In Vitro Comparison of the Mechanical and Optical Characteristics of the Storz Flex-X^{C1} Single-use Ureteroscope and the Storz Flex-X^{C} Reusable Flexible Ureteroscope

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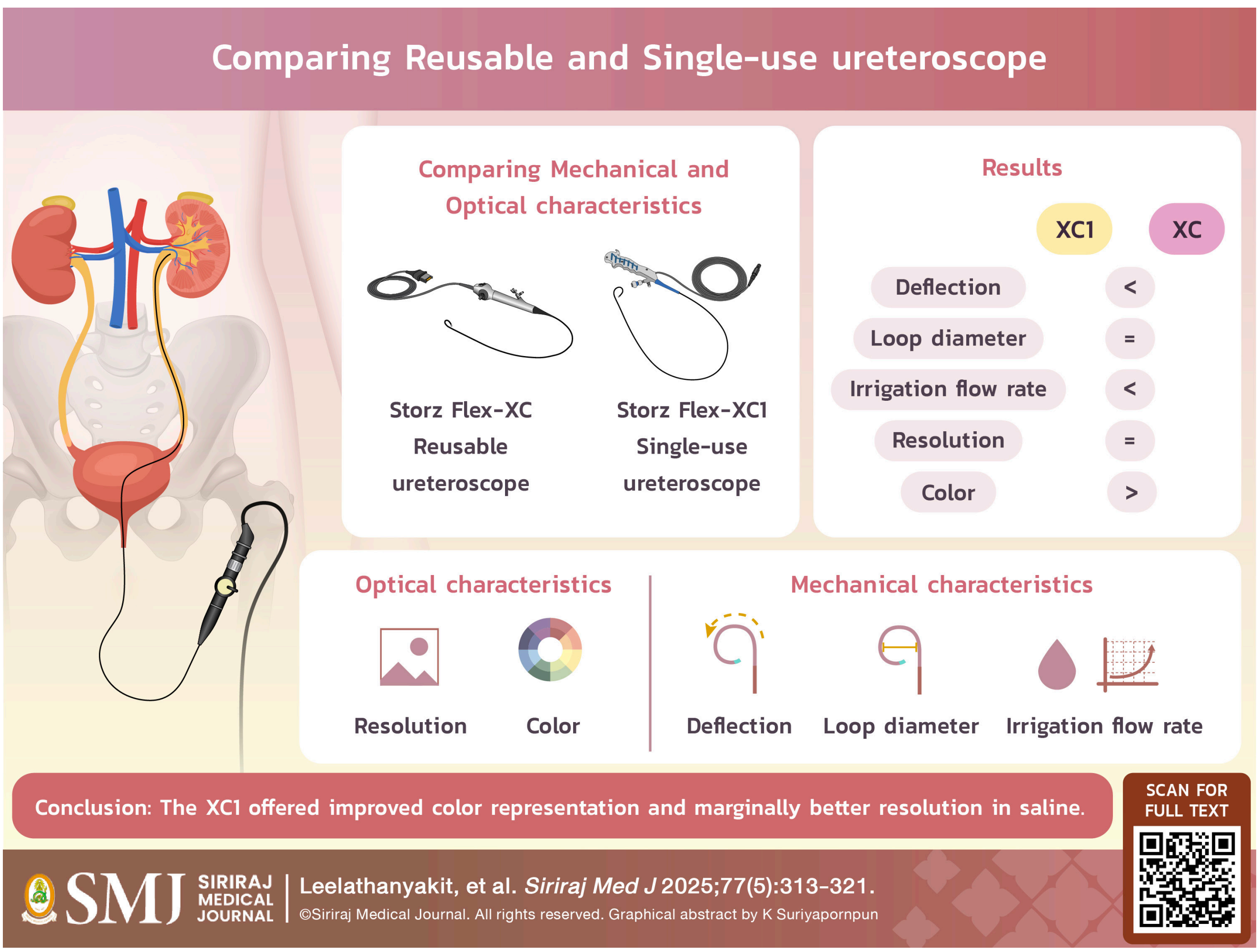

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ABSTRACT

Objective: This study compared the mechanical and optical characteristics of the Storz Flex-X^{C1} single-use ureteroscope and the Storz Flex-X^{C} reusable flexible ureteroscope. The mechanical parameters comprised the upward/downward deflection, loop diameter, and irrigation flow rate. The optical parameters were image resolution and color representation.

