

Review Article

Biomechanics and suction force of menstrual cups: implications for IUD users

Amulya Koppa Manjunath¹, Mudigere Gowda Sanjay¹,
Pavan Kumar Chikkavalli Muddanna^{2*}, Robin George², Nishchay Gowda Suragahalli¹,
Aishwarya Manjegowda¹, Amrutha Thoobinakere Devarajegowda¹,
Sujan Surya Dinesha¹, Prem¹

¹Sri Adhichunchanagiri College of Pharmacy, Adhichunchanagiri University, B.G. Nagara, Mandya, Karnataka, India
²Department of Pharmacy Practice, Sri Adhichunchanagiri College of Pharmacy, Adhichunchanagiri University, B.G. Nagara, Mandya, Karnataka, India

Received: 23 December 2025

Revised: 10 February 2026

Accepted: 13 February 2026

*Correspondence:

Pavan Kumar Chikkavalli Muddanna,
E-mail: pavankumarcml5@gmail.com

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ABSTRACT

The concurrent use of menstrual cups and intrauterine devices (IUDs) is increasingly common due to the ecological, economic, and health benefits associated with menstrual cups. Understanding these biomechanical factors is essential to ensure patient safety and effective contraceptive use. A narrative review of existing literature was conducted to evaluate the biomechanical mechanisms involved in menstrual cup usage among IUD users. Published studies, case reports, and clinical observations were analysed with a focus on suction pressure, vaginal seal formation, force displacement, and user-related factors. Variations in anatomical characteristics, menstrual cup design, IUD type, and insertion-removal techniques were examined to assess their influence on IUD stability and expulsion risk. The review indicates that menstrual cups can generate negative pressure within the vaginal canal, which may exert upward forces on IUD strings and the device itself. Improper breaking of suction during cup removal and direct traction on IUD strings were identified as key contributors to IUD displacement and expulsion. The combined use of menstrual cups and IUDs presents potential biomechanical risks, particularly related to suction forces and improper removal techniques. While menstrual cups remain a safe and environmentally sustainable option for menstrual hygiene, increased awareness, proper user education, and careful consideration of cup design and IUD string management are essential. Further clinical and biomechanical studies are needed to establish standardized guidelines and minimize complications among IUD users who choose menstrual cups.

Keywords: Menstrual cup biomechanic, IUD expulsion risk, Suction dynamics, Patient safety, Product design innovation

INTRODUCTION

Attaining good menstrual health is not only a question of making sure access to menstrual products exists, but it also depends on individuals possessing the resources they require in order to be able to actively engage in all aspects

of life throughout their menstrual cycle. These resources could exemplarily consist of information, materials, sanitation facilities, supportive environments.¹ Women are using various sanitary products such as reusable cloth pads, commercial sanitary pads, tampons, wool pads, reusable tampons, and menstrual cups during menstruation. Menstrual cup was introduced as an

alternative of sanitary napkins and environmentally friendly sanitary product but because of unawareness in India its uses are very minimal.² Intrauterine device (IUD) is an effective and crucial method of contraception.³ With the increased use of IUDs for family planning and growing use of reusable menstrual protection methods like menstrual cups, it is crucial to consider the potential effects of their concurrent use.⁴ To determine and review the mechanical means by which menstrual cup wearing might lead to IUD displacement or expulsion.⁵ The intrauterine contraceptive device, one of the long acting reversible contraceptive methods, is among the most effective and safest family planning method.⁶

MENSTRUAL CUPS

In 1932 first menstrual cup was patented and in 1987 the Keeper in United States became first commercial brand producing menstrual cups.⁷ Menstrual cups are characterized by being non-absorbent, reusable, bell shaped medical grade silicone devices inserted into the vagina to gather menstrual blood provides a reusable alternative to sanitary pads, which generate a lot of waste.⁷ They are environmentally friendly as well as cost effective. Although their use is limited in India because of a lack of awareness and the preference for pads.⁸

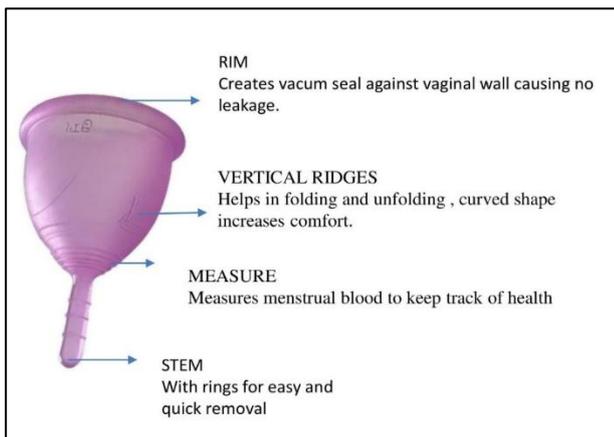


Figure 1: Menstrual cup.

