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TRAUMA AND RECONSTRUCTIVE UROLOGY

Prospective controlled *ex vivo* observational study on changes in elasticity of ureteral stents following clinical use

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Introduction Ureteral stents significantly impair health-related quality of life. Advances in stent material, particularly in polyurethane compositions, may mitigate adverse effects. This study evaluated *ex vivo* changes in the elasticity of ureteral stents made from a novel thermoplastic polyurethane composite (HybridPRO Technology by Urotech) compared to a control stent.

Material and methods In this prospective controlled *ex vivo* observational study, 97 patients undergoing ureteroscopy received one of two types of tethered 7 Fr, 28 cm ureteral stents. Eleven patients underwent bilateral procedures, yielding a total of 108 stents (54 per group). Group 1 received a polyurethane stent with HybridPRO Technology and group 2 received a polyurethane stent without HybridPRO Technology. After removal, stents were measured at the patient's bedside using a hanging apparatus with a predetermined 400 g load. *In vitro* (room temperature) and *ex vivo* elongations were recorded, and the net difference was calculated.

Results *In vitro* measurements showed a median elongation of 4 mm (IQR: 4–4) in group 1 vs 2 mm (IQR: 2–2) in group 2. *Ex vivo*, group 1 elongated significantly more (median, 12 mm; IQR: 11–13) compared to group 2 (median: 5 mm; IQR: 4–6; p <0.001). The net difference was larger in group 1 (median: 10 mm; IQR, 9–11) compared to group 2 (median: 3 mm; IQR: 2–4; p <0.001).

Conclusions Ureteral stents incorporating HybridPRO Technology demonstrated significantly greater elongation under standardized load after use compared to a control stent. These findings indicate material changes ex vivo; however, the clinical implications regarding comfort or quality of life remain to be determined in future studies.

Key Words: biomaterials ‹› thermoplastic polyurethane ‹› ureteroscopy ‹› mechanical properties ‹› stent design

INTRODUCTION

Ureterorenoscopy (URS) is a widely used and minimally invasive diagnostic and therapeutic approach for nearly all upper urinary tract pathologies. Continuous advancements, such as miniaturization and the integration of vacuum-assisted systems, have expanded its applications, establishing URS as the leading modality for kidney stone treatment [1, 2]. However, the frequent concomitant use of ureteral stents contributes to an increased spectrum of procedure-related complications. Stent placement is primarily performed to drain an acute obstruction, as seen in ureteral calculi, or prophylactically after URS to prevent secondary obstruction due to ureteral edema. Ureteral stents, however, have a substantial negative impact on quality of life [3]. Current guidelines advocate for limiting stent use and recommend omitting stent placement after uncomplicated ureteroscopy [4]. Furthermore, advancements

in stent material development may enhance patient comfort. The literature on stent material and biocompatibility is limited, relying primarily on *in vitro* studies and retrospective analyses. There is evidence to suggest that softer stents may have less of a negative impact on health-related quality of life than stiffer stents [5]. However, a certain degree of material rigidity is advantageous during stent placement, as it generates sufficient axial pressure to overcome a potential obstruction in the upper urinary tract. By modifying the composition of the most common material of ureteral stents, thermoplastic polyurethane, a range of material properties can be achieved. The aim of the present study was to measure the elasticity of ureteral stents made from a novel thermoplastic polyurethane composite called HybridPRO Technology immediately after clinical application. The hypothesis underlying this thermoplastic polyurethane composition is that an increase in elasticity occurs following implantation in the human body. In a prospective controlled observational study, we compared the change of elasticity to an established control without HybridPRO Technology.

MATERIALS AND METHODS

Study design and data evaluation

Between July 2023 and November 2024, 312 patients with urolithiasis underwent ureteroscopy – with or without simultaneous percutaneous nephrolitholapaxy – and 252 patients underwent diagnostic ureteroscopy on an inpatient basis at our department. All patients underwent preoperative urine analysis that either showed no bacterial growth or were appropriately treated based on urine culture results. After ureteroscopy, patients are managed according to one of three protocols: no stent placement; placement of a ureteral stent that is removed on an outpatient basis after approximately 7–14 days; or placement of a tethered ureteral stent, which is removed on the ward after a few days. The choice of protocol was at the discretion of the operating surgeon. The primary objective of our study was to evaluate changes in the elasticity of the thermoplastic polyurethane material of indwelling ureteral stents after implantation in the human urinary tract. To avoid artifacts due to encrustations, only tethered stents with a short indwelling time were measured according to the study protocol. Tethered stents were included, whereas those removed on an outpatient basis were excluded. Furthermore, to avoid artifacts due to elevated body temperature, ureteral stents from patients with postoperative fever were excluded from the study. Participating patients consented to participate in this study and were non-randomly assigned to two groups:

- group 1: tethered thermoplastic polyurethane stent (Whitestar, Urotech) 7 Fr, 28 cm;
- group 2: tethered thermoplastic polyurethane stent (Hydropur, Uromed) 7 Fr, 28 cm.

Of these, 97 patients received one of the two investigated tethered stents postoperatively. Eleven patients underwent bilateral ureteroscopy and received a stent in each ureter (of those, eight patients received one stent of each group), resulting in a total of 108 stents – 54 per group. Following an intraoperatively determined indwelling time, the stents were removed on the ward and immediately measured. Postoperative complications according to the Clavien–Dindo classification and laboratory values were documented. Informed consent was obtained from all patients prior to study inclusion.

Experimental design of elasticity assessment

In this study, elongation under a standardized tensile load was used as a pragmatic surrogate parameter for material elasticity. It should be noted that this setup does not represent a full viscoelastic characterization in the material-science sense, but rather a comparative and pragmatic bedside assessment of tensile elongation under defined conditions in order to assess *ex vivo* changes of ureteral stent material. Standards such as ASTM D412, ASTM D2240, and ISO 527 for the assessment of elastomeric and polymeric devices are laboratory-based methods and cannot be applied at the patient's bedside; therefore, they are unable to capture immediate *ex vivo* material changes. The primary aim of this study was to assess the change in elasticity of the thermoplastic polyurethane material after exposure to the human urinary tract. Immediately following the removal of the indwelling bladder catheter with the attached tethered ureteral stent, the stent was measured at the patient's bedside. The experimental setup is illustrated in Figures 1–4. In summary, the removed stent was clamped in a hanging device designed by a 3D printer (Prusa MK3S, Material: Filament ABS), which was freely suspended from a stand. After securing the stent, the connecting element of the hanging device was removed so that the stent represented the only link between the proximal and distal ends of the hanging device. Subsequently, two lead weights of 200 g each were attached to the distal end of the hanging device. The distal end of the hanging device itself weighs 20 g.

The change in the distance between the proximal and distal ends was recorded using a ruler mounted at the distal end of the hanging device. To ensure that the stent did not shift within the apparatus, the distances from the colored markers on the stent to the ends of the hanging device were compared before and after the measurement. The body temperature of the patient and the room temperature were recorded. The measurement load of 400 g was predetermined prior to the study. The materials science literature shows that, under tensile loading, thermoplastic polyurethane initially exhibits a linear force–elongation relationship, which subsequently transitions to an exponential curve [6]. *In vitro* assessment prior to this study shows that the chosen weight of 400 g falls within the linear region for both stent types used in this study (Suppl. Figures 1, 2).

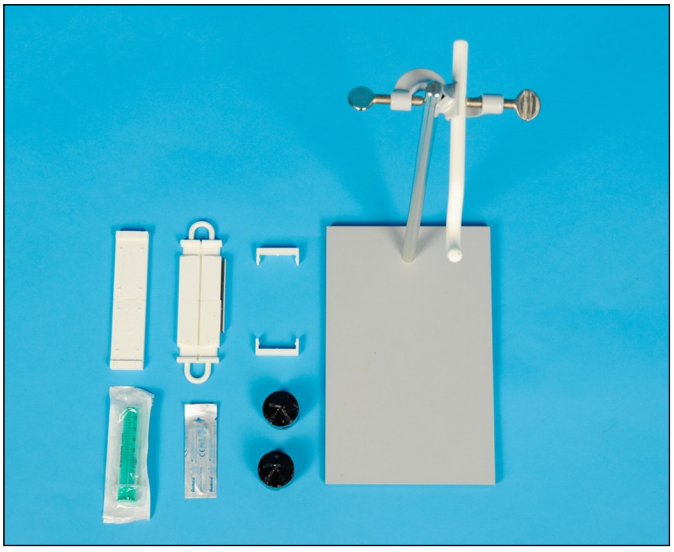


Figure 1. *Experimental setup for bedside tensile elongation measurement, including the hanging device, securing clamps, stand, and standardized 400 g load.*

Polyurethane composition of HybridPRO Technology

Thermoplastic polyurethane is a block copolymer synthesized by the reaction of two distinct monomer species, yielding polymer chains composed of alternating A and B segments (Figure 1–4). The high polarity of monomer A drives the formation of strong physical interactions among A blocks on adjacent chains, resulting in microphase separation into crystalline hard domains (A) and amorphous soft domains (B). The crystalline A domains confer rigidity and tensile strength to the polyurethane, whereas the amorphous B domains impart extensibility and elasticity [7]. By varying the chemical nature of the monomers and the ratio of hard to soft segments, one can tailor the material's mechanical profile. This control allows the hard phase to exist either as numerous finely dispersed domains or as fewer, larger domains, thus enabling a wide spectrum of physical and mechanical properties [8]. The pronounced in-body softening observed in HybridPRO Polyurethane ("HybridPRO effect") arises from three concurrent phenomena:

1. Thermodynamic softening: Elevated temperature increases the free volume between polymer chains, reducing the force required for deformation.

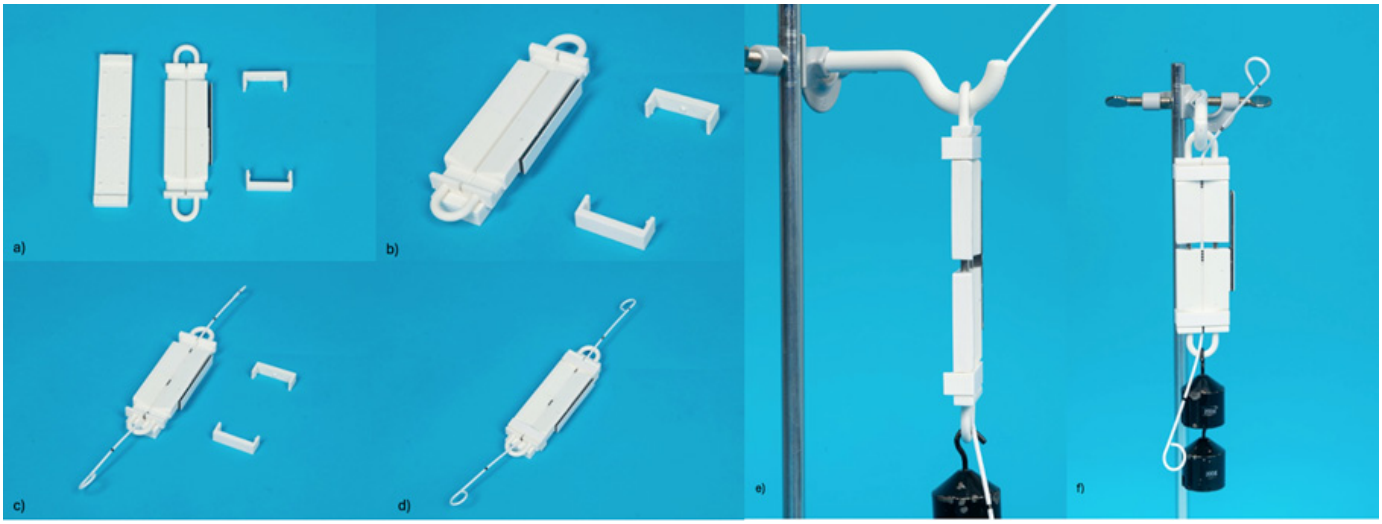


Figure 2. *Elasticity assessment step by step:* **a)** *connecting element, hanging device and two clamps;* **b)** *hanging device placed on connecting element;* **c)** *stent placed on hanging device;* **d)** *stent secured by two clamps;* **e)** *connecting element removed and 400 g weight attached to hanging device;* **f)** *final configuration with 400 g weight attached.*

Figure 3. *Hanging device with removed connecting element and secured stent with 400 g weight attached.*

2. Moisture plasticization: Water uptake into the polymer matrix facilitates chain mobility by acting as a molecular lubricant, further lowering stiffness.

While both effects are common to many polymers and induce moderate softening, HybridPRO Polyurethane exhibits a strong reduction in modulus due to:

3. Interfacial bond disruption: With rising temperature, the inter-segment physical bonds at the hard–soft interfaces progressively dissociate. The magnitude of this effect scales with the total interfacial area; thus, thermoplastic polyurethane featuring a high proportion of finely dispersed hard segments undergoes the most significant temperature-dependent softening [9].

Statistical analysis

Testing for normal distribution of variables was performed with the Shapiro–Wilk test. Continuous variables are reported as medians with interquartile ranges (IQR), while categorical variables are presented as absolute counts with corresponding percentages. The Mann–Whitney U test was used for comparing continuous variables, and the χ^2 test was applied for categorical variables. Statistical analyses were performed using R (version 3.6.3), Prism 6 (GraphPad Software, San Diego, CA), and MedCalc version 23 (MedCalc, Ostend, Belgium). Two-sided p-values <0.05 were considered statistically significant.

Bioethical standards

The study adhered to the ethical principles of the Declaration of Helsinki and was approved

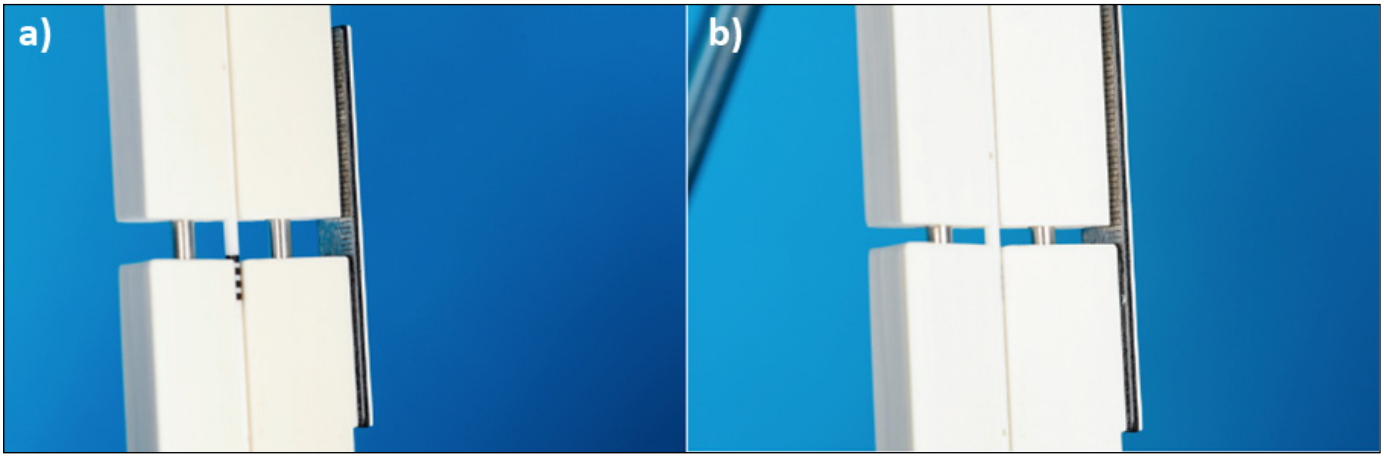


Figure 4. *Exemplary depiction of the elasticity assessment of the two ureteral stents used in this study:* **a)** *Whitestar, Urotech;* **b)** *Hydropur, Uromed.*

by the University Ethics Committee (approval No. #22-0949).

RESULTS

Perioperative patient characteristics

Detailed patient characteristics are displayed in Table 1. Each group comprised 54 patients. The median age was comparable between groups: 54 years (IQR 44–66) in group 1 vs 54 years (IQR 44–65) in group 2 (p = 0.5). The proportion of male patients was slightly higher in group 2, 36/54 (67%) vs 32/54 (59%), although this difference was not statistically significant (p = 0.4). Both the body mass index (BMI) and American Society of Anesthesiologists (ASA) score, used to assess comorbidities and anesthesia risk, were comparable between groups. Nearly all patients underwent ureteroscopy for stone treatment (52/54 [96%] in both groups), with a small number receiving diagnostic ureteroscopy (2/54 [4%] in both groups). 10/54 (19%) patients in group 1 were concurrently treated with a percutaneous approach during stone treatment vs 8/54 (15%) patients in group 2. Preoperative urine culture was positive in 16/54 (30%) patients

Table 1. *Patient characteristics. Continuous values are presented as median and interquartile range (IQR); categorical values are given as number (n; %)*

Characteristics	Group 1	Group 2	p
No. of patients	54	54	
Age, years [median, IQR]	54 (44–66)	54 (44–65)	0.5
Male [n (%)]	32 (59%)	36 (67%)	0.4
Female [n (%)]	22 (41%)	18 (33%)	
Ureteroscopy – stone [n (%)]	52 (96%)	52 (96%)	0.6
Concurrent percutaneous approach [n (%)]	10 (19%)	8 (15%)	
Ureteroscopy – Diagnostic/ Therapeutic [n (%)]	2 (4%)	2 (4%)	
Positive preoperative urine culture	16 (30%)	6 (11%)	0.02
OP duration, minutes [median, IQR]	57 (29–79)	47 (33–73)	0.6
Postoperative creatinine level, mg/dl [median, IQR]	1 (0.8–1.1)	0.9 (0.8–1.08)	0.6
Postoperative increase of creatinine level, mg/dl [median, IQR]	0 (-0.1–0.1)	0 (-0.1–0.1)	0.8
Postoperative eGFR, ml/min/1.73 m^2 [median, IQR]	83 (68–97)	92 (76–103)	0.1
Postoperative decrease of eGFR, ml/min/1.73 m^2 [median, IQR]	0 (–6–10)	0 (–6–8)	0.8
Postoperative CRP level, mg/dl [median, IQR]	0.5 (0.1–1.1)	0.5 (0.13–0.9)	0.7
Postoperative increase of CRP level, mg/dl [median, IQR]	0.15 (0–0.7)	0 (-0.18–0.4)	0.04
Postoperative leukocyte count, G/l [median, IQR]	7.8 (6.1–10)	8.7 (6.8–10.3)	0.4
Postoperative increase of leukocyte count, G/l [median, IQR]	0.28 (-0.68–2.6)	0.93 (-0.87–3.3)	0.6
Postoperative hemoglobin level, g/dl [median, IQR]	13.5 (12.4–14.9)	13.8 (12.7–14.8)	0.8
Postoperative decrease of hemoglobin level, g/dl [median, IQR]	0.4 (0–0.9)	0.5 (0.1–1.2)	0.5
Clavien–Dindo I	21 (39%)	22 (41%)	0.8
Clavien–Dindo II	1 (2%)	0	
Clavien–Dindo IIIa	0	0	
Clavien–Dindo IIIb	0	0	
Clavien–Dindo IV	0	0	
Clavien–Dindo V	0	0	
BMI [median, IQR]	25.5 (23–28)	27 (24–32)	0.1
ASA score [median, IQR]	2 (2–3)	2 (2–3)	1
Max. stone diameter, mm [median, IQR]	7 (5–11)	6.5 (5–8)	0.2
Stent indwelling time [median, IQR]	2 (2-3)	2 (1–2)	0.1

ASA score – American Society of Anesthesiologists score; BMI – body mass index; CRP – C-reactive protein; eGFR – estimated glomerular filtration rate (calculated using the CKD-EPI 2009 equation)

of group 1 and in 6/54 (11%) patients of group 2 (p = 0.02). Additionally, the median operative time was 57 minutes (IQR: 29–79) in group 1 compared to 47 minutes (IQR: 33–73) in group 2 (p = 0.6). Postoperatively, no significant differences were observed in the trajectories of key laboratory parameters related to renal function, inflammatory markers, and blood loss, nor in complications as graded by the Clavien–Dindo system. Specifically, Clavien–Dindo grade I complications occurred in 21 out of 54 patients (39%) in group 1 and in 22 out of 54 patients (41%) in group 2 (p = 0.8), with these complications consisting primarily of a postoperative need for analgesia or anticholinergic medications. However, we observed a difference in postoperative increase of C-reactive protein (CRP) levels, although absolute values were low (group 1: 0.15 mg/dl (0–0.7) vs group 2: 0 (–0.18–0.4), p = 0.04). The median stent indwelling time was 2 days in both groups (p = 0.1).

Elasticity assessment

The results of the elasticity assessment at bedside following stent removal are displayed in Table 2. *In vitro* measurements of five ureteral stents of each group at room temperature showed that group 1 had a median elongation of 4 mm (IQR: 4–4) compared to 2 mm (IQR: 2–2) in group 2. Elasticity assessment at bedside revealed a significantly higher median elongation in group 1 at 12 mm (IQR: 11–13) vs 5 mm (IQR: 4–6) in group 2 (p <0.001) (Figure 5). Furthermore, the net difference between the *in vitro* and *ex vivo* elongation was higher in group 1, with a median of 10 mm (IQR: 9–11), compared to 3 mm (IQR: 2–4) in group 2 (p <0.001) (Figure 6). When analyzing patients who received bilateral ureteral stents – one from each group – a significant net difference in our elasticity assessment was also observed (group 1: median 8 (IQR: 8–8) vs group 2: median 2 (IQR: 2–3, p <0.001) (Figure 7). Room temperature and body temperature were comparable between groups (Table 2).

DISCUSSION

Ureteral stents significantly increase the complication potential of an otherwise safe ureteroscopy. One approach to mitigating the impact on quality

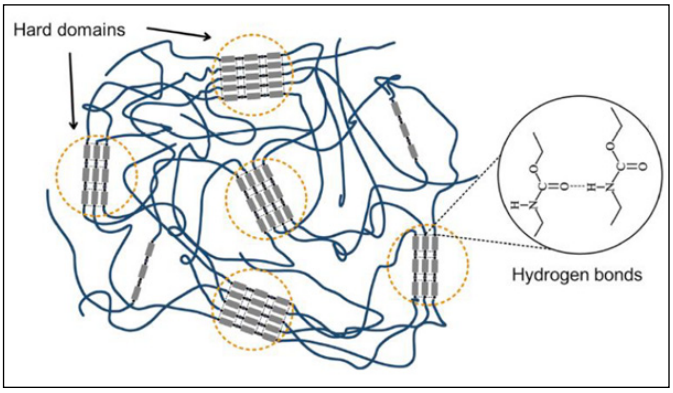


Figure 5. *Schematic drawing of thermoplastic polyurethane structure.*

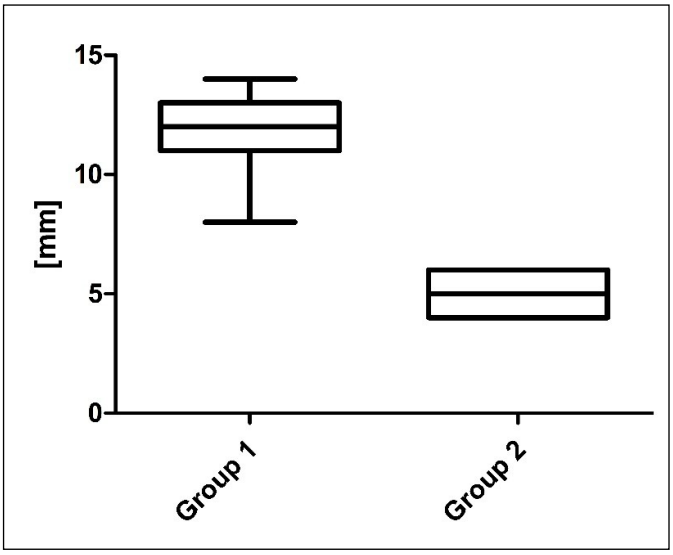


Figure 6. *Boxplot of elongation by elasticity assessment at bedside after removal of the tethered ureteral stent.*
p <0.001

Table 2. *Elasticity assessment at bedside after removal of the tethered ureteral stent. Continuous values are presented as median and interquartile range (IQR)*

	Group 1	Group 2	p
Room temperature at assessment, °C [median, IQR]	22.0 (21.8–22.3)	22.1 (21.8–22.4)	0.3
Body temperature at assessment, °C [median, IQR]	36.6 (36.3–36.9)	36.6 (36.3–36.8)	0.9
Elongation *in vitro* at room temperature, mm [median, IQR]	4 (4–4)	2 (2–2)	
Elongation *ex vivo*, mm [median, IQR]	12 (11–13)	5 (4–6)	<0.001
Elongation difference *in vitro – ex vivo*, mm [median, IQR]	10 (9–11)	3 (2–4)	<0.001

of life associated with stent placement is to improve the biocompatibility of the stent material. However, the literature on the material science of ureteral stents is sparse. Studies suggest that softer stents are better tolerated than stiffer ones. The aim of the present study was to evaluate the material properties of ureteral stents made from a novel thermoplastic polyurethane composition (HybridPRO, Urotech) by determining whether exposure to the human urinary tract leads to an increase in elasticity. After prospectively enrolling 97 patients and measuring 108 ureteral stents, we observed a significantly greater increase in elongation in the HybridPRO group. The median *ex vivo* elongation was 12 mm in group 1 vs 5 mm in group 2 ($p < 0.001$), with a net difference of 10 mm vs 3 mm, respectively. However, our study was limited to *ex vivo* material behavior, and no patient-reported outcomes were assessed. Therefore, any potential clinical advantages regarding pain, urinary symptoms, or quality of life remain hypothetical and require dedicated prospective studies assessing clinical symptoms and material properties.

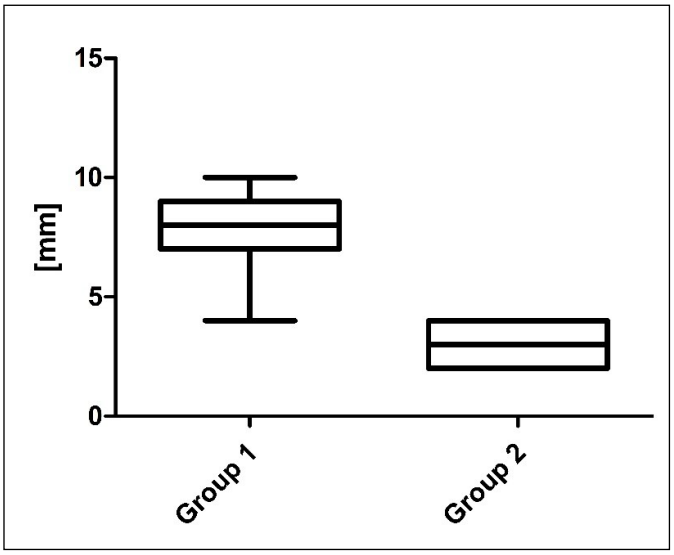


Figure 7. *Boxplot of net difference of elongation compared to in vitro elasticity assessment.*
p <0.001

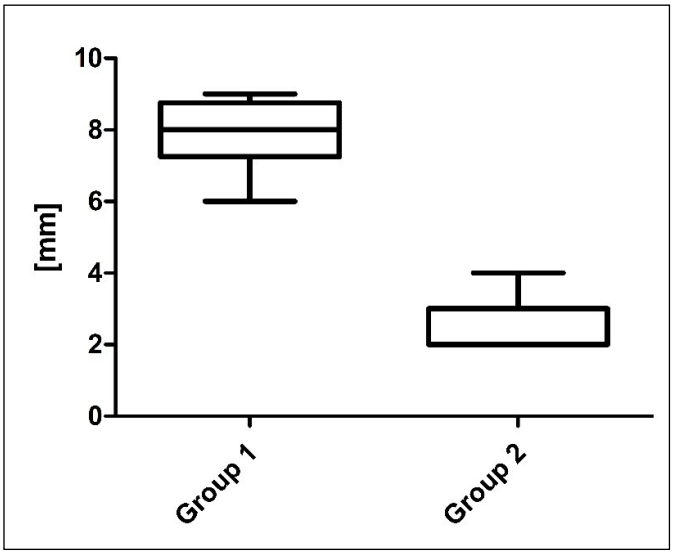


Figure 8. *Boxplot of net difference of elongation compared to in vitro elasticity assessment of patients with bilateral ureteral stents of each group (n = 8).*
p <0.001

Numerous studies have documented the negative impact of ureteral stents on health-related quality of life. Even after a brief indwelling period, nearly 90% of patients report stent-related symptoms that necessitate analgesic treatment, and many also report missed workdays [10]. In a multicenter retrospective analysis, Hiller et al. demonstrated that stent placement following ureteroscopy increases the likelihood of an emergency department visit by 25% [11], highlighting the significant clinical and economic imperative to minimize stent-related complications. A simple and effective measure is to adhere to current guideline recommendations to omit placement of a ureteral stent after uncomplicated ureterorenoscopy [4].

The literature on the influence of stent material on health-related quality of life (HRQOL) remains sparse. A systematic review by Boeykens et al. [5] found that, in general, softer ureteral stents are better tolerated than stiffer ones. Nevertheless, some degree of material rigidity is advantageous during stent placement, as it ensures an optimal balance between the inner and outer diameters. Materials that are excessively soft may achieve adequate hardness for drainage only by adopting an unfavorably large outer diameter, which is clinically disadvantageous. Ureteral stents are typically manufactured from either thermoplastic polyurethane or silicone [12], not accounting for hybrid materials. Silicone stents are generally softer than thermoplastic polyurethane stents and, for instance, are not equipped with a tether. A prospective, multicenter randomized controlled trial by Wiseman et al. demonstrated that silicone stents are associated with reduced flank pain and dysuria compared to a control ureteral stent made of polyurethane [13]. Thus, current scientific evidence led Boeykens et al. [5] to conclude that silicone ureteral stents are better tolerated than non-silicone stents. However, silicone stents are 3–5 times more expensive than polyurethane stents in many healthcare systems and have not been widely adopted in stone therapy to date.

Thermoplastic polyurethane on the other hand can be produced and retailed at a lower price range and can accomplish various material properties. This can be achieved by modifying its core composition and/or its coating. The most common coating is a hydrophilic layer to facilitate placement of the stent [5]. Other forms of ureteral stent coatings aimed at preventing encrustation or microbial colonization have shown divergent results in clinical studies [14, 15]. Studies comparing different thermoplastic polyurethane compositions used in ureteral stents are sparse, as the manufacturers do not disclose their formulations. Nevertheless, several studies have demonstrated that different thermoplastic polyurethane ureteral stents impact HRQOL differently, with softer stents generally being better tolerated than harder ones [16]. The term "soft" can, however, encompass various properties such as flexibility, elasticity, and wall thickness. It has not been investigated yet which of these characteristics has the greatest impact on health-related quality of life. In the literature, several approaches have been used to characterize the "soft" property. One method is that of the American Society for Testing and Materials (ASTM), which employs a durometer to measure the force required to indent the material with a pin gauge, expressed in Shore-A hardness units [17]. Other studies have compared different ureteral stents *in vitro* by measuring the force necessary for a 90° flexion [18]. The *in vitro* study by Hendlin et al. [17] used a similar experimental setup to assess tensile strength as our study, albeit by measuring the force required to extend the ureteral stent by 5 mm for 1 second. The experimental setup of the present study for measuring softness or tensile strength has not been previously described in the literature. The aim of our study was to examine changes in the thermoplastic polyurethane properties of ureteral stents before and after exposure to the urinary tract. A key advantage of our setup is its ease of implementation at the patient's bedside, enabling measurements to be taken before any temperature-related changes in the thermoplastic polyurethane occur. To our knowledge, such changes in the thermoplastic polyurethane properties of ureteral stents have not yet been described *ex vivo*.

There are several limitations to our study. Most importantly, although we were able to demonstrate structural changes in ureteral stent material *ex vivo* using a novel bedside system, we did not assess corresponding clinical effects in terms of patient discomfort, voiding dysfunction, encrustation, or infection. Another limitation is the non-randomized allocation of ureteral stents. Although the patient characteristics did not differ between the groups, confounders cannot ultimately be ruled out. In particular, a difference in the presence of positive urine cultures was observed between the groups studied. Previous studies have shown that urine composition can influence ureteral stent material through encrustation [19], which in turn may affect its elasticity. Consequently, our data cannot definitively determine whether the higher elasticity observed is attributable to the lower rate of positive urine cultures or to differences in the composition of the polyurethane itself. However, due to the observational nature of our study, no causal conclusions can be drawn, and propensity score matching was not feasible because of insufficient statistical power. Next, the analysis of the net difference from baseline elongation at room temperature was performed using five ureteral stents with different lot numbers. Although virtually no variance was observed, this represents a substantial discrepancy compared with the 108 stents that were measured in total during the study. A more precise approach would have been to perform dry measurements of each individual stent prior to clinical use in patients. Another limitation is the incomplete disclosure of the HybridPRO thermoplastic polyurethane composition due to competitive trade secrets, which prevents us from establishing a causal relationship between our measurements and the material properties. Next, we documented the maximum diameter from axial, coronal, or sagittal imaging to represent the surgical complexity. However, studies have shown that stone volume provides a more accurate representation of this parameter [20]. Finally, our study is monocentric, and our experimental setup has not yet been described or externally validated. An important methodological consideration is the interpretation of "elasticity" in our setup. In this study, we measured elongation under a fixed tensile load as a simplified surrogate rather than a full viscoelastic characterization. Although standardized laboratory tests – such as ASTM D412 (tensile strength), ASTM D2240 (Shore A and D hardness), or ISO 527 (polymer characterization) – are internationally recognized for the assessment of elastomeric and polymeric devices and would provide more detailed material data, they cannot be performed immediately at the patient's bedside and would therefore not capture the short-term *ex vivo* changes that were the focus of this study. Our approach was thus designed as a pragmatic and reproducible clinical comparison under standardized conditions. However, further studies are

necessary to confirm our methodology and *ex vivo* observations.

CONCLUSIONS

This prospective *ex vivo* study demonstrated that ureteral stents with a novel thermoplastic polyurethane composition, called HybridPRO Technology, achieve significantly greater elasticity after use compared to conventional polyurethane stents. These findings suggest that ureteral stents with HybridPRO Technology may combine the handling advantages of rigid stents with the tolerability of softer stents. Clinical studies assessing patient-reported outcomes are warranted to confirm this hypothesis.

CONFLICT OF INTEREST

Michael Chaloupka serves as a scientific advisor for Urotech GmbH and receives contractual compensation. The manufacturer had no role in the study design, data collection, data analysis, interpretation of the results, or preparation of the manuscript. The study was investigator-initiated and conducted independently at our institution. No payment was made for recruitment, conduct, or any similar activities related to this study. The other authors have nothing to disclose.

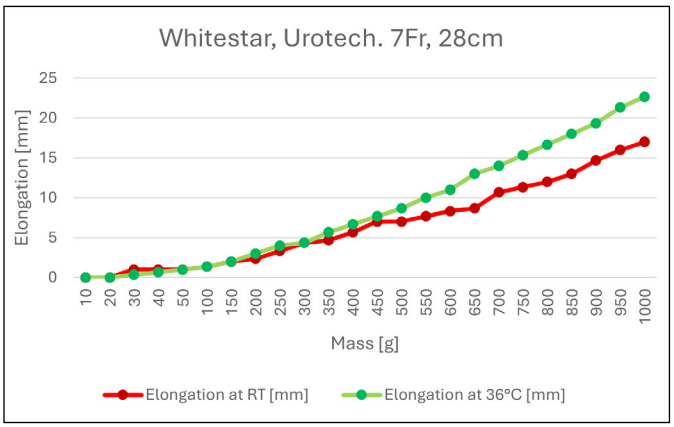
FUNDING

This research received no external funding.

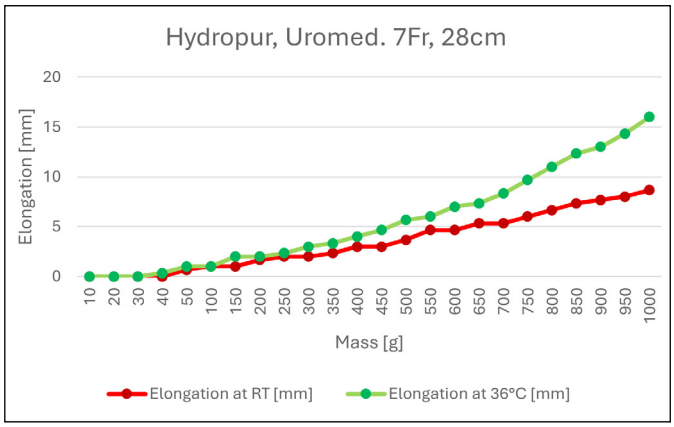
ETHICS APPROVAL STATEMENT

This study received approval from the local ethics committee (approval No.: #22-0949).

SUPPLEMENTARY MATERIALS



Suppl. Figure 1. *In vitro elasticity assessment of Whitestar, Urotech 7 Fr 28 cm at room temperature (RT) and after exposure to 36°C water. Experiment is representative of three different assessments performed in triplicate.*



Suppl. Figure 2. *In vitro elasticity assessment of Hydropur, Uromed 7 Fr 28 cm at room temperature (RT) and after exposure to 36°C water. Experiment is representative of three different assessments performed in triplicate.*

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