Materials and Methods: We conducted an in vitro evaluation of two Karl Storz flexible ureteroscopes. Specifically, we examined the Storz Flex-X^{C1} single-use and Storz Flex-X^{C} reusable scopes for upward/downward deflection angles, loop diameter, irrigation flow rates, image resolution, and color representation. The Storz Professional Image Enhancement System was also applied.

Results: The Storz Flex-X^{C} reusable ureteroscope achieved greater upward/downward deflection angles than did the Storz Flex-X^{C1} single-use ureteroscope when a 200 µm laser or a 1.9 Fr tipless basket was used, with mean differences of 1.9°–2.2° and 2.3°–5.6°, respectively. No clinically significant difference in loop diameter was found. The Storz Flex reusable scope achieved a higher irrigation flow rate with an empty working channel (mean difference of 2.25 ml/min). Both scopes demonstrated identical image resolutions in air and in a normal saline solution, but the Storz Flex single-use device showed superior color representation.

Conclusion: The Storz Flex-X^{C} reusable flexible ureteroscope displayed slight advantages in terms of the deflection angle and irrigation flow rate. The Storz Flex-X^{C1} single-use flexible ureteroscope offered improved color representation and marginally better resolution in saline.

Keywords: Flexible ureteroscopes; reusable; deflection angle; resolution; single use (Siriraj Med J 2025; 77: 313-321)

INTRODUCTION

Nephrolithiasis has a lifetime incidence ranging from 1% to 13% in the general population and between 1% and 5% among Asian individuals.[1,2] In Thailand, the northeastern region exhibits the highest incidence of nephrolithiasis compared to other regions in the country.[3] The renal pelvis is the most common stone location within the urinary tract.[4] Advances in ureteroscope and laser lithotripter technologies have increased the preference for endourology over percutaneous nephrolithotomy and extracorporeal shock wave lithotripsy in treating nephrolithiasis. According to the 2023 European Association of Urology guidelines, endourology is recommended for managing both ureteral and renal calculi across all anatomical locations.

Ureteroscopy, which was introduced in 1912, uses a 9.5 Fr pediatric cystoscope as a flexible instrument. The first fiber-optic flexible ureteroscope without a working channel was developed by Marshall in 1964.[5] In 1979, ureteroscopes equipped with working channels enabled intraureteral lithotripsy via electrohydraulic and ultrasonic lithotripters. However, their application was initially limited to the lower ureter. Therapeutic flexible ureteroscopy, which allows access to the renal pelvis and all calyces, was invented in 1987 and began clinical use in 2008.[6]

A wide range of flexible ureteroscopes are available from many manufacturers. Karl Storz is a leading provider of reusable flexible ureteroscopes. However, single-use ureteroscopes have gained increasing popularity in endourology.[7,8] Although single-use flexible ureteroscopes cost more than reusable models do, they reduce reprocessing and maintenance expenses and minimize the risk of contamination with urinary tract pathogens.[9,10] Moreover, single-use devices may be preferable for managing multiple large stones in the lower renal pole of recurrent stone formers or in patients with a steep infundibulopelvic angle (≤ 50°), since these conditions increase the risk of ureteroscope damage.[11] Compared with reusable ureteroscopes, LithoVue (Boston Scientific) is an early single-use flexible ureteroscope that provides complete visualization, correct identification of calyces, effective stone retrieval, and improved image quality.[12] Karl Storz recently introduced Flex-X^{C1}, a single-use flexible ureteroscope intended to mimic the performance of the established Storz Flex-X^{C} reusable model.

This study aimed to compare the mechanical and optical characteristics of the Storz Flex-X^{C1} single-use ureteroscope and the Storz Flex-X^{C} reusable flexible ureteroscope.

