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The Effect of Bike Seat Models on Perineal Pressure During Cycling: Implications for Patients After Lower Genitourinary Reconstructive Surgery

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The Effect of Bike Seat Models on Perineal Pressure During Cycling: Implications for Patients After Lower Genitourinary Reconstructive Surgery

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OBJECTIVE To understand the effect of bicycle saddle shape and size on the pressure transmitted to the perineum, as prolonged perineal pressure and microtrauma amongst avid cyclists may increase the risk for complications following lower genitourinary surgery.

METHODS We tested five seats (Bontrager, Waterloo, WI) with varying levels of padding and morphology (comfort, fitness, fitness gel, race, and performance) for two different riders. The seats were installed on a Peloton stationary exercise bike (New York City, NY). Force measurements were performed using a 9833E-50 Large F-Socket Sensor (Tekscan, South Boston, MA). We measured total and perineal forces in three conditions at the same resistance: (a) at rest (not pedaling); (b) at 8 mph; (c) at 15 mph.

RESULTS Significant differences across the bicycle seats were observed with fitness gel seats providing the lowest perineal pressure. In all measurements, perineal forces were significantly lower at 15 mph compared to 8 mph ($P < .001$). When a rider used an oversized seat, less force was exerted compared to the appropriate size at both 8 mph ($P < .001$) and 15 mph ($P < .001$) speeds. Conversely, an undersized seat significantly increased perineal pressures at both 8 mph ($P = .018$) and 15 mph ($P = .007$).

CONCLUSION Larger seats constructed of more impressionable materials absorb a greater total force and act to distribute the subject's weight thereby delivering less force to the perineum. More perineal pressure is delivered at lower speeds and at rest likely due to the cyclist lifting off the seat during times of strenuous activity. UROLOGY 179: 174–180, 2023.

Although the cardiovascular benefits of cycling are well documented,[1] there is evidence to suggest that perineal pressure from the saddle may cause neurovascular trauma to the perineum, increasing the risk for transient genital numbness. Evidence about whether cycling leads to sexual dysfunction is mixed.[2,3] The straddling position a cyclist assumes for prolonged periods on a narrow saddle-style bike seats has been postulated to result in perineal ischemia and may increase the risk for cyclists to acquire urethral stricture disease as well as sexual and pelvic floor dysfunction.[4-6]

Prior studies have demonstrated that common saddle morphologies exert pressures exceeding 120 mmHg (17 kPA) on the anterior perineum of the rider, generating a sufficient compression force to overcome systolic perfusion pressures and cause temporary cessation of blood flow to the external genitalia.[7,8] Therefore, of particular Urologic concern are patients who cycle following lower genitourinary reconstruction who may already have compromised urethral or penile hemodynamics as a result of trauma, radiation, or prior surgery. For example, prior reports have demonstrated an 18%-22.5% incidence of sexual dysfunction in anastomotic urethroplasty when compared to stricturotomy and augmentation urethroplasty.[9] This is thought to be due to neurovascular disruption of erectile tissues.[10] Accordingly, this high-risk group may be at further risk for adverse lower genitourinary track outcomes, especially following perineal

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surgery—artificial urinary sphincter erosion, urethral atrophy, or urethral stricture recurrence.

Given the correlation of perineal pressure to concerns for lower genitourinary health, attention has previously been given to the design and construction of a saddle that may reduce perineal pressure in occupational bicyclers.[11,12] Schwarzer et al used transcutaneous measured penile oxygen pressures to demonstrate that wider saddles, particularly those that can support both ischial tuberosities, leads to a less decline in penile oxygen pressures during cycling.[13] Using the same model, Nayal et al demonstrated that alternating between a sitting to standing position helped to improve penile oxygenation. Importantly, 3 minutes of continuous seated cycling required 10 minutes of recovery off the saddle to return penile oxygenation pressures to baseline.[14] Additionally, further studies have investigated the role of exercise intensity[15] as well as the angulation of the saddle.[7] Pressure studies on the anterior perineum demonstrated that saddles oriented 10 degrees downward exhibited significantly less pressure (19.1 kPA) than those oriented horizontally (34.2 kPA), or 10 degrees upward (55.6 kPA).[7]

Though previous studies have assessed saddle characteristics to reduce pressure on the perineum, there is a lack of data amongst commercially available products. In the present study, we sought to measure pressure patterns amongst five commercially available saddles to determine which would be the most appropriate to shield the perineum and therefore recommend use for avid cyclists following perineal surgery. We hypothesized that larger saddles would distribute the rider's weight more evenly and be an ideal choice for these high-risk patients.