Use of the menstrual cup (MC) includes folding up the cup, inserting it in the vagina, and letting it expand into position. Technique may take some practice, but when in place, it is leak proof and comfortable. Cups can be used for 12 hours and need to be emptied, cleaned and reinserted if necessary.⁹ They help in solving period poverty and align with some of the most important Sustainable Development Goals (SDGs) such as health, hygiene, sustainability, and gender equality as shown in the Figure 1. Menstrual cup users in real life may experience more difficulties such as insertion, removal, leakage, and discomfort than in clinical trials. These problems are widespread in the early stages but can be minimized by adequate education and assistance, resulting in improved user experience and usage.¹⁰

IUDS

An IUD, is a small, T shaped birth control device that is placed inside the uterus to avoid pregnancy. An IUD is a long term, reversible method of birth control and is commonly used because it works very well and is convenient.¹¹ Because it is a "fit and forget" system, IUDs are more compliant and effective than pills and are thus well suited to prevent unintended pregnancies. Although copper IUDs do not offer STI protection, WHO and ACOG affirm that IUDs are safe and appropriate for most women, including adolescents.¹² Intrauterine contraception (IUC) is appropriate for all medically eligible women, including childless women. It should be offered as one of the choices among available contraceptives during counseling sessions.¹³ Two principal types of IUDs exist: copper IUDs and levonorgestrel releasing (hormonal) IUDs. Copper IUDs are non-hormonal, have a shelf life of 10 to 12 years, and can also be used as emergency contraception, but might lead to heavier periods. Hormonal IUDs (such as Mirena, Kyleena, Skyla) release progestin, have a shelf life of 3 to 8 years, decrease heavy bleeding, and tend to give lighter or no periods.³ IUDs are safe, very effective contraceptives for teens, also helpful to treat heavy bleeding and dysmenorrhea.¹⁴

MENSTRUAL CYCLE

The endometrium, or the uterine lining, becomes thicker monthly under hormonal stimulation to accommodate a possible pregnancy. If not fertilized, it is shed as menstrual blood; if fertilized, it sustains the embryo.¹⁵ A regular menstrual cycle has synchronized hormonal control via the hypothalamic pituitary ovarian axis and consists of follicular, ovulatory, and luteal phases. Cycles with bleeding of 3 to 7 days.¹⁶ Menarche is the beginning of menstruation (at age 13), and menopause is the cessation of menstruation (at age 45). The 28 days menstrual cycle (range 21 to 35), on average, readies the body for pregnancy by way of hormonal changes.¹⁷ Menstrual hygiene is extremely important where it's a using clean, safe products and having water, soap, and private facilities for dignified care. Good hygiene avoids infections and contributes to health, education, and gender equality but remains a victim of stigma and resource constraints for many.¹⁸

ANATOMICAL AND FUNCTIONAL OVERVIEW

The uterus is a hollow, pear-shaped organ that plays a central role in several reproductive functions, including menstruation, pregnancy, and childbirth.¹⁹

VAGINAL AND UTERINE ANATOMY RELEVANT TO DEVICE USE

The female reproductive system is wholly contained within the pelvic cavity and consists of both internal and external structures. All of these structures are held in place

by different ligaments that anchor them to the pelvis.²⁰ The internal sex organs are contained within the true pelvis and consist of the vagina, cervix, uterus, fallopian tubes, and ovaries.²¹ The uterus is a hollow, muscular organ of the female pelvis used for menstruation, pregnancy, and giving birth. Inverted triangular in coronal section, it is an important part of the menstrual cycle and embryo growth.⁷

MENSTRUAL CUP POSITIONING AND FUNCTION

MC are hygienic and ecofriendly, yet their usage in India is low as there is not much awareness and women prefer sanitary pads.⁷ MC is placed inside the vagina. When placed, the menstrual cup stretches into an oval form and needs to be placed in between the posterior fornix and pubic bone such that it covers the cervix. For removal, a finger is used to hook behind the rim of the cup, most often behind the pubic bone.²² MC are containers inserted into the vagina to hold menstrual flow. If made of nonperishable materials, they can be reused.²³