MATERIALS AND METHODS

We conducted an in vitro study at Siriraj Hospital using two Karl Storz flexible ureteroscopes: the Storz Flex-X^{C1} single-use ureteroscope and the Storz Flex-X^{C} reusable ureteroscope. We examined their mechanical and optical characteristics.

The mechanical assessments examined the following items: the upward/downward deflection angles, the loop diameter of the upward/downward deflection, the angle of view, and the irrigation flow rate under three working-channel conditions. The optical evaluations were assessments of image resolution and color representation.

We also applied the Storz Professional Image Enhancement System. This system comprises five software modes that enhance imaging and visualization. "Clara" provides homogeneous illumination at all depths of view. "Chroma" intensifies image contrast; Clara and Chroma can be combined. "Spectra A" filters out red tones, whereas "Spectra B" enhances green and blue light. These filters help endoscopists identify tumor stalks and vessels more easily.

Mechanical characteristics

We evaluated the upward/downward deflection angles under three working-channel conditions: an empty channel, a channel containing a 200 µm laser fiber (TFL-FBX200s), and a channel containing a 1.9 Fr tipless nitinol basket (Boston Scientific Zero Tip). Each ureteroscope was tested 36 times to measure upward/downward deflection angles and loop diameters. Between each test, we allowed the scope to rest for 1 minute while it returned to its neutral position. The loop diameter was defined as the maximum horizontal diameter attained at full deflection.

We then measured the irrigation flow rate via a pressure-regulated irrigation system (Uromat E.A.S.I., Karl Storz, Tuttlingen, Germany) under the same three conditions: an empty channel, a channel with a 200 µm laser fiber, and a channel with a 1.9 Fr tipless nitinol basket. The inflow pressure was 200 mmHg, and the maximum flow rate was 250 ml/min. The total volume of fluid exiting the ureteroscope tip in 1 minute was recorded in milliliters.

Optical characteristics

We assessed resolution using a 1951 U.S. Air Force Test Pattern Card (Edmund Optics, Barrington, NJ, USA) under two conditions: in air and in normal saline solution. The resolution measurements were obtained at distances of 0.5 cm, 1 cm, 2 cm, and 3 cm. The resolution, reported in line pairs per millimeter, was calculated with the following formula:

$$\text{Resolution} = 2^{\text{Group} + (\text{element} - 1)/6}$$

We evaluated color representation via a Gretag Macbeth color checker target (Edmund Optics). Fourteen reviewers (12 urological residents and 2 fellows) graded color quality in a blinded manner. Each reviewer assigned a score from 0 to 2, where "0" indicated no similarity to the reference colors, "1" indicated slight similarity, and "2" indicated strong similarity.

Statistics

The correlation of mechanical characteristics between the two scopes was determined using the Pearson test, and the correlation of optical characteristics was determined using Wilcoxon's signed-rank test. All statistical analyses were performed using IBM SPSS Statistics 25.0. There were 36 observations by one observer for the mechanical comparisons and 14 observers for the optical comparisons.

RESULTS

Mechanical characteristics

The mechanical comparisons between the Storz Flex-X^{C1} single-use ureteroscope and the Storz Flex-X^{C} reusable flexible ureteroscopes assessed through the loop diameter, upward/downward deflection angle, and irrigation flow rate indicated weak to very weak correlations. These findings suggest that the two ureteroscope models differ in their mechanical characteristics as shown in Table 1.

When the working channels were empty, the ureteroscopes presented comparable upward/downward deflection angles. However, the Storz Flex-X^{C} reusable ureteroscope demonstrated significantly greater deflection angles when the working channel contained a laser fiber or a 1.9 Fr tipless nitinol basket (Table 2).

With respect to loop diameter, the Storz Flex-X^{C} reusable ureteroscope performed better under all three conditions (empty, laser, and basket), with mean differences of 0.06–0.27 mm. (Table 3).

For the irrigation flow rate, the Storz Flex-X^{C} reusable ureteroscope achieved higher flow with an empty working channel. Both ureteroscopes experienced reduced irrigation flow when the working channel was occupied (Table 4).

Optical characteristics

The resolution measurements were identical between the Storz Flex-X^{C1} single-use ureteroscope and the Storz Flex-X^{C} reusable flexible ureteroscope at distances of 0.5 cm, 1 cm, 2 cm, 3 cm, and 5 cm (Tables 5 and Fig 3).

With respect to color representation, the Storz Flex-X^{C1} single-use ureteroscope performed better in both air and normal saline. The difference was statistically significant in the normal saline group ($P = 0.002$; Tables 6 and Fig 2).

TABLE 1. Specifications of Storz Flex-X[C1] single-use and Storz Flex-X[C] reusable flexible ureteroscopes.

Specification	Storz Flex-X[C1] single use flexible ureteroscope	Storz Flex-X[C] reusable flexible ureteroscope
Direction of view	0°	0°
Angle of view	105°	105°
Working length	70°	70°
Outer diameter	9 Fr	8.5 Fr
Working channel	3.5 Fr	3.6 Fr
Deflection	Up 270°; down 270°	Up 270°; down 270°

TABLE 2. Upward and downward deflection angles of ureteroscopes under different conditions.

Ureteroscope		Empty working channel (degree±SD)	200 µm laser fiber (TFL-FBX200s) (degree±SD)	With 1.9 Fr tipless nitinol basket (degree±SD)
Storz Flex-X[C1] single use	Upward deflection	274.9±1.9	254.6±2.6	256.2±2.2
	Downward deflection	276.8±1.5	258.6±2.6	254.3±2.9
Storz Flex-X[C] reusable	Upward deflection	274.5±2.2	256.8±2.6	256.8±2.6
	Downward deflection	276.2±2.3	260.5±2.1	260.0±2.3

TABLE 3. Loop diameters of ureteroscopes under various conditions.

Ureteroscope		Empty working channel (cm±SD)	200 µm laser fiber (TFL-FBX200s) (cm±SD)	With 1.9 Fr tipless nitinol basket (cm±SD)
Storz Flex-X[C1] single use	Upward deflection	2.92±0.04	3.02±0.04	2.96±0.05
	Downward deflection	2.925+0.05	3.00+0.03	2.99+0.03
Storz Flex-X[C] reusable	Upward deflection	2.91+0.06	2.99+0.09	2.94+0.04
	Downward deflection	2.88±0.05	2.98±0.04	2.95±0.03

TABLE 4. Irrigation flow rates of ureteroscopes under different conditions.

Ureteroscope	Empty working channel (ml/min)	200 µm laser fiber (TFL-FBX200s) (ml/min)	With 1.9 Fr tipless nitinol basket (ml/min)
Storz Flex-X^{C1} single use	69.51±0.75	40.62±0.62	17.96±0.47
Storz Flex-X^{C} reusable	71.77±0.76	41.98±1.08	17.29±0.35
Mean difference (P-value)	-2.26 (0.14)	-1.36 (0.92)	0.67 (0.76)

TABLE 5. Resolution of ureteroscopes in air and normal saline solution.

Ureteroscope		Storz Flex-X^{C1} single use	Storz Flex-X^{C} reusable
0.5 cm (lp/mm)	Air	3.56	3.56
	NSS	3.56	3.56
1 cm (lp/mm)	Air	3.56	3.56
	NSS	3.56	3.56
2 cm (lp/mm)	Air	3.56	3.56
	NSS	3.56	3.56
3 cm (lp/mm)	Air	3.17	3.17
	NSS	3.56	3.56
5 cm (lp/mm)	Air	2	2
	NSS	2.52	2.52

Abbreviations: lp/mm, line pairs per millimeter; NSS, normal saline solution

TABLE 6. Color representation of ureteroscopes in air and normal saline solution.

	Ureteroscope	Median	Range	*P* value
Air	Storz Flex-X^{C1} single use	1.5	0-2	0.058
	Storz Flex-X^{C} reusable	1.0	0-2	
NSS	Storz Flex-X^{C1} single use	1.0	0-2	0.002
	Storz Flex-X^{C} reusable	0.5	0-1	

Abbreviations: NSS, normal saline solution

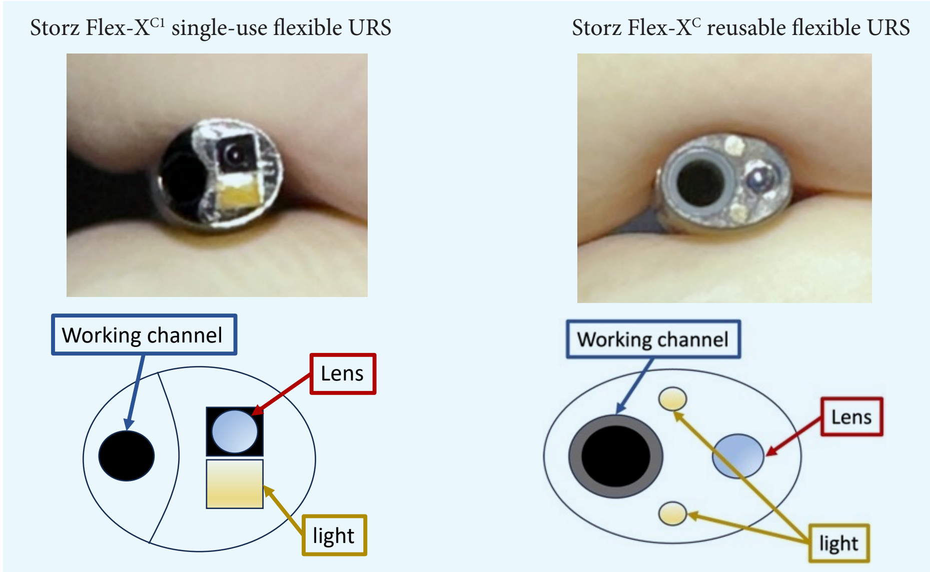

Fig 1. Comparison of Storz Flex-X^{C1} single-use and Storz Flex-X^{C} reusable flexible ureteroscope tips.

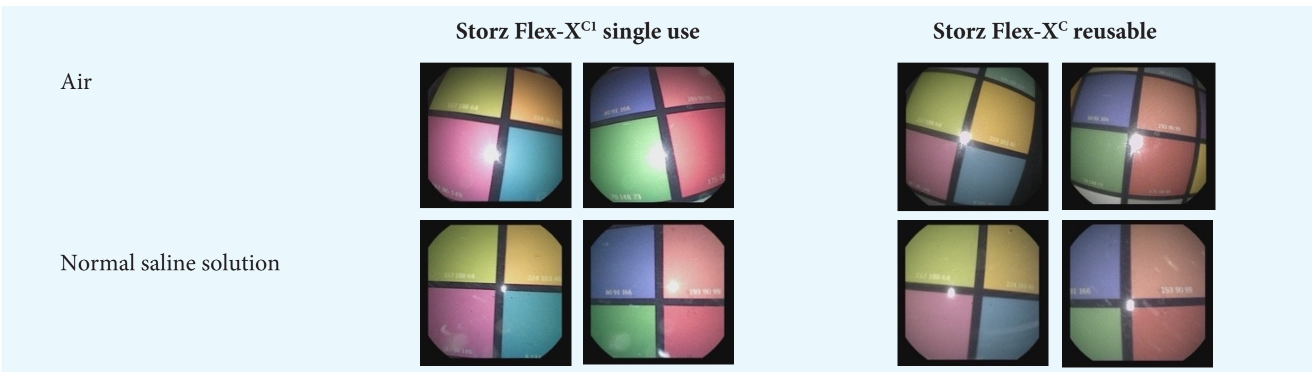

Fig 2. Color representation of Storz Flex-X^{C1} single-use and Storz Flex-X^{C} reusable flexible ureteroscopes in air and normal saline solution.

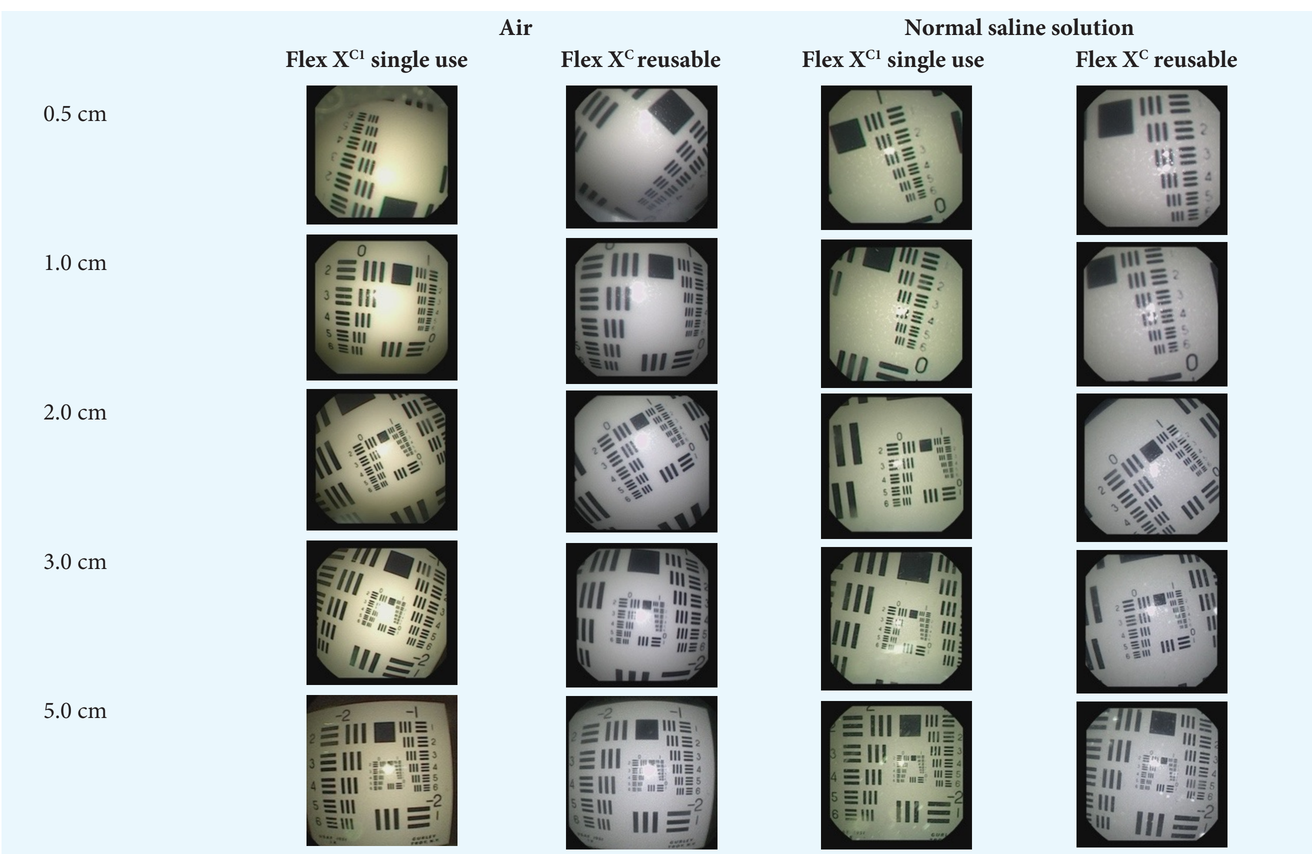

Fig 3. Resolution of Storz Flex-X^{C1} single-use and Storz Flex-X^{C} reusable flexible ureteroscopes in air and normal saline solution.

DISCUSSION

This study compared the mechanical and optical characteristics of two Karl Storz flexible ureteroscopes. According to their specifications, both ureteroscopes share a similar direction of view, angle of view, and working length. However, the single-use Flex-X^{C1} ureteroscope features a slightly larger outer diameter (9 Fr vs 8.5 Fr) and a slightly smaller working channel (3.5 Fr vs 3.6 Fr) than the reusable Flex-X^{C} ureteroscope (Table 1). Both devices have working channels positioned at the 3 o'clock orientation, which generally favors stone ablation in the right kidney. Under gravity, the calyces appear on the left side of the screen, whereas the stones tend to settle on the right side. This arrangement allows the laser, originating from the 3 o'clock direction, to access stones more easily.[13]

Regarding mechanical characteristics, no significant differences emerged in the upward/downward deflection angles when both ureteroscopes were tested with empty working channels. Thus, their suitability for diagnostic procedures is similar. However, when the working channel was occupied by either a 200 µm laser fiber (TFL-FBX200s) or a 1.9 Fr tipless basket, the reusable Flex-X^{C} achieved significantly greater deflection angles (approximately 2°–5°). This difference may be attributed to the more durable materials and craftsmanship of the reusable scope. A greater deflection angle may confer a therapeutic advantage during complex procedures.

A smaller loop diameter can facilitate access to challenging lower-pole calyces, enabling more efficient stone management within difficult anatomical configurations.[13] In this study, the Flex-X^{C} reusable ureteroscope achieved slightly smaller loop diameters under all three testing conditions (empty, laser, and basket), with mean differences ranging from 0.06–0.27 mm. Although these differences are generally minor, they may provide a subtle benefit in highly complex scenarios. Nonetheless, such small variations are unlikely to significantly affect overall performance in most clinical situations.

The irrigation flow rate influences intrarenal pressure and fluid temperature control, which is critical in preventing complications.[14] In our study, the Storz Flex-X^{C} reusable flexible ureteroscope had a modest, although statistically nonsignificant, advantage in terms of the irrigation flow rate compared with the Flex-X^{C1} single-use device. When the working channel was obstructed, both ureteroscopes experienced reduced flow rates without significant differences.

The two ureteroscopes demonstrated identical resolutions under air and normal saline conditions, as shown in Table 5 and Fig 3. However, for color representation, the Flex-X^{C1} single-use ureteroscope performed better in normal saline than did the reusable Flex-X^{C}, as shown in Table 6 and Fig 4.

Furthermore, the Flex-X^{C1} single-use ureteroscope is compatible with various imaging and monitoring systems, allowing flexible integration into existing surgical platforms. It is also the only single-use ureteroscope compatible with visual enhancement features, including the Storz Professional Image Enhancement System. This system's functions such as Chroma, which intensifies pixel-to-pixel brightness, and the two Spectra modes, which enhance image contrast can improve the visualization of blood vessels, mucosa, and small lesions.[15] These enhancements may provide clinical benefits (Fig 4).

CONCLUSION

The Flex-X^{C1} single-use ureteroscope and the Flex-X^{C} reusable flexible ureteroscope showed identical Flexresolutions, with the single-use device offering improved color representation. The reusable Flex-X^{C} ureteroscope demonstrated superior mechanical characteristics in some parameters, but these differences may be minor. Importantly, this was an in vitro study. In clinical practice, surgeon skills and experience may mitigate small mechanical disparities. Many of these variations may not translate into significant clinical differences during kidney stone management.

Data Availability Statement

The data supporting this study are available from the corresponding author upon reasonable request.

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DECLARATION

Grants and Funding Information

There are no sources of funding to disclose.

Conflict of Interest

There are no conflicts of interest to report.

Registration Number of Clinical Trial

None.

Author Contributions

Conceptualization and methodology, S.S. and E.C.; Investigation, C.L.; Formal analysis, C.L.; Visualization and writing – original draft, C.L., E.C., T.T., K.P., S.J., P.R.,

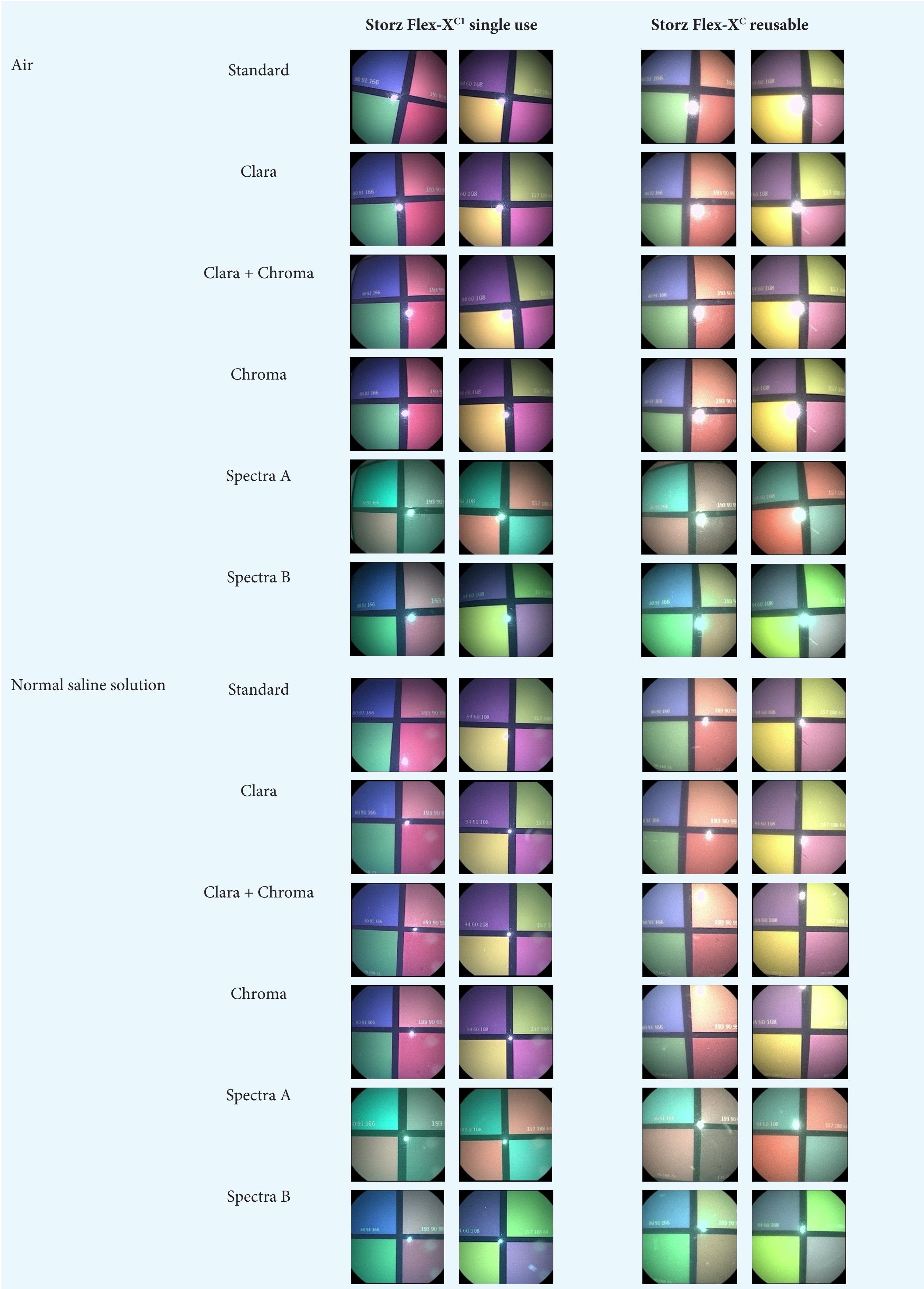

Fig 4. Comparison of color representation modes for Storz Flex-X[C1] single-use and Storz Flex-X[C] reusable flexible ureteroscopes in air and normal saline solution.

V.W., T.M., T.H., K.J., and S.S.; Writing – review and editing, S.S. and E.C. ; Supervision, S.S. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

No artificial intelligence tools or technologies were used in the writing analysis.

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