Preventing Damage to Arthroscopic Lens During Surgery

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Purpose: To evaluate the relation between the relative diameter of instrument tips and the distance between the arthroscopic lens and the tips of the instruments in terms of preventing lens damage during arthroscopy. **Methods:** By use of a custom-designed station device with 2 perpendicular portals, images of multiple-sized shaver tips (2.5, 3.5, 4.0, 5.0, and 5.5 mm) were obtained from 4 different arthroscopes (4 mm 30°, 4 mm 70°, 2.7 mm 30°, and 2.7 mm 70°) at varying distances of 0 to 10 mm at 1-mm increments. The relative diameter of the visualized instrument tips and the distance between the arthroscopic lens and the tips of the instruments were evaluated. **Results:** The relative diameter of the shaver tips measured by 2 investigators showed excellent intraobserver and interobserver reliability. By use of 2 mm as the safe distance from the arthroscopic lens to the tip of the shaver, 13 of 14 arthroscopic lens–shaver combinations were considered safe when the visualized shaver tip was smaller than one-half of the arthroscopic visual field. Six of 14 combinations were considered unsafe when the visualized shaver tip was larger than three-fourths of the visual field. **Conclusions:** In this experimental study, the safe distance of 2 mm could be maintained when arthroscopic instruments used during surgery (e.g., shavers and burrs) were observed to be less than one-half of the arthroscopic visual field. The relative diameter of the visualized instrument tip was a reliable guide to prevent arthroscopic lens damage. **Clinical Relevance:** To avoid damaging the arthroscope lens during surgery, arthroscopists can maintain a safe distance by keeping the relative diameter of the instrument tip (e.g., arthroscopic burr) to less than one-half of the arthroscopic visual field.

Arthroscopy is one of the most common procedures performed by orthopaedic surgeons. Data from the case lists submitted for the part II certification examination of the American Board of Orthopaedic Surgery during 1999-2003 have shown knee arthroscopy to be the most common procedure.[1] In addition, ankle arthroscopy is the most common procedure reported in foot and ankle subspecialty part II and the foot and ankle recertification examination. Arthroscopic procedures account for approximately 40% of the top 25 procedures performed by the candidates, with an increasing trend. In parallel with advancements in arthroscopic techniques and instruments, arthroscopy has been applied to smaller joints with more restricted space (e.g., wrist, elbow, ankle, subtalar, and metatarsophalangeal joints). In particular, arthroscopy has been used to assist joint preparation for arthrodesis of the ankle and subtalar joints with the benefits of causing less pain, swelling, and postoperative scarring, as well as allowing outpatient surgeries to be more feasible and in some cases reducing time to fusion.[2-4] Various degrees of damage to the arthroscopic instruments seem inevitable for both novices and those orthopaedic surgeons performing arthroscopic surgeries regularly. Although several authors have reported instrument breakage as a complication associated with arthroscopic procedures, the true incidence and the consequences of instrument damage have not been completely reported.[5-8]

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We have found that damage to the arthroscopic lens from shavers and burrs is common, especially in arthroscopic assisted arthrodesis of small joints. A scratch on the lens may impair visualization, leading to surgical complications or surgical delay while instrumentation is cleaned or replaced during a procedure. More damage to the lens may cause broken pieces to come loose within the joint, requiring a complicated removal. Replacement of the damaged parts results in increased surgical time, not to mention the high cost of the lens. Because of distortion and magnification effects, the absolute size of the visualized instrument tip may not give surgeons the correct visual feedback about the real distance between the arthroscope lens and the tip of the shaver or burr.

The purpose of this study was to evaluate the relation between the relative diameter of the instrument tips and the distance between the arthroscope lens and the tips of the instruments. It was hypothesized that there was a safe working distance of 2 mm when the instrument covered less than three-fourths of the visual field.

METHODS

A custom-designed station device was constructed with 2 connected external ring frames and a cylindrical shape container filled with normal saline solution (Fig 1). Two plastic arthroscopic cannulas were mounted perpendicularly (90°/90° orientation) on the external ring frame. Four commonly used types of arthroscopes were used as visualization tools; 4-mm 30°, 4-mm 70°, 2.7-mm 30°, and 2.7-mm 70° arthroscopes (Smith & Nephew Dyonics, Andover, MA). The 4-mm arthroscope was sequentially paired with 3.5-, 4-, 5-, and 5.5-mm shavers (Smith & Nephew Dyonics). The 2.7-mm arthroscope was sequentially paired with 2.5-, 3.5-, and 4-mm shavers (Fig 2A).

