may be justified by improved accuracy and reduced complication rates.

CONCLUSION

Increasing nasal tip projection can be extremely challenging in secondary rhinoplasty. The K-wire cartilage fixation technique is a powerful tool that can be used in challenging cases. There is a known risk of errant K-wire placement with mucosal violation or dental injury. The look-ahead navigation method offers improved accuracy for K-wire placement compared with the traditional "blind" technique.

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