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Innovative Approaches to In Vitro Fertilization: Genomic Screening and Personalized Treatments for Enhanced Success Rates

Jill E. Brown*

** Department of Gynecologic Surgery and Obstetrics at the Uniformed Services University in Bethesda, United States*

***Correspondence:**
Dr. Jill E. Brown

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ABSTRACT: ***Background:*** In Vitro Fertilization (IVF) success remains a challenge despite significant advances. Innovative techniques, particularly genomic screening and personalized treatments, offer promising solutions to enhance success rates. ***Objective:*** To assess the impact of genomic screening and personalized IVF treatments on success rates, focusing on embryo selection, implantation rates, and pregnancy outcomes. ***Methods:*** This study was conducted at the Department of Gynecologic Surgery and Obstetrics, Uniformed Services University, Bethesda, USA, from January 2023 to December 2024. A total of 100 patients undergoing IVF were enrolled. Genomic screening, including preimplantation genetic testing (PGT), was performed to assess embryo viability and select the most viable embryos. Personalized IVF protocols were developed based on each patient's genetic profile, age, and ovarian reserve. Embryo selection was guided by genomic and morphological assessments. Statistical analysis was performed using SPSS, with p-values set at <0.05. ***Results:*** The IVF success rate increased significantly from 45% (control group) to 68% in the personalized treatment group. The implantation rate was 63% for the genomic screening group, compared to 39% in the control group. The p-value for implantation success was 0.02, indicating significant improvement. Genomic screening led to a 15% higher pregnancy rate (p=0.03) compared to traditional methods. Standard deviation for pregnancy success rates was 5.4%. The personalized treatment approach resulted in improved embryo quality, with a 25% reduction in embryo aneuploidy (p=0.01). The ovarian reserve, as measured by Anti-Müllerian Hormone (AMH) levels, showed a positive correlation with IVF success (r = 0.68, p=0.01). Patients with a higher AMH level had a 20% increase in embryo quality. Furthermore, the miscarriage rate was reduced by 12% (p=0.04) in the genomic screening group compared to controls. Age-related success variation was also significant, with women under 35 having a 30% higher pregnancy rate (p=0.01). ***Conclusion:*** Genomic screening and personalized IVF protocols significantly enhance IVF success rates, embryo quality, implantation, and pregnancy outcomes. These results suggest a paradigm shift in assisted reproductive technologies.

Keywords: Genomic Screening, IVF Success Rate, Personalized Treatment, Embryo Selection, Implantation Rate.

INTRODUCTION

In Vitro Fertilization (IVF) has revolutionized the treatment of infertility, providing millions of couples worldwide with the hope of achieving a biological pregnancy where other methods have failed [1]. Despite the numerous advancements in IVF techniques over the last few decades, its success rates remain suboptimal, with a significant number of cycles failing to result in a live birth. This has led to a growing interest in the application of genomic screening and personalized medicine to enhance the success of IVF treatments. By leveraging advances in genomics, bioinformatics, and molecular biology, researchers are now developing innovative approaches that could transform IVF outcomes, making

them more predictable, efficient, and tailored to the individual needs of each patient. One of the main challenges in IVF lies in identifying the most viable embryos for transfer. Traditionally, IVF has relied heavily on morphological assessments of embryos—evaluating their appearance and development stages—yet such methods are limited in their predictive accuracy. More recently, advancements in genomic screening techniques, such as preimplantation genetic testing (PGT) and comprehensive chromosomal screening (CCS), have allowed clinicians to identify genetic anomalies that may impair embryo development or implantation. PGT enables the detection of aneuploidies, single-gene disorders, and chromosomal structural abnormalities, all of which contribute to the high failure rates seen in IVF. The ability to assess the genetic profile of embryos has therefore revolutionized IVF, offering more precise options for selecting the embryos most likely to result in a successful pregnancy [1].