METHODS

Study Subjects and Setting

We tested five bicycle seat models within the same product line (Bontrager, Trek Bicycle Corporation, Waterloo, WI) with varying levels of padding and morphology, which were designed for different levels of intensity (comfort, fitness, fitness gel, race, and performance). The fitness and fitness gel seats were of the same dimensions where the gel seat was made of a more compliant foam. All seats incorporated a channel cut-out for the perineum of the rider. Two healthy male cyclists rode on the appropriate bicycle seats, which were sized per manufacturer recommendations given the width of their respective pelvis (Rider 1 = medium, Rider 2 = large, Supplementary Fig. 1). Demographic information and body composition measurements were taken from the riders for comparison. Body fat percentage was calculated using the U.S. Navy formula, %Fat = 86.010 × Log(abdomen − neck) − 70.041 × Log(height) + 30.30, which is specific for male gender with all measurements in centimeters.

In addition, we tested the effect of using undersized and oversized comfort seats for the riders. Rider 1 was placed on the medium-sized comfort seat for Rider 2 and Rider 2 was placed on the large-sized comfort seat for Rider 1. During this evaluation, Rider 1 used an inappropriately wider seat and Rider 2 used a saddle too narrow than recommended by the manufacturer. The seats were installed on a Peloton stationary exercise bike (New York City, NY). The riders wore appropriately fitted nonpadded athletic shorts and Peloton cycling shoes. This study's protocol was reviewed and was accepted by our Institutional Review Board.

Measurement of Perineal Pressures

We performed measurements using a 9833E-50 Large F-Socket Sensor and associated dedicated Windows software (Tekscan, South Boston, MA). The sensor is a thin plastic sheet and measures pressure using 15 × 16 embedded sensor cells. We taped the sensor to the seats such that pressure was measured across entire seat (Supplementary Fig. 2). The bicycle was adjusted to ensure that the two cyclists had standardized torso (45°) and knee (25°) angles. Using the software, we calibrated the sensor for each cyclist prior to measurement for all types of bicycle seats. We set the acquisition rate for pressure sensors to 50 Hz. We measured total and perineal forces in three conditions at the same level of resistance (level 30/100, moderate resistance): (a) at rest (not pedaling); (b) at 8 mph; (c) at 15 mph. We recorded raw force measurements instead of transforming the values into standard units for pressure because nontransformed direct output from the sensor has been shown to be more stable for analysis.[16]

Data Processing and Analysis

We reviewed the recorded frames and identified the pressure points associated with the ischial tuberosities. Using these two landmarks, we calculated the perineal pressure by fitting a previously-defined 4 × 5 rectangle of sensors over the region of the saddle located anteriorly to the ischial tuberosities[12] to sum the values. We also recorded total force for each frame by adding the values recorded by each of the 15 × 16 sensors. Raw data from 100 frames for each measurement were imported into STATA 14.2 (StataCorp, College Station, TX). The normal distribution of data was verified using Shapiro–Wilk test. The statistical significance was determined using *t* or Mann-Whitney *U* tests where applicable. Two-sided *P* values of less than .05 were considered statistically significant.

Outcomes

The primary outcome was pressure measurements to the perineum using five saddles at three varying points of exercise: rest, 8 mph, and 15 mph. The secondary outcome was variations in perineal pressure associated with under and over-sizing of the saddle.

RESULTS

Rider 1 was of a normal body weight and body fat composition (BMI = 24, body fat = 15%) vs Rider 2 who was overweight when comparing similar body metrics (BMI = 27, body fat = 19%). The demographics

Table 1. Comparison of forces exerted on perineum stratified by type/size of the bike seat and speed.