UNDERSTANDING SUCTION MECHANICS IN MENSTRUAL CUPS

Effectiveness of MC is contingent on fit and design, not merely material firmness. Cups that are too small or too soft might not seal well, leading to leaks, while those too firm or too large will be uncomfortable. Best suction is achieved with a well-fitting cup that opens completely.²⁴

How menstrual cups create suction

MC, intravaginal silicone devices, which can be reused, work through creating suction to trap menstrual fluid and stay firmly in position. The suction is created when the cup expands and forms a seal against the vaginal walls, so proper relaxation of muscles is needed for easy insertion and removal. Without previous release of suction, users particularly those with a high cervix may strain, either overloading or stretching the pelvic floor muscles (PFM).²⁵

Seal formation and pressure zones

Suction is generated when the menstrual cup expands and creates a seal along the vaginal walls, creating zones of pressure that hold the cup in position. Muscle relaxation is crucial during insertion and removal to enable the cup to expand to its full capacity and preserve this seal without pain.²⁵

Suction strength: variability by cup design and material

MC have four components: rim, release holes, cup body, and stem. Placed by folding the rim, the cup inflates to seal and is worn for a period of up to 12 hours. Shape, rim size (31 to 54 mm), and capacity (8 to 37 mL) all differ as shown in the Figure 2. The stem range is up to 27 mm, with total lengths of cups ranging between 43 to 111 mm. Types

such as stemless or looped stem cups are suitable for individuals with short vaginal length or dexterity impairments as shown in the Table 1.²⁶

Table 1: Types of menstrual cup and their dimensions.

| Dimension | Small | Medium | Large |
|-----------|---------|--------|-------|
| Capacity | 15 ml | 25 ml | 30 ml |
| Diameter | 42.5 mm | 46 mm | 48 mm |
| Height | 58 mm | 63 mm | 74 mm |



Figure 2: Types of menstrual cup.

IUD placement and mechanism of action

The intrauterine contraceptive device is a form of long-acting reversible contraception that is one of the safest and most effective methods of contraception.²⁷ IUDs are generally around 28 to 32 mm in width and 30 to 36 mm in length. While it has been the general presumption that the uterine cavity can accept these measurements in all women, recent ultrasound evidence indicates that the uterine cavity, especially in nulliparous females, may be smaller than the typical IUD diameter. This supports the need to assess unique anatomical variations when choosing a suitable IUD. Smaller sized IUDs with a width of around 28 mm and a length of 30 mm might be a better option in nulliparous or younger patients.⁶ All IUDs cause a localized inflammatory reaction within the uterine cavity, which distorts the normal physiology of the endometrium and myometrium and changes the uterine microenvironment to render the uterine cavity inappropriate for pregnancy.²⁸

COMPARISON OF DIFFERENT IUD TYPES (COPPER VS HORMONAL)

IUDs are a very reliable form of long-acting reversible contraception and come in two main forms: copper IUDs (for example, TCu 380A) and hormonal levonorgestrel (LNG) IUDs (for example, Mirena, Skyla). The copper IUD is a non-hormonal device that will last 10 to 12 years and has a first-year failure rate of approximately 0.08%. It does this by releasing copper ions, which create a

spermicidal environment in the uterus that prevents fertilization. While highly effective, the copper IUD has side effects in the nature of heavier periods, increased cramping, and higher expulsion rates compared to hormonal IUDs. It is often preferred by individuals who

need long term non hormonal contraception that can also be used as an emergency method of contraception when inserted with or within five days following unprotected sex.

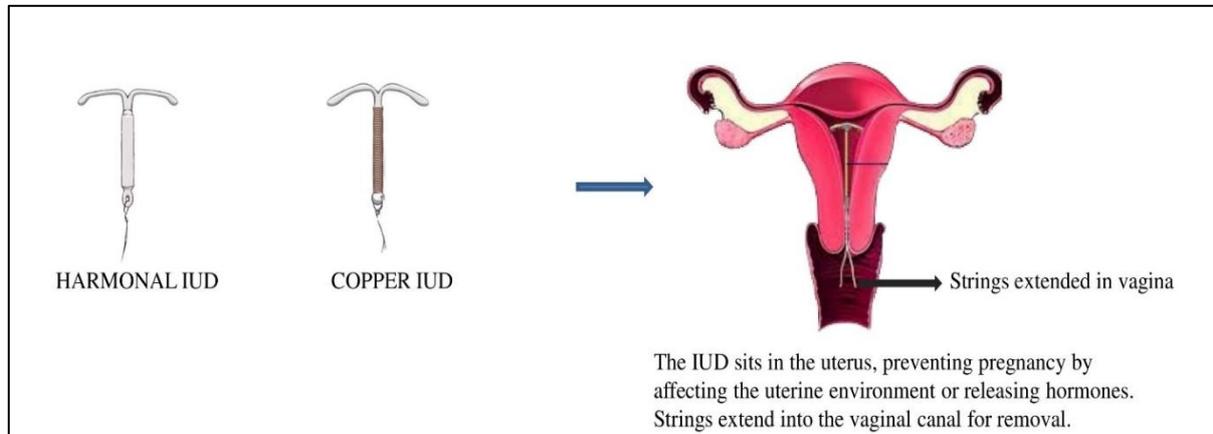


Figure 3: Types of IUDs.

Alternatively, hormonal LNG IUDs release progestin that makes cervical mucus thicker to block sperm, thins the uterine lining, and suppresses ovulation in a portion of women. The IUDs also have a very low first year failure rate of around 0.02% and can last for 3 to 8 years, depending on the type. One of the most significant advantages of LNG IUDs is their ability to reduce menstrual bleeding, and amenorrhea (loss of periods) occurs in about 20% of the users within the first year. LNG IUDs also have a lower expulsion rate compared to copper IUDs. Besides contraception, LNG IUDs are most often used for the management of menorrhagia (heavy menstrual bleeding) and provide endometrial protection, particularly for patients being treated with estrogen therapy. Both copper and LNG IUDs are greater than 99% effective and safe for the majority of individuals. The choice between them depends on personal preferences, such as side effects tolerance of hormones, desired change in menstrual bleeding, and future family plans. Although copper IUD may be the best choice for women who would like hormone free contraception even with the price tag of heavier periods as shown in the Figure 3. LNG IUD is the preference of women who prefer lighter or no periods and other non-contraceptive benefits.²⁹

BIOMECHANICAL INTERACTION BETWEEN MENSTRUAL CUPS AND IUDS

The vagina, an integral part of the female reproductive system, has been largely under researched in the field of biomechanical study.⁴ Concurrent use of a MC with an IUD might be linked to an increased risk of IUD expulsion.³⁰ There are two mechanisms that have been put forward to account for IUD expulsion related to MC use. The first is traction of the IUD strings unintentionally by the user while removing the cup, which can displace the device as shown in the Figure 4.

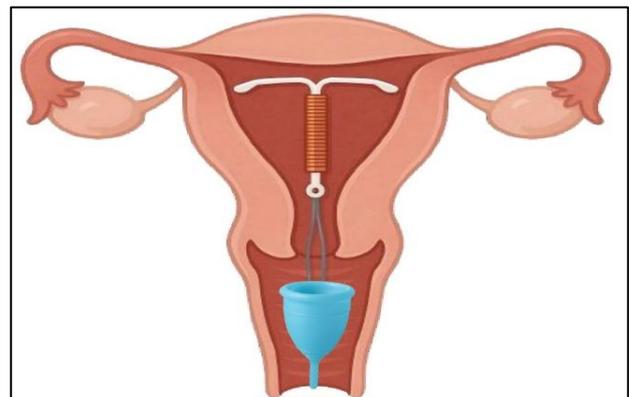


Figure 4: Interaction between menstrual cup and IUD.

The second is that the negative pressure obtained when inserting or removing the menstrual cup can produce a downward force on the IUD through its strings. There is also a risk of the strings mechanically snagging on the cup upon removal, further increasing the risk of expulsion.

Pathways of mechanical influence on IUD position

A systematic review of seven studies reported 73 IUD expulsion events; the expulsion rates varied from 3.7% to 18.6%. Several mechanical pathways have been recognized and included in these outcomes as recognized by the review: The use of a MC along with an IUD can cause displacement due to suction pressure when taking out the IUD, accidental pull-on IUD strings, and improper removal without breaking the seal. Stiffness, size, and form of the cup can vary how much it presses against the cervix, and shorter cervix to vaginal length increase the probability of contact. Some models of IUDs are higher in expulsion.⁴

IMPACT OF REPEATED USE AND CUP REMOVAL TECHNIQUES

One possible explanation for IUD displacement when using a MC is the suction that is applied when removing the cup. Another probable cause is inadvertent tugging of the IUD strings when inserting or removing the cup. Multiple uses of a MC in women who have an IUD may lead to IUD displacement through cumulative mechanical stress from the process of insertion and removal, especially if suboptimal techniques are utilized.³¹ MC design like firmness, shape, and suction release hole influences suction strength and IUD displacement risk. IUD characteristics such as string length also affect this risk, particularly when the cup is taken off without breaking suction.³²

CLINICAL OUTCOMES AND PATIENT SAFETY

Use of a MC has been determined to be an independent risk factor for IUD displacement. Clinicians need to know this association in order to properly counsel patients and assist them in making the most appropriate choice of menstrual protection when using an IUD.³²

IUD EXPULSION: RATES, PATTERNS, AND RISK FACTORS

IUD expulsion is affected by several factors, such as the time of insertion, IUD type, and the route of delivery. The rate of expulsion is significantly higher with early postpartum insertions, especially after vaginal delivery, than it is with interval insertions after the involution of the uterus.³³ Concomitant use of a MC with an IUD can be related to an increased risk of IUD expulsion.³⁴

REPORTED CASES OF PAIN, CRAMPING, OR DISLODGE MENT

Patient centered contraceptive counseling enhances satisfaction and decision making. Adverse effects such as discomfort, cramping, and bleeding which are a leading reason for early IUD removal should be discussed. Alongside recommending short term NSAIDs, providers must counsel patients about the course of symptoms. Especially with copper IUDs, clear, evidence-based advice can enhance tolerance and reduce the likelihood of dislodgement.³⁵ A coronal 3D view of the uterus is useful in unambiguously imagining the location of an IUD. It is possible for the whole device to be visualized in the uterine cavity using this view, thereby enhancing the identification of problems like displacement or embedding of the IUD, which could be responsible for pelvic discomfort or irregular bleeding.³⁶

USER EDUCATION AND ERROR IN TECHNIQUE

MC are also budget friendly and environmentally friendly in comparison to traditional menstrual products, but usage safely depends heavily on proper technique. Misuse of

technique in inserting, placing, and managing suction pressure can lead to discomfort, injury, or infection.³⁷ The majority of new users will experience difficulties with seal attainment, and there will be leaking or excessive suction and trouble while trying to remove. Without proper training, users may create improper habits that render effectiveness and safety non-existent.³⁰

BIOMECHANICS AND SUCTION FORCE: MAJOR CHALLENGES

MC design involves making a subtle suction seal against the walls of the vagina so that there are no leaks. But if the cup does not open completely upon insertion, it becomes uncomfortable or may not hold the menstrual fluid at all. On the other hand, too much suction can be painful to remove and result in vaginal irritation or mucosal trauma.²⁵ Users who insert the cup without breaking the seal first may suffer pain or, in some instances, contribute to pelvic floor strain. All these biomechanical considerations underscore the need for positive insertion, positioning, and removal instructions.³⁸

EFFECT OF POOR TECHNIQUE ON PATIENT SAFETY

Poor use of MC has several deleterious effects. Ongoing leaks from improper position may lead to frustration and prevent continued use. Over suction during removal can cause vaginal abrasions or minor trauma, especially for women with sensitive tissues.³⁸ Also, neglect of proper hygiene frequent emptying the cup being too infrequent or improper cleaning can lead to infections, including toxic shock syndrome (TSS), although such occurrences are still uncommon. Proper education to mitigate these risks is needed for patient safety.³⁹

ENHANCING USER EDUCATION FOR IMPROVED OUTCOMES

Proper instruction can dramatically decrease user errors and increase comfort. Care providers ought to stress the necessity of releasing the suction seal prior to removal by pinching the cup's base. Teaching various folding methods (such as the C fold or punch down fold) can assist users with inserting more easily.⁴⁰ Also, suggesting softer cups for patients who find high suction painful might make it easier to use.⁴¹ Follow up assistance, such as troubleshooting manuals or consultations with a medical professional, can also aid users in handling obstacles and maintaining safe, long-term application.⁴²

RECOMMENDATIONS FOR CLINICAL PRACTICE

MC is increasingly popular, as a sustainable and cost-effective alternative to traditional menstrual products. However, improper use can lead to discomfort, leaks, or even rare complications like vaginal lacerations or IUD

displacement. Below are evidence-based recommendations for clinical practice.⁴³

SAFE USE OF MENSTRUAL CUPS WITH IUDS

The combination of MC and IUDs has been controversial due to the risk of IUD displacement because of suction pressure. Although there is limited evidence that MC directly lead to higher IUD expulsion rates, the following precautions can reduce risks. Patients can be advised to crack the seal of the cup gently prior to removal in order to prevent creating too much suction, which theoretically could knock out the IUD. Also, individuals with recently inserted IUDs might consider wearing alternative menstrual products during the first few cycles following insertion because expulsion is most likely to occur during this time.⁴⁴

STRING MANAGEMENT AND TIMING POST IUD INSERTION

MC users must handle their IUD strings properly to avoid unintentional pulling. Patients should frequently check the positioning of the strings, and clinicians may shorten or relocate them. Depending on personal preferences, it is frequently recommended to postpone cup use for 4 to 6 weeks following insertion in order to allow for IUD stabilization.⁴⁴

PATIENT COUNSELLING AND INFORMED CONSENT

Informed consent counselling should cover the theoretical but not evidenced risk of IUD expulsion with cup use. Patients must learn proper insertion and removal technique, including breaking the seal carefully. Shared decision making is essential some patients wish to avoid cups at all costs, while others may opt to proceed cautiously. This discussion should be recorded in the patient's note to provide clarity and reduce medicolegal hazards.⁴⁵

GAPS IN RESEARCH AND FUTURE DIRECTIONS

Despite growing popularity, key gaps remain in understanding the biomechanics of MC, particularly regarding safety, efficacy, and inclusivity.⁴⁶ Addressing these gaps through rigorous research and innovation can improve product design, clinical guidance, and user experience.⁴⁷

NEED FOR STANDARDIZED TESTING PROTOCOLS

The lack of standardized testing methodologies for MCs is one of the main impediments to guaranteeing uniform product quality and safety.⁴⁸ Inconsistent testing methods for MCs hinder comparisons and lead to unreliable performance. Lab models often fail to reflect real vaginal conditions like muscle movement, body position, and anatomy, causing some cups to work in tests but not in

actual use.²³ These constraints in existing assessment techniques highlight the necessity for rigorous, systematic test protocols that more accurately mirror physiological conditions.⁴⁹ To fix these issues, we need clear standards that reflect real life use. Safe suction levels should be defined to protect vaginal tissues while still preventing leaks, especially for those with IUDs.⁵⁰ MCs should be labelled with clear stiffness ratings instead of vague terms like “soft” or “firm.” Testing should mimic real life movements to better reflect actual use. This helps users and healthcare providers make more informed choices.⁴³

Advances in computational modelling, like finite element analysis, can improve testing by simulating how MCs interact with the body. These virtual models help researchers study different cup designs and anatomical variations without relying on physical prototypes.²⁶ Computational methods of this type could supplement physical testing by allowing quick repetition of design ideas and performance prediction over a wide range of population groups.⁵¹ Combining advanced modelling with standard tests can greatly improve MC safety and design. Creating global testing guidelines will need collaboration between regulators, manufacturers, and scientists to ensure they are both practical and scientifically sound.⁵¹

INCLUSION OF DIVERSE POPULATIONS AND ANATOMIES

The existing research and product development landscape for MCs is plagued by major gaps in portraying representative user populations.⁵² Most research and products focus on adult, mobile, cisgender women in Western countries. This overlooks important differences in groups like adolescents with developing anatomy, postmenopausal women with vaginal atrophy, or people with pelvic floor conditions. These gaps limit safe and effective use across diverse users.⁴⁷ Transgender men and nonbinary individuals receiving testosterone therapy are of particular concern, as they commonly develop vaginal atrophy that might need specialized cup designs.⁵³ This exclusion of research and development from these groups sets up barriers to the use of safe and comfortable cups for many potential customers, potentially making the product inaccessible to entire demographic groups.⁵⁴

MAPPING A PATH TO MORE REPRESENTATIVE SOLUTIONS

In order to eliminate these key gaps, future studies need to focus on systematic anthropometric investigations that include the entire range of vaginal measurements across various ages, ethnic groups, and physiological conditions.⁵⁵ Baseline data should guide mc designs tailored to specific needs, such as smaller cups for teenagers or adapted shapes for those with pelvic conditions. Including underrepresented groups like post hysterectomy patients and gender diverse individuals in trials is essential to ensure safety and effectiveness. Collaboration with disability advocates can support universally designed products that are inclusive, accessible, and free from stigma.⁵⁶

ENACTING INCLUSIVE PRACTICE WITHIN PRODUCT DEVELOPMENT

Going forward, product development should involve diverse user groups and real-world testing. Collaborating with healthcare experts in adolescent, transgender, and pelvic care can guide better design. Clear sizing charts and selection tools will help users make informed choices.⁵⁷ Additionally, educational resources should be developed to assist healthcare professionals in recommending suitable cup choices for patients within the entire range of ages, body types, and disease states. By adopting this holistic strategy to inclusivity, the menstrual care market can guarantee that its products actually work for all people who menstruate, across age, anatomy, and ability.⁵⁸

PRODUCT INNOVATION OPPORTUNITIES

The technology of MCs offers many areas for biomechanics led innovation that may make a major difference in user comfort and safety. A potential development direction is the creation of stiffness variable cups with segmented construction that dynamically responds to pelvic muscle tone.⁵⁹ Smart materials of this kind may change their rigidity with no manual interference in relation to muscle contractions during various activities, maybe avoiding discomfort while ensuring leak protection. Another innovative idea involves the incorporation of pressure sensitive valves that release excess suction automatically when preset pressure levels are reached.⁶⁰ This option would be especially useful to avoid possible complications due to excessive force from suction, e.g., irritation of the vaginal wall or displacement of the IUD. Further, there is increasing need for low profile discs and cups that are designed specifically for users who have high cervixes or who are sensitive to the bulk of standard cup design. These designs may render MC more available to a wider variation of anatomies and personal preferences.⁶⁰

MITIGATING SUCTION FORCE AND IUD DISPLACEMENT HAZARDS

The link between IUD stability and MC use needs deeper research and better product design. While there's some evidence of expulsion risk, more large-scale studies and lab tests using realistic models are needed. This research could lead to safer cup designs with anti-suction features and clear "IUD safe" labels to guide users and healthcare providers.⁶¹

THE FUTURE OF SMART MENSTRUAL CUP TECHNOLOGY

Emerging smart technologies hold great promise for the next generation of menstrual health products. Integrated sensor systems have the potential to transform cup use through real time feedback on correct placement, seal quality, and level of suction, and in reducing the learning

curve for first time users. The sensors could be linked to smartphone apps, providing personalized use information and reminders for best hygiene practice. At the same time, extensive biocompatibility studies must be conducted in order to determine long term material interactions with the vaginal microbiome, especially for new smart materials and sensor elements.⁶² These studies must not only assess short term safety but also cumulative effects of long-term exposure to these materials over a number of menstrual cycles. In combination, all these technological innovations would turn MCs from passive collectors into smart health monitoring systems without compromising on their primary advantages of affordability and sustainability. All these innovations need to be developed keeping in mind the stringent test protocols and human centred design approaches to make them address various needs without compromising safety or accessibility.⁶³

SUMMARY OF FINDINGS

The current body of research on MC biomechanics reveals several critical knowledge gaps that need to be addressed to ensure product safety and efficacy. A primary concern is the insufficient understanding of suction dynamics; particularly how varying levels of negative pressure interact with vaginal walls and potentially affect intrauterine devices. The review also highlights major limitations to our understanding of ideal material properties, such as how various silicone preparations and thicknesses perform about pelvic muscle activation and position changes over a normal day of use. Additionally, current products tend not to address the entire range of anatomical variation, which presents accessibility issues for patients with atypical physiological requirements like those with pelvic floor disorders or postmenopausal alteration.⁶⁴

While MCs have obvious environmental and economic benefits when compared to disposable menstrual products, their potential is currently limited by a number of factors. There is no standardized, physiologically relevant testing paradigm, which prevents impartial comparison of product performance or the creation of safety standards. This lack of standardization is especially problematic with the growing market diversity and worldwide uptake of these products.⁶⁵ Further, the absence of inclusive design principles from both research and product development designates that many groups adolescents, transgender people, and those with particular medical needs are not able to use cups that are adjusted to their anatomy and physiology.

There are a number of fundamental issues that stand out as calls for urgent action in both research and clinical care. The risk of displacement remains a major concern with present evidence being contradictory but indicative of potential effects of cup suction on device stability. Variability in performance across anatomically different users suggests that more personalized sizing systems and design configurations are necessary. Most importantly, the

lack of evidence based clinical guidelines removes from clinicians precise protocols for endorsing cups to diverse patient groups, especially in individuals with particular medical concerns like IUDs or pelvic floor dysfunction. Such deficiencies in knowledge and standardization are both challenges and opportunities for the development of MC technology and availability.⁶⁵

IMPLICATIONS FOR GYNAECOLOGY AND PRODUCT SAFETY

For Gynaecologist's and medical professionals, these results highlight the need for patient specific advice when suggesting MCs, especially among IUD users and those with special anatomical or physiological factors (e.g., pelvic floor dysfunction, postmenopausal atrophy, or teenage users). Establishing standardized safety procedures like measured suction limits and material flexibility targets would increase product dependability and fewer complications. Moreover, regulatory agencies need to promote thorough pre market testing that considers actual in use biomechanical forces to ensure cups are safe before they end up on the market.^{66,67}

FINAL REMARKS FOR RESEARCHERS AND CLINICIANS

The future direction of MC research and practice hinges on concerted, interdisciplinary efforts to overcome existing limitations. Priorities for researchers include the establishment of standardized biomechanical testing methods that mimic in vivo conditions, such as dynamic measurement of suction forces during activity and full assessment of seal integrity across different physiological states. Such testing must go beyond laboratory conditions to include proper simulations of everyday movement, exercise, and anatomical variation. At a minimum, the research community must espouse more inclusive clinical trials that proactively recruit and assess diverse populations including adolescents undergoing menarche, gender variant individuals on hormone therapy, patients with pelvic floor disorders. These investigations must use rigorous methodologies to identify anatomical variations and distinctive use challenges of these groups.^{68,69}

Product design innovation is an essential area for enhanced MC safety and usability. Future innovation must be directed toward engineering solutions such as pressure sensitive valves that adjust suction automatically, stiffness adjustable materials to suit different pelvic muscle tone, and smart technologies that offer real time feedback regarding optimal placement. For IUD users in particular, studies need to define firm, evidence-based recommendations using well conducted prospective trials that measure any risk of expulsion. These efforts can be augmented with product design improvements that reduce risk associated with suction while preserving performance. Ultimately, making MCs genuinely inclusive will necessitate continuous cooperation among biomedical engineers, material scientists, gynaecologists, and public

health researchers to close current knowledge gaps and bring findings into clinical practice and product standards.

CONCLUSION

These cups are made to Mold to the shape of the vaginal canal, providing a secure but comfortable fit. The most commonly used medical grade silicone gives the desired balance of flexibility and firmness, so the cup holds its shape while still conforming to movement. Correct insertion will cause the cup to open up and create a gentle suction seal against the walls of the vagina, avoiding leaks without being overly tight. This vacuum action is essential to function, although ill-fitting or excessive insertion may result in temporary discomfort or infrequent complications, like IUD displacement. Future developments in MC technology can target improvement in material elasticity, vacuum control, and individualized sizing to better fit various anatomies. Research into long term biomechanical impacts on the pelvis floor and IUD interaction could also improve safety and convenience. As a whole, the biomechanics of MCs show a successful fusion of physiology and engineering and offer an effective solution to menstrual management.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to Sri Adhichunchanagiri College of Pharmacy, Adhichunchanagiri University, B.G. Nagara, Mandya, Karnataka, for providing the academic environment and necessary support to carry out this review work. Authors also extend their special thanks to the Department of Pharmacy Practice for their guidance, encouragement, and access to academic resources throughout the preparation of this manuscript and also acknowledge the valuable insights, discussions, and collaborative efforts of all contributors involved in reviewing the literature and refining the manuscript.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: Not required

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Cite this article as: Manjunath AK, Sanjay MG, Muddanna PKC, George R, Suragahalli NG, Manjegovda A, et al. Biomechanics and suction force of menstrual cups: implications for IUD users. *Int J Res Med Sci* 2026;14:1234-44.