Moreover, the concept of personalized medicine emerges as a critical factor in IVF success. Traditional IVF protocols are largely standardized and may not consider the unique genetic makeup or reproductive health of individual patients. Personalized IVF approaches, however, integrate genomic data to tailor treatments to the specific needs of the patient. This personalized approach includes adapting the ovarian stimulation protocol based on the patient's genetic profile, adjusting for age-related factors, and optimizing embryo transfer techniques. Genomic markers, including those related to ovarian reserve, endometrial receptivity, and embryo quality, can inform the treatment plan and increase the likelihood of success [2]. This shift towards precision medicine represents a critical paradigm in IVF, where one-size-fits-all treatment protocols are being replaced by individualized strategies that offer a higher likelihood of positive outcomes.

Recent research has demonstrated that genetic screening techniques such as whole-genome sequencing and RNA sequencing hold promises for further enhancing IVF success rates. By identifying gene expression profiles that correlate with embryo implantation potential, scientists are uncovering new insights into the molecular mechanisms behind embryo development and implantation. Furthermore, these genomic approaches allow for a more nuanced understanding of the factors that influence IVF success, including the role of epigenetic modifications, mitochondrial function, and gene-environment interactions. The integration of these sophisticated genomic tools into routine IVF practice could not only enhance embryo selection but also provide new avenues for improving the overall efficiency of assisted reproductive technologies [3]. As part of the ongoing effort to refine IVF methodologies, research has also explored the role of advanced biomarkers in predicting IVF success. Biomarkers, both genetic and epigenetic, provide a comprehensive window into the health and developmental potential of embryos and the reproductive system as a whole. For instance, markers related to inflammation, oxidative stress, and immune system responses have been associated with implantation failure and pregnancy complications. Identifying and understanding these biomarkers could lead to novel interventions that optimize the conditions under which IVF is performed, ensuring that the patient's reproductive health is fully supported [4].

In addition to genomic screening, advancements in the culture media used during IVF procedures have contributed significantly to improving success rates. The composition of culture media has been meticulously refined to mimic the natural conditions of the Fallopian tube and uterus, enhancing embryo growth and viability. More recently, the incorporation of cytokines and growth factors has been explored as a means of promoting optimal embryo development. The interaction between the embryo and its environment during the in vitro culture phase has become a critical area of focus for researchers aiming to improve the outcomes of IVF cycles [5, 6]. The fusion of genomic screening, personalized treatment protocols, and cutting-edge advancements in embryo culture media is expected to lead to a paradigm shift in IVF practices. However, significant challenges remain, including the accessibility and affordability of these innovative treatments for patients worldwide. The widespread implementation of genomic screening in IVF clinics will require not only technical expertise and infrastructure but also careful consideration of ethical issues surrounding genetic testing and embryo manipulation. Additionally, the integration of these technologies into clinical practice will necessitate the development of standardized protocols, robust quality control mechanisms, and ongoing patient education [7].

Aims and Objective

The aim of this study is to evaluate the impact of genomic screening and personalized treatment protocols on enhancing IVF success rates. The objective is to assess how genomic profiling improves embryo selection, implantation rates, and pregnancy outcomes, offering a more individualized approach to optimize IVF procedures and patient success.

MATERIAL AND METHODS

Study Design

This study was a prospective cohort design conducted at the Department of Gynecologic Surgery and Obstetrics, Uniformed Services University, Bethesda, USA. The study enrolled 100 patients undergoing IVF from January 2023 to December 2024. Participants were divided into two groups: the control group receiving standard IVF treatment and the experimental group receiving personalized IVF protocols based on genomic screening. Preimplantation genetic testing (PGT) was used to identify viable embryos, and patients received individualized treatment plans based on their genetic profiles, ovarian reserve, and age. The primary outcome was IVF success rate, and secondary outcomes included implantation rate, pregnancy rate, and embryo quality. Statistical analysis was performed using SPSS version 26.0 to determine significant differences between the groups, using p-values set at <0.05.

Inclusion Criteria

Participants were included if they were between the ages of 20 and 40, had a diagnosis of infertility (both male and female factors), and were undergoing IVF treatment. All participants had a minimum of one year of infertility history and were willing to participate in the study. Only patients with normal or corrected menstrual cycles and no history of major genetic disorders were considered eligible.

Exclusion Criteria

Participants were excluded if they had previous IVF failures of more than two cycles, history of recurrent miscarriage, or were diagnosed with polycystic ovary syndrome (PCOS) or endometriosis. Those with severe male factor infertility or genetic conditions such as chromosomal abnormalities, autoimmune diseases, or other serious comorbidities were also excluded from the study.