	Speed	Rider 1	*P* Value†	Rider 2	*P* Value†
Comfort	8 mph	680.6 (50.9)	Ref.	823.9 (147.8)	Ref.
	15 mph	431.9 (223.5)	Ref.	448.6 (300.6)	Ref.
Fitness	8 mph	544.6 (59.3)	**<.001**	872.5 (166.4)	.168
	15 mph	484.2 (134.7)	**< .001**	387.1 (220.7)	.420
Fitness gel	8 mph	492.6 (63.0)	**<.001**	389.8 (71.2)	**<.001**
	15 mph	443.6 (187.0)	.215	226.4 (97.0)	**<.001**
Race	8 mph	930.9 (90.1)	**<.001**	870.6 (108.4)	**.047**
	15 mph	525.2 (162.9)	**<.001**	412.2 (138.2)	**.019**
Performance	8 mph	1757.2 (193.5)	**<.001**	1166.3 (154.0)	**<.001**
	15 mph	770.6 (289.7)	**<.001**	542.0 (299.7)	**<.001**

Values are mean (SD) of raw forces.
† *P* values show statistical significance between each type of bike seat and comfort seat as the reference, at both 8 and 15 mph. Statistically significant *P* values are shown in bold typefaces.

and characteristics of the two riders are demonstrated in Supplementary Table 1.

The mean forces exerted on perineum were significantly different between the comfort seat as the reference and other seat types for both seat sizes, except for fitness gel seat for Rider 1 at 15 mph ($P = .215$) and the fitness seat at both 8 mph ($P = .168$) and 15 mph ($P = .420$) for Rider 2 (Table 1). For both riders, the performance seat, which is both thinner and stiffer, was associated with the highest mean perineal forces at both 8 and 15 mph. However, for Rider 2, there was less of a difference observed across the other seat morphologies. For Rider 2, the fitness gel seat was associated with the lowest mean perineal forces at 8 and 15 mph. Figure 1 shows the pressure heatmaps and line graphs associated with medium seats at three different conditions. Comfort seat dispersed pressure more uniformly than all other types of bicycle seats.

We compared perineal forces at two different speeds for each type of the seat. In all measurements, perineal forces were significantly lower at 15 mph compared to 8 mph ($P < .001$, Table 1). When using bike seats of inappropriate sizes, the oversized seat exerted less force on perineum while the undersized seat was associated with greater perineal force compared to their appropriate sizes (Table 2). This is also evident in the heatmaps that perineum is better protected with oversized seat compared to the equivalent undersized seat (Fig. 2).

COMMENT

When determining the effect of cycling on perineal pressure, our study demonstrates that there are multiple factors to consider, which are attributable to the rider, the type of cycling activity, as well as the construction and size of the saddle. We observed that at lower cadences and at rest, the wider seat acts to distribute the weight of the rider more evenly. This is especially evident in the data for Rider 1 compared to Rider 2. When comparing the two riders, Rider 1 has less subcutaneous fat in the buttocks and perineum. With more direct bony pressure on the saddle, the construction of the seat is crucial for limiting the perineal force.

Rider 2, on the other hand, has increased adiposity of the buttocks and perineum that help to decrease the pressure on the perineum, regardless of the particular size of the seat. This explains why there were similar pressure measurements observed between the comfort, fitness, and race saddles.

In addition to the size of the saddle, the foam compliance helps determine pressure. For both Rider 1 and Rider 2, the fitness gel seat was found to deliver the least force to the perineum in all measurements except at the higher cadence for Rider 1. When comparing the standard fitness seat to the gel fitness seat, both riders were found to benefit from a saddle made of a softer composition. Furthermore, the fitness gel seat performed better than the wider comfort seat constructed of less compliant materials. As the intended use of the seat increased in competitiveness, the seats not only became narrower but also employed a stiffer construction. Therefore, it is possible that the differences observed in the low cadences of Rider 1 could have been more from the material of the saddle rather than their respective size. However, when Rider 1 was placed on the identical comfort saddle of a larger size, we observed the perineal pressure to significantly decrease (Fig. 2).

