

Fertility Preservation Approaches for Sustainable Reproductive Health

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Introduction

Fertility preservation (FP) encompasses a broad spectrum of medical, surgical, and technological approaches designed to protect reproductive potential in individuals at risk of infertility due to medical interventions, diseases, or natural aging. In recent years, FP has evolved beyond its initial oncologic focus to include people postponing parenthood for social or personal reasons, and those affected by autoimmune or systemic disorders (ASCO, 2025; Anderson et al., 2020).

Through these methods, individuals confronted with cancer or other health conditions retain the possibility of conceiving and raising genetically related offspring in the future. Advances in cryobiology and the deepened understanding of gonadal physiology have shifted FP from an experimental concept to an established component of reproductive medicine. As survival outcomes and life expectancy continue to improve, preserving fertility now contributes not only to physiological health but also to psychological recovery and long-term quality of life, reinforcing FP's role as an essential dimension of sustainable healthcare and human development (Baram et al., 2019).

Principles of Fertility Preservation

The fundamental goal of FP is to protect reproductive function without interfering with essential medical treatment (Henry et al., 2023). The optimal strategy depends on several patient-specific factors—age, disease type, urgency of therapy, and available gametes or tissue. Early counseling and the involvement of a multidisciplinary care team are crucial for effective decision-making.

Selecting an appropriate FP method involves evaluating whether the approach aims to mitigate gonadotoxic effects or to store reproductive material such as gametes, embryos, or gonadal tissue. It is equally important to differentiate between fertility impairment caused by the underlying illness itself and damage arising from its treatment. Surgical, chemotherapeutic, and radiotherapeutic modalities may each affect hormonal balance or directly harm germ cells and reproductive organs, making the clinical approach inherently complex (ASCO, 2025; Anderson et al., 2020).

Indications for Fertility Preservation

FP should be considered for individuals at risk of infertility due to gonadotoxic chemotherapy, pelvic radiotherapy, surgery involving reproductive organs, or progressive age-related decline. Increasingly, elective or “social” oocyte freezing is being adopted by women who wish to delay pregnancy (Dolmans & Donnez, 2021; De Vos et al., 2021). FP in children and adolescents is also gaining importance as survival rates among pediatric cancer patients rise. The indications for fertility preservation are shown in Table 1.

The 2025 ASCO guideline update highlights FP as an essential aspect of comprehensive cancer care, reaffirming oocyte and embryo cryopreservation as the standard options for postpubertal females. Ovarian tissue cryopreservation is now considered an effective alternative, especially for prepubertal patients or those unable to undergo stimulation (Cobo et al., 2021, Finkelstein et al., 2024). For males, sperm cryopreservation remains the primary and most reliable method, while testicular tissue storage is still classified as experimental and should be performed within research settings (Schlegel et al., 2021; Martin et al., 1999).

Table 1

Indications for Fertility Preservation

Indication	Description
Cancer	Treatments like chemotherapy and radiation can damage fertility
Autoimmune diseases	Gonadotoxic therapies used to treat these conditions may impact fertility
Genetic disorders	Conditions associated with premature ovarian insufficiency
Delayed childbearing	Social egg freezing for women choosing to postpone pregnancy

Established Methods of Fertility Preservation

In adult males, sperm cryopreservation remains the principal and most straightforward method for fertility preservation (ASCO, 2025; Anderson et al., 2020). In contrast, options available for females are more diverse but generally invasive, costly, and associated with variable success rates and potential risks.

Male Fertility Preservation:

For postpubertal males, sperm cryopreservation before initiating gonadotoxic therapy remains the most practical approach. When semen collection is not possible, surgical sperm retrieval methods such as TESA, TESE, or microTESE may be used. In men with testicular cancer, viable tissue may be collected during orchiectomy through oncoTESE.

Patients are advised to defer attempts at conception for at least a year after chemotherapy or radiotherapy due to possible genetic risks (Schlegel et al., 2021; Martin et al., 1999).

In prepubertal boys, cryopreservation of testicular tissue can be considered within ethically approved clinical research frameworks, with informed consent clearly explaining its experimental nature and current lack of established therapeutic use. Male patients are advised to avoid attempting conception for at least one year following chemotherapy or radiotherapy due to the risk of treatment-induced germ cell mutations.

Female Fertility Preservation:

Available FP techniques for females include oocyte and embryo freezing, ovarian tissue cryopreservation (OTC), and temporary ovarian suppression with GnRH agonists. Each method is suited to specific clinical circumstances and has distinct benefits and constraints (Dolmans & Donnez, 2021; De Vos et al., 2021).

Oocyte cryopreservation, involving controlled stimulation and vitrification of mature oocytes, has achieved success rates comparable to those of fresh IVF cycles. Embryo cryopreservation remains the preferred option when a sperm source is available. OTC provides opportunities for prepubertal girls or patients requiring urgent therapy, while GnRH agonists may offer partial ovarian protection but cannot replace cryostorage methods (Kuwayama et al., 2005; Kuleshova et al., 1999). The techniques and considerations for female fertility preservation are presented in Table 2.

Table 2

Fertility Preservation Options for Females: Techniques and Considerations

1. Embryo cryopreservation:
● Widely accepted for use in postpubertal patients. ● Requires access to sperm from a partner. ● Involves controlled ovarian stimulation, typically lasting about 10–14 days. ● May postpone the initiation of oncologic therapy for approximately 2–6 weeks.
2. Oocyte cryopreservation:

- An established technique applicable to postpubertal individuals.
- Does not depend on sperm availability at the time of preservation.
- Offers greater independence in future reproductive decision-making.
- Appropriate for patients who prefer to avoid donor sperm use or embryo storage.
- Requires 10–14 days of ovarian stimulation prior to oocyte retrieval.
- Could result in a short delay of 2–6 weeks before commencing cancer treatment.

3. Ovarian tissue cryopreservation:

- Currently the only viable option for prepubertal girls.
- Holds potential for both fertility restoration and hormonal function recovery.
- Can be performed without postponing cancer therapy.
- Does not necessitate hormonal stimulation protocols.
- Still considered an investigational or developing approach.
- Involves laparoscopic removal of ovarian tissue followed by future reimplantation.
- Carries a theoretical risk of reintroducing malignant cells upon transplantation.

Preservation Technique

With the introduction of vitrification, it has been demonstrated that the cellular damage caused by the slow-freezing method was significantly reduced, leading to improved success rates (Kuwayama et al., 2005; Kuleshova et al., 1999). The use of the microinjection technique has helped to overcome fertilization difficulties arising from zona hardening induced by the freeze–thaw process, resulting in further improvement in success rates. As a result of these advances, oocyte cryopreservation was approved for clinical use in the United Kingdom in 2000. In 2013, the American Society for Reproductive Medicine (ASRM) removed oocyte cryopreservation the experimental category and recognized it as a routine clinical procedure (ASRM Guideline, 2013). Following these developments, oocyte cryopreservation has become an integral component of assisted reproductive technologies (Dolmans & Donnez, 2021; Cobo et al., 2021).

Cryopreservation refers to a series of chemical processes that enable the long-term storage of cells and tissues at subzero temperatures. Two main freezing techniques are used: the previously common “slow-freezing” method and the “vitrification” method currently preferred in clinical practice. Although the slow-freezing technique yielded satisfactory results in earlier years, its practical challenges and lower success rates compared with fresh oocytes have led to a marked decline in its use. Vitrification, which employs higher

concentrations of cryoprotectants, reduces the risk of ice crystal formation, and allows for a very rapid and practical application, has now taken its place in clinical practice with high success rates. The first live birth following vitrification was reported by Kuleshova et al. in 1999, and in 2005, Kuwayama et al. developed the widely adopted “Cryotop” vitrification method.

Today, many in vitro fertilization (IVF) programs have adopted vitrification for oocyte cryopreservation. The National Institutes of Health (NIH) guidelines updated in 2013 recommend the use of the vitrification method for embryo or oocyte cryopreservation when adequate equipment and expertise are available ((NIH Guideline, 2013; Dolmans & Donnez, 2021; Cobo et al., 2021).

Outcomes and Success Rates

FP success is influenced by patient age, ovarian reserve, and the number of stored gametes or embryos. More than 200 live births have been reported worldwide following ovarian tissue transplantation. Sperm cryopreservation continues to yield high post-thaw viability and satisfactory pregnancy outcomes, with reports suggesting up to 50% live birth success among cancer survivors using ICSI (Schlegel et al., 2021; Martin et al., 1999).

Currently, vitrified oocyte cycles have achieved success rates nearly comparable to those of fresh IVF cycles. Post-vitrification oocyte survival rates have reached approximately 84% following the warming process. Although these rates vary depending on the age at which oocytes are cryopreserved, a remarkable improvement has been observed over time: while in 1999, approximately one pregnancy was achieved per 100 frozen oocytes, today, one pregnancy can be achieved with around 20 oocytes, yielding outcomes comparable to those obtained with fresh oocytes (Dolmans & Donnez, 2021; De Vos et al., 2021).

Emerging and Experimental Approaches

Experimental FP approaches include in vitro maturation (IVM) of oocytes, artificial ovary development, and stem cell-based gametogenesis. These technologies aim to offer fertility options for patients where conventional methods are not feasible, such as prepubertal children or those with hematologic malignancies. Recent trials on IVM and artificial ovarian scaffolds indicate promising early outcomes.

Ethical and Psychosocial Considerations

FP raises complex ethical and psychosocial questions, including consent in minors, posthumous use of gametes, and equitable access (Henry et al., 2023; ASRM Ethics Committee, 2018). Informed consent should emphasize realistic expectations and

possible complications. Psychological counseling before and after FP can reduce anxiety and improve long-term satisfaction (Baram et al., 2019).

The clinical use of vitrified gametes and embryos has long been regarded as an ethically acceptable practice in many countries. Both the American Society for Reproductive Medicine (ASRM) and the European Society of Human Reproduction and Embryology (ESHRE) recognize gamete and embryo cryopreservation as safe, effective, and evidence-based components of modern reproductive care (Dolmans & Donnez, 2021; Cobo et al., 2021).

Also, fertility preservation in prepubertal girls and boys presents a significant challenge, as their gonads are not sensitive to gonadotrophins due to absence of receptors, so it is not easy to obtain mature oocyte and spermatocyte (ASCO, 2025; Anderson et al., 2020). Additionally due to certain regional and traditional prejudices, guardians may exhibit hesitation or reluctance toward the oocyte retrieval procedure for minor girls. For the same reason, invasive techniques may not be applicable for preteen boys who may experience difficulties in ejaculation. These issues represent areas that require further development and clarification in terms of both clinical and ethical application within this field (Henry et al., 2023; ASRM Ethics Committee, 2018).

Sustainability and Health Policy Perspective

From a sustainable health perspective, fertility preservation to the long-term continuity of reproductive health and social well-being by empowering individuals to give reproduction chance in spite of medical or environmental challenges (Henry et al., 2023). Sustainable health emphasizes preventive care, equity, and the responsible use of medical technologies—principles that align closely with fertility preservation (ASCO, 2025; Anderson et al., 2020). Integrating fertility preservation into sustainable health frameworks encourages the efficient use of healthcare resources, reduces the emotional and social burden of infertility, and supports reproductive rights. Furthermore, environmentally conscious innovations in cryopreservation technologies and the promotion of ethical, accessible, and cost-effective practices will be essential for maintaining both human and ecological sustainability in reproductive medicine (Henry et al., 2023; ASRM Ethics Committee, 2018).

Conclusion

Fertility preservation has become a critical component of modern reproductive and oncologic care, supported by major advances in cryobiology and assisted reproductive technologies. Techniques such as vitrification, ovarian tissue transplantation, and sperm cryopreservation have significantly improved success rates, offering new opportunities for individuals facing infertility due to medical treatment or elective reasons. These

developments not only safeguard reproductive potential but also align with the broader goals of sustainable health by enhancing long-term well-being and quality of life.

However, ongoing challenges remain in ensuring equitable access, addressing ethical concerns, and improving the environmental sustainability of cryogenic systems. Future directions include the development of innovative technologies such as in vitro gametogenesis, stem cell-derived gametes, and artificial reproductive tissues. Greater international collaboration, ethical oversight, and integration of fertility preservation into public health policies are essential to promote equitable, efficient, and sustainable reproductive healthcare worldwide.

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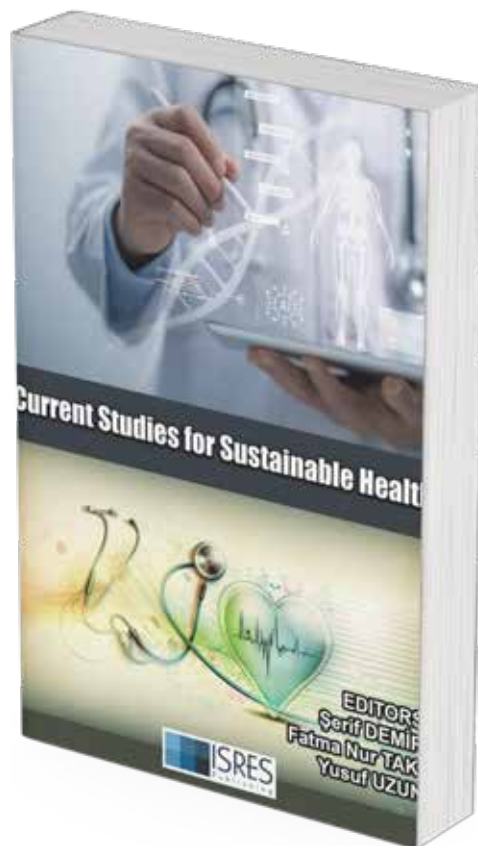
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