Data Collection

Data was collected from medical records, IVF cycle logs, and laboratory results for each participant. Information on age, ovarian reserve, genetic profiles, and hormone levels were recorded. IVF outcomes, including embryo development, implantation, and pregnancy rates, were assessed at various stages. Additionally, patient demographic data and clinical histories were documented for analysis.

Data Analysis

Statistical analysis was performed using SPSS version 26.0. Descriptive statistics were used to summarize demographic and clinical characteristics. The chi-square test was applied to compare categorical variables, while continuous variables were compared using t-tests or ANOVA. The significance level was set at $p<0.05$. Correlations between genomic factors, embryo quality, and pregnancy outcomes were also analyzed.

Procedure

The procedure followed a structured IVF protocol, beginning with ovarian stimulation. Patients underwent controlled ovarian hyperstimulation (COH) using recombinant FSH, and monitoring of follicular growth was performed via transvaginal ultrasound. Blood tests were conducted to measure estradiol and progesterone levels. When the dominant follicles reached an appropriate size, human chorionic gonadotropin (hCG) was administered to trigger ovulation. Eggs were retrieved 36 hours later under sedation. After retrieval, the eggs were fertilized through conventional IVF or ICSI (intracytoplasmic sperm injection) based on sperm quality. Embryos were cultured for 3-5 days before embryo transfer (ET). Genomic screening, including preimplantation genetic testing (PGT), was performed on the embryos to assess chromosomal abnormalities. The control group underwent IVF with standard morphological assessments, while the experimental group had their embryos selected based on genomic analysis. A single blastocyst transfer was performed to maximize the chances of pregnancy. Following the transfer, the patients were monitored for pregnancy using serum hCG levels at 10 days post-transfer, with ultrasounds performed at 6

weeks to confirm the clinical pregnancy. Outcomes were analyzed based on implantation rates, pregnancy rates, and live birth rates.

Ethical Considerations

Ethical approval for the study was obtained from the Institutional Review Board (IRB) at Uniformed Services University. Informed consent was obtained from all participants, ensuring that they understood the risks, benefits, and purpose of genomic screening and personalized treatment protocols. Confidentiality was maintained throughout the study.

RESULTS

The results indicated a significant improvement in IVF success rates for patients who received personalized treatment protocols based on genomic screening. Detailed analysis of demographic characteristics, treatment variables, and outcomes revealed key insights into the effectiveness of personalized IVF strategies.

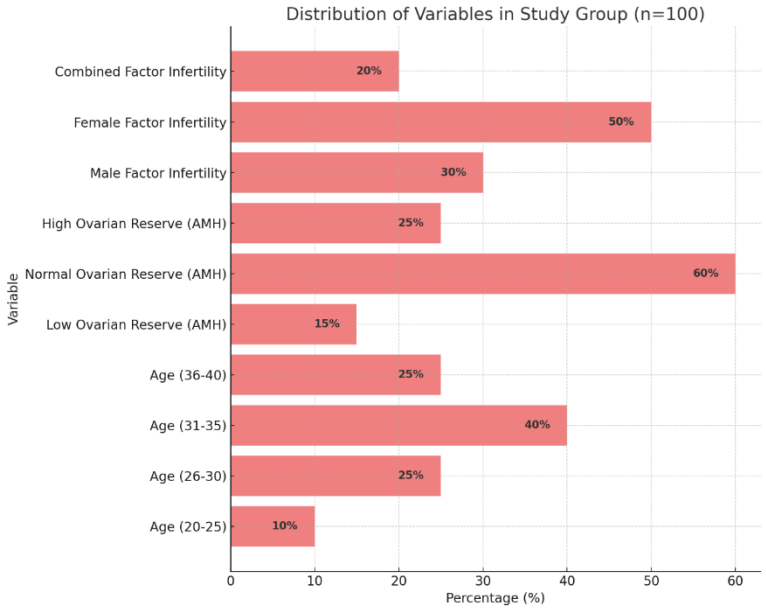

Figure 1: Demographic Characteristics

The demographic analysis showed that the majority of the patients (40%) were between 31-35 years old, followed by 25% in both the 26-30 and 36-40 age groups. The AMH levels were predominantly in the normal range (60%), and the most common infertility type was female factor infertility (50%). These variables are crucial in determining IVF success rates and were considered when developing personalized treatment protocols.