The images were sequentially captured with increasing distances between the arthroscope lens and tip of the shaver (L-T distance). The L-T distances were progressively increased from touching at 0 to 10 mm at 1-mm increments measured by a Vernier caliper with 0.01-mm precision (Fig 2B). The same study protocols were applied for each pair of instruments. Without digital zoom, each captured image was analyzed for the ratio between the maximum diameter of the visualized shaver tip and the diameter of the entire arthroscopic visual field (T/F ratio) (Fig 2C). The relation between T/F ratio and L-T distance was evaluated. The measurements were performed by 2 experienced arthroscopists twice at 2 weeks apart using ImageJ software (National Institutes of Health, Bethesda, MD).[9]

The interobserver and intraobserver agreement was assessed by use of intraclass correlation coefficients. The mean results from both observers, as well as interobserver and intraobserver reliability, were assessed. A score above 0.80 indicates excellent agreement. A score ranging from 0.61 to 0.80 indicates good agreement. A score of 0.41 to 0.60 indicates moderate agreement whereas 0.21 to 0.40 indicates fair agreement. A score of 0.20 or below indicates poor agreement.

RESULTS

The intraclass correlation coefficient indicated excellent measurement agreement for both interobserver reliability (0.99) and intraobserver reliability (0.99).

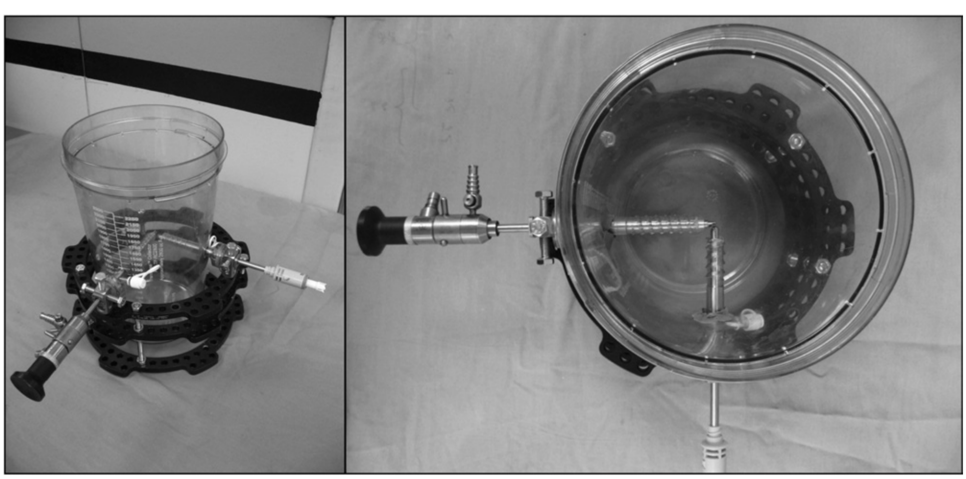

FIGURE 1. Arthroscope and shaver sleeves were mounted perpendicular (90°/90° orientation) with a custom device.

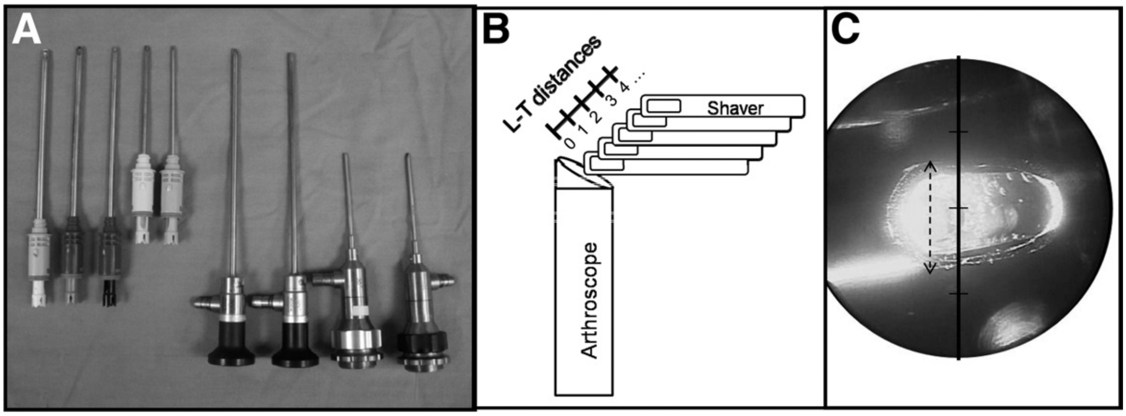

FIGURE 2. (A) Arthroscopes and shavers. (B) Drawing of arthroscopic setting. The arthroscope lens was fixed in place while the L-T distances were progressively increased from touching at 0 to 10 mm at 1-mm increments. (C) Arthroscopic view showing shaver tip distance (double-dash arrow) and visual field distance (vertical black line).

Overall, when the safe distance was set at 2 mm of the L-T distance, the T/F ratios averaged 0.71, ranging from 0.47 to 0.98. The T/F ratios for all arthroscopic lens–shaver combinations are shown in Table 1 and Fig 3.

The T/F ratio approached 1.00 at or before the point of touching between the instrument tips and the arthroscopic lens (0-mm L-T distance) in all combinations except the 3.5-mm shaver/4-mm 30° arthroscope (T/F ratio, 0.94) (Fig 3A) and the 2.5-mm shaver/2.7-mm 70° arthroscope (T/F ratio, 0.91) (Fig 3D).

At a T/F ratio of 0.5, by use of 2 mm as the safe distance from the arthroscopic lens to the tip of the shaver, 13 of 14 arthroscopic lens–shaver combinations were considered safe when the visualized shaver tip was smaller than one-half of the arthroscopic visual field (Table 1). Six of fourteen combinations were considered unsafe when the visualized shaver tip was larger than three-fourths of the visual field.

According to Fig 3, all the curves had a less negative gradient as the L-T distances were increasing, indicating more responsiveness of the T/F ratio at decreased L-T distance. Plateau effects of the T/F ratio were observed with all 5.5- and 5-mm shavers. They were also shown with the 4-mm shaver in either the 2.7- or 4-mm 70° arthroscope, whereas none was observed with the 2.5- and 3.5-mm shavers. This phenomenon corresponded to when the visual field was totally obscured by the shavers at a very close range.

TABLE 1. *T/F Ratios With Safe Distance of 2 mm Between Lens and Shaver*

	2.7-mm Arthroscope		4-mm Arthroscope	
	30°	70°	30°	70°
2.5-mm shaver	0.64*	0.66*	—	—
3.5-mm shaver	0.66*	0.76	0.52*	0.47*†
4.0-mm shaver	0.76	0.76	0.52*	0.72
5.0-mm shaver	—	—	0.77	0.79
5.5-mm shaver	—	—	0.98	0.97

*A shaver that was considered unsafe when the visualized instrument tip was greater than three-fourths of the arthroscopic field.
†A shaver that was considered unsafe when the visualized instrument tip was greater than one-half of the arthroscopic field.

DISCUSSION

The purpose of this study was to develop a practical way to avoid lens damage when performing visualization by use of power instruments during arthroscopic surgery. Using the relation between the relative diameter of the instrument tips and the distance between the arthroscopic lens and the tips of the instruments, we found that most of the instrument tips touched the arthroscopic lens when the visualized instrument tip covered all of the arthroscopic visual field with a few exceptions. Relatively large instruments covered the entire visual field, even though they were 1 or 2 mm from touching the lens (Figs 3A-C). In this scenario the lens may not be damaged even when the entire visual field is covered. For small shaver tips (e.g., 2.5 mm) used with the 2.7-mm 70° arthroscope, the maximum relative diameter of the shaver tip was too small to cover the visual field at touching (Fig 3D).

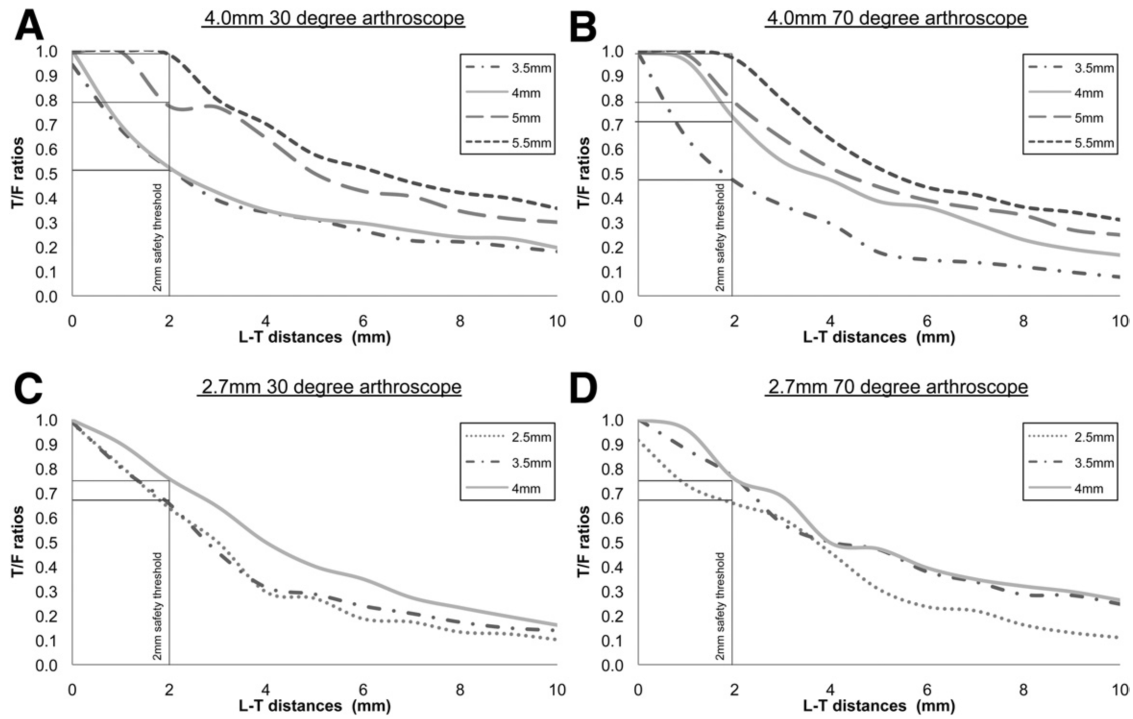

FIGURE 3. (A-D) Correlations between ratios of diameter of visualized instrument tip and diameter of entire arthroscopic visual field (T/F ratio) and distance between arthroscopic lens and tip of shaver (L-T distance) for each arthroscope lens and shaver. The T/F ratio with a 2-mm L-T distance (i.e., safety threshold between arthroscope lens and tip of shaver) is shown for each shaver tip size.

A safe distance between the arthroscopic instruments and the lens varies based on surgeon's arthroscopic skill, nature of the procedure, condition of the joint involved, type of instruments, and size of the instruments. In this study the 2-mm L-T distance was used to determine the minimum safety distance threshold. On the basis of this study, a general rule can be applied across all conditions, that it is safe with a 2-mm buffer zone to see a shaver tip smaller than one-half of the arthroscopic visual field. Plateau effect of the large shavers (5.5, 5, and 4 mm) was a benefit because surgeons will see the instrument tip blocking the entire visual field before instrument touching. This safety factor may help decrease the theoretically higher chance of damage from the more aggressive nature of the maneuvers with larger instruments. This benefit is absent with the small shavers (2.5 and 3.5 mm), which allow instrument touching to occur before the entire visual field is covered, and therefore the general rule should be applied in this situation to avoid damage.

Detrimental consequences of the damaged arthroscopic lens include both decreased patient safety and increased global health care costs.[10] This study provides a practical visual feedback measurement regarding the closeness of the instruments to the end of the arthroscope during surgery. This information may be particularly useful in orthopaedic residency training programs, where trainees are developing their arthroscopic skills. The safe working distance can be adjusted according to other characteristics of the surgery as well as the surgeon's experience.

We recognize the limitations of this study. First, an in vitro study may not entirely represent the true intraoperative environment in patients. However, we elected to use normal saline solution as the medium because it is a commonly used irrigation fluid. Second, the arthroscopes and the shavers were at fixed perpendicular orientation, which may not replicate true surgical procedures. We believe that different instrument orientations should not substantially distort the measurements because most shavers or abraders have a tip with a hemispherical-shaped end.

CONCLUSIONS

In this experimental study, the safe distance of 2 mm can be maintained when arthroscopic instruments used during surgery (e.g., shavers and burrs) were seen to be less than one-half of the arthroscopic visual field. The relative diameter of the visualized instrument tip was a reliable guide to prevent arthroscopic lens damage.

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