Additionally, both riders demonstrated a reduction in the perineal force when increasing the cadence. To achieve a higher cadence, riders partially "lifted off" the saddle. This helps explain why there was less perineal pressure delivered during higher speeds, which was fairly equivalent regardless of the type of saddle used. These findings agree with prior work that demonstrated that increased time standing while cycling and higher handlebar heights were associated with lower odds of genital sores and numbness.[4,14]

Using the information collected, we determine that patients desiring to cycle following lower genitourinary

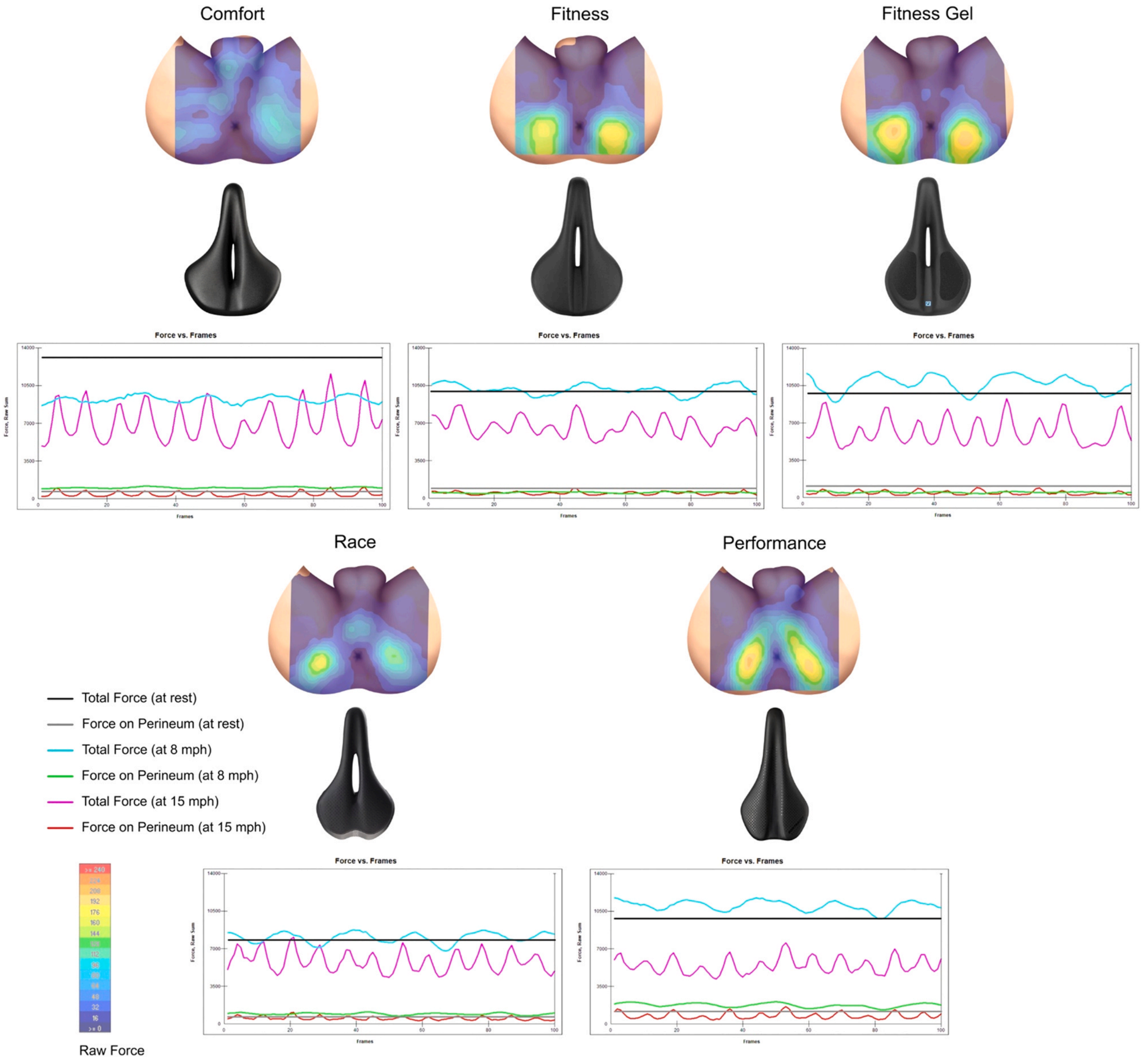

Figure 1. Pressure heatmaps demonstrate average raw force exerted on perineum at 8 mph. Line graphs show perineal and total forces at rest, 8 mph, and 15 mph. (Color version available online.)

reconstructive surgery should be encouraged to acquire wider seats which should be constructed from the softest cushioning to most evenly distribute the rider's weight. Riders should not be discouraged from engaging in high-intensity riding given the decreased pressures we observed. Dedicated periods "out of the saddle" are also beneficial for decreasing overall pressure on the perineum.

Our study has several limitations that should be acknowledged. Of important to note is that by nature of a stationary bicycle, we studied a "flat-road." Though not

Table 2. Comparison of forces exerted on perineum with bike seats of inappropriate sizes.

Rider	Speed	8 mph	15 mph
Rider 1	Appropriately-sized	823.9 (147.8)	448.6 (300.6)
	Undersized	879.0 (127.9)	466.9 (189.6)
	P value	**.018**	**.007**
Rider 2	Appropriately-sized	680.6 (50.9)	431.9 (223.5)
	Oversized	219.5 (213.6)	187.5 (101.3)
	P value	**<.001**	**<.001**

Values are mean (SD) of raw forces.
Statistically significant *P* values are shown in bold typefaces.

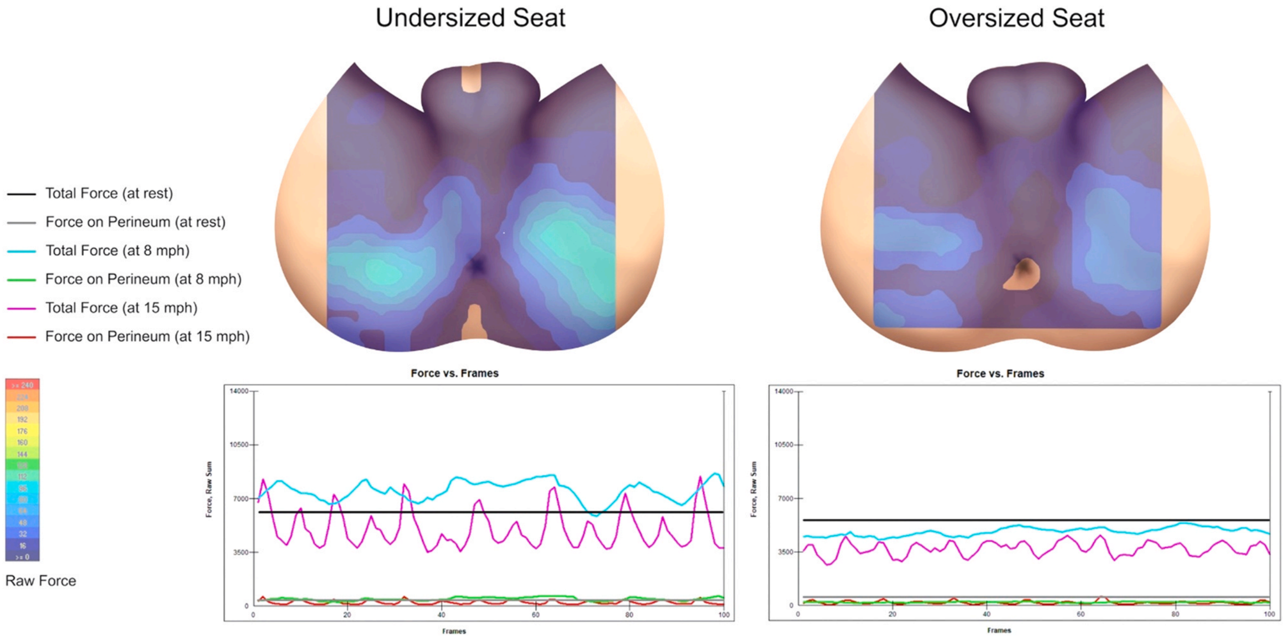

Figure 2. Pressure heatmaps of undersized and oversized comfort seats at 8 mph and associated line graphs. (Color version available online.)

tested, we would assume that uneven terrain, such as in mountain biking, would add additional stress to the perineum as it absorbs the shocks from traveling over the various hazards on these trails. In addition, we enrolled two riders in this study. Future studies with more riders and seat brands should be done to validate our findings. However, we believe if the bicycle is adjusted based on a standardized torso and knee angles, the pressure studies will be comparable for riders with similar body habitus. Lastly, we tested five differently shaped saddles with varying levels of stiffness from a single manufacturer to identify the optimal design and construction. Although these saddles cover a broad range of saddles available on the market, we acknowledge that there are many other products in the marketplace.

CONCLUSION

Wider and softer saddles distribute the weight of the rider and help to shield the perineum from higher pressures when compared to similar seats that are constructed narrower and of less compliant materials. This is especially important in riders who have less body fat and therefore less subcutaneous tissue to absorb and distribute the pressure of the cyclist. In addition, riding at higher cadences could decrease the perineal pressure as compared to recreational low-speed cycling. The findings of our study may inform patients who seek to cycle following lower genitourinary reconstructive surgery.

CONSENT FOR PUBLICATION

All authors provide consent for publication.

Declaration of Competing Interest

None Declared.

Acknowledgment. None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.urology.2023.03.057.

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EDITORIAL COMMENT

Cycling is a known risk factor for developing urethral stricture disease.[1] However, reconstructive urologists are often asked to make recommendations regarding biking safety and risk reduction following endoscopic management or urethroplasty. This clinical challenge will only increase with the increasing popularity of cycling that occurred during the COVID-19 pandemic. Wider bike saddles made from softer materials have been shown to reduce perineal pressure.[2,3] Currently, there is a knowledge gap in how saddle characteristics and sizing translate to commercially available bike seats.

In this study, the authors evaluate perineal pressure measurements at various speeds on a stationary bike using commercially available saddles. Additionally, the impact of saddle size is evaluated. Among 5 Bontrager saddles tested, the fitness gel saddle provided the lowest perineal pressure. As expected, saddle under-sizing increased perineal pressures. However, saddle over sizing drastically reduced pressure. This study provides practical information for both the patient and urologist. First, clinicians can now recommend a specific seat to patients who are interested in cycling. Second, and most importantly, we can counsel patients on the benefit of saddle over sizing to reduce pressure and risk.

As the authors allude to, I look forward to application of this methodology to additional saddle brands. Further questions that remain include how specific bike activity (mountain biking, road biking, commuter biking) impacts perineal pressure measurements, timing of return to cycling after urethroplasty, and long-term urethroplasty durability with cycling activity.

Declaration of Competing Interest

None Declared.

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AUTHOR REPLY

We thank the author for this comment. Reconstructive surgeries pose unique challenges given that outcomes are largely based on the patient's postsurgical quality of life. Therefore, achieving a successful restorative outcome is greatly dependent upon those activities the patient found meaningful prior to their surgery. Many of our patients wish to return to cycling after complex perineal repairs or prosthetic implantation. For others, it may be a different aerobic exercise, weight training, or winter activities. The task of the reconstructive urologist is to adapt the surgical platform to the patient's story and perspective. While challenging, this is extremely rewarding.

Cycling poses an immediate threat to perineal surgery, and we sought to develop an infrastructure by which cyclists and urologists can achieve optimal outcomes with a patient-centered approach. As the author states, many questions remain unanswered, and the choice of saddle is only one of several variables. We hope that our work will engage the surgeon and the cyclist, as well as challenge manufacturers to invest in product design for these unique circumstances.

Consent for publication

All authors provide consent for publication.

Declaration of Competing Interest

None Declared.

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