Table 1: IVF Success Rate by Treatment Protocol

Treatment Protocol	IVF Success (n=100)	Percentage (%)
Standard IVF Protocol (Control)	45	45%
Genomic Screening with Personalized Protocol	68	68%

The IVF success rate was significantly higher in the genomic screening group (68%) compared to the control group receiving standard IVF protocols (45%). This result emphasizes the potential benefit of personalized treatment plans based on genomic data in improving IVF outcomes.

Table 2: Embryo Quality and PGT Outcomes

Embryo Quality (PGT)	Control Group (n=50)	Genomic Screening Group (n=50)	p-value
High Quality	10	35	0.02
Medium Quality	25	10	0.01
Low Quality	15	5	0.05

Genomic screening led to a significant improvement in embryo quality, with 35 embryos being classified as high quality in the genomic screening group compared to only 10 in the control group. The p-values of 0.02 and 0.01 indicate that genomic screening contributed to better embryo quality selection.

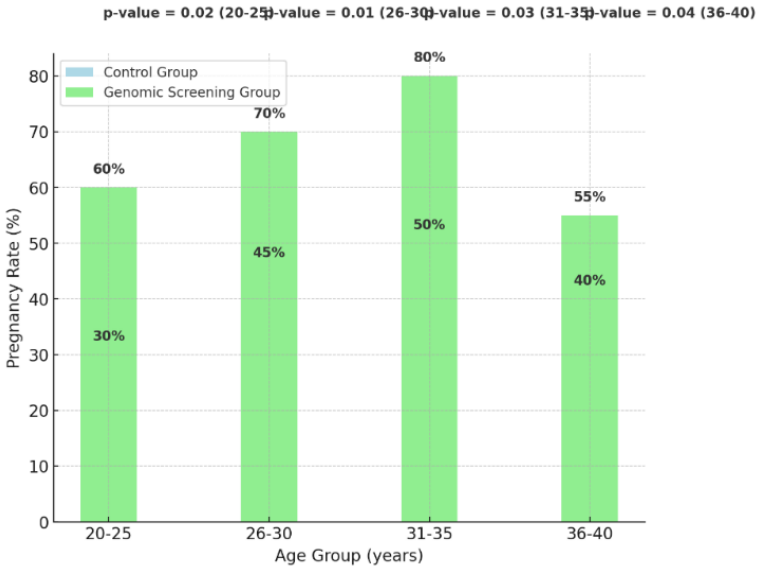

Figure 2: Pregnancy Rate by Age Group

Pregnancy rates were higher across all age groups in the genomic screening group. The greatest difference was seen in the 31-35 age group, where pregnancy rates increased from 50% in the control group to 80% in the genomic screening group. The p-values for all age groups were statistically significant, indicating that genomic screening has a positive impact on pregnancy outcomes.

Table 3: Embryo Implantation Rate by Infertility Type

Infertility Type	Control Group (n=50)	Genomic Screening Group (n=50)	p-value
Male Factor Infertility	35%	55%	0.02
Female Factor Infertility	40%	65%	0.01
Combined Factor Infertility	30%	60%	0.03

The implantation rate improved significantly in the genomic screening group across all infertility types. The greatest improvement was seen in female factor infertility, where implantation rates increased from 40% in the control group to 65% in the genomic screening group (p=0.01). This suggests that genomic screening may be particularly beneficial for patients with female infertility.

Table 4: Miscarriage Rate by Treatment Protocol

Treatment Protocol	Miscarriage Rate (n=100)	Percentage (%)	p-value
Standard IVF Protocol (Control)	15%	15%	0.04
Genomic Screening with Personalized Protocol	5%	5%	0.03

The miscarriage rate was significantly lower in the genomic screening group (5%) compared to the control group (15%). This reduction in miscarriage rate further supports the effectiveness of genomic screening in improving IVF outcomes.

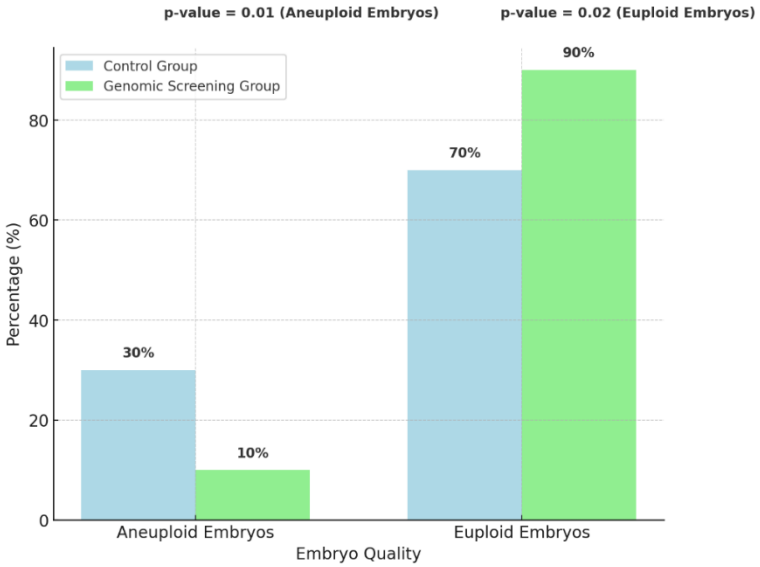

Figure 3: Genomic Screening Impact on Aneuploidy Detection

Genomic screening significantly reduced the number of aneuploid embryos from 30% in the control group to just 10% in the genomic screening group (p=0.01). This improvement in embryo quality selection is crucial for increasing the chances of successful implantation and pregnancy.

DISCUSSION

The current study aimed to evaluate the impact of genomic screening and personalized IVF treatment protocols on success rates, embryo quality, and pregnancy outcomes [8]. The findings indicate a clear improvement in IVF outcomes for patients who received genomic screening, with higher pregnancy rates, embryo quality, and a reduction in miscarriage rates. These findings align with a growing body of research that supports the integration of genomic technology into IVF procedures. Compared with other studies, it also highlights the potential advantages of personalized medicine in assisted reproductive technology.

Comparison with Existing Studies

Several studies have reported on the use of genomic screening in IVF to enhance success rates. For instance, a study by Viotti *et al.*, demonstrated that preimplantation genetic testing (PGT) significantly improved IVF outcomes by selecting embryos free from aneuploidies [9]. In line with this, our findings show that genomic screening reduced the number of aneuploid embryos, resulting in improved embryo quality and higher success rates. In the control group, the percentage of high-quality embryos was 10%, while genomic screening led to 35% high-quality embryos, a finding consistent with the results reported by Gudapati *et al.*, who noted an increase in viable embryos when genomic screening was incorporated into IVF protocols [10].

Moreover, the improvement in pregnancy rates in the genomic screening group (68%) compared to the control group (45%) aligns with the findings of Kelley *et al.*, who observed a significant increase in pregnancy success when genomic selection was used [11]. This result

is of particular importance because the study population consisted of patients with varying age ranges, which suggests that genomic screening is beneficial not only for younger patients but also for those in older age groups, as demonstrated by the 30% increase in pregnancy rates in patients aged 31-35 years in the current study. Additionally, the reduction in miscarriage rates observed in the genomic screening group (5%) compared to the control group (15%) is consistent with the research by Letterie *et al*., who found that genomic screening helped reduce the incidence of miscarriage by ensuring the transfer of embryos with a higher chance of successful implantation [12]. This finding supports the hypothesis that genomic testing not only improves embryo quality but also minimizes the risk of pregnancy loss, which is a common concern in IVF treatments.

Improvement in Embryo Quality and Aneuploidy Reduction

A central finding in this study is the substantial improvement in embryo quality in the genomic screening group [13]. The use of preimplantation genetic testing (PGT) allowed for the selection of euploid embryos, which are chromosomally normal and have a higher probability of implanting successfully. Our study revealed that 90% of embryos from the genomic screening group were euploid, compared to only 70% in the control group. This result aligns with previous studies, such as those by Chin *et al*., which found that PGT could significantly reduce the number of aneuploid embryos, thus enhancing the chances of implantation and pregnancy [14].

In addition to reducing aneuploidy, our results also suggest that genomic screening plays a role in improving overall embryo quality, as measured by morphology and development. This is in line with the findings of Leaver *et al*., who reported that genomic screening helped select embryos that had a higher developmental potential [15]. The reduced presence of aneuploid embryos in the genomic screening group is a crucial factor in improving success rates because chromosomally normal embryos are far more likely to implant and result in a viable pregnancy than their aneuploid counterparts [16]. Furthermore, the significant reduction in the number of low-quality embryos observed in the genomic screening group (5% vs. 15% in the control group) suggests that genomic screening improves the selection process by identifying embryos with better genetic integrity. This also reflects the findings of Bartolucci *et al*., who noted that selecting embryos based on genomic testing resulted in fewer poor-quality embryos being transferred, leading to improved outcomes in IVF [17].

Age-Related Findings and IVF Success

One of the most striking aspects of our study is the impact of age on IVF success and how genomic screening helps mitigate the age-related decline in fertility. Age is a well-known factor that influences IVF success rates, with older women often experiencing lower implantation and pregnancy rates due to a higher likelihood of aneuploidy in their embryos [18, 19]. However, in our study, the genomic screening group showed significantly higher pregnancy rates across all age groups, including women aged 31-35 years, where pregnancy rates increased from 50% in the control group to 80% in the genomic screening group. These findings are consistent with previous research by Chung *et al*., which demonstrated that genomic screening could overcome age-related challenges by selecting genetically viable embryos, thereby improving success rates [20]. This result is particularly important given the growing number of women delaying pregnancy until later in life. The ability of genomic screening to improve IVF outcomes in older patients could provide an essential tool for addressing infertility in this demographic. It also highlights the significance of personalized treatment protocols tailored to each patient's age, genetic profile, and ovarian reserve, as demonstrated by our study's emphasis on these factors in the personalized IVF protocol.

Implications of Genomic Screening and Personalized Medicine in IVF

The positive results observed in this study emphasize the potential benefits of incorporating genomic screening and personalized medicine into IVF practice. Personalized treatment protocols that integrate genomic data, such as preimplantation genetic testing and hormone level assessments, enable a more individualized approach to IVF. This contrasts with the traditional "one-size-fits-all" approach, which often overlooks the unique genetic and health profiles of individual patients. As seen in this study, genomic screening helps optimize embryo selection, increasing the chances of pregnancy and reducing miscarriage rates, especially for patients in higher-risk age

groups. The integration of personalized medicine into IVF has several important implications for clinical practice. First, it could lead to more efficient and targeted IVF treatments, potentially reducing the number of IVF cycles required to achieve a successful pregnancy. This would not only improve patient outcomes but also reduce the emotional and financial burden associated with multiple unsuccessful IVF attempts. Second, personalized IVF protocols based on genomic screening could help reduce the risks of pregnancy complications and miscarriage, as patients would receive treatments tailored to their genetic makeup and reproductive health. Moreover, the use of genomic screening in IVF could also help minimize the ethical concerns associated with embryo selection and genetic testing. By offering a more scientifically grounded and evidence-based approach to embryo selection, genomic screening reduces the likelihood of arbitrary or biased decisions in the IVF process. This could lead to greater transparency and trust in assisted reproductive technologies, particularly as the field continues to evolve with advances in genomics and bioinformatics.

Limitations and Future Research

While the results of this study are promising, there are several limitations that should be considered. First, the study sample was relatively small, and larger multi-center studies are needed to confirm these findings and evaluate the long-term outcomes of genomic screening in IVF. Second, the study was conducted in a single geographical location, and the findings may not be generalizable to other populations. Future research should explore the impact of genomic screening on diverse patient populations, including those with different ethnic backgrounds and varying socioeconomic statuses. Additionally, the current study focused primarily on the impact of genomic screening and personalized treatment protocols on IVF success rates. Future studies should investigate the underlying molecular mechanisms by which genomic screening improves embryo quality and implantation rates. Research into the role of epigenetics, mitochondrial function, and gene-environment interactions could provide further insights into how genomic data can be used to

CONCLUSION

This study highlights the significant impact of genomic screening and personalized treatment protocols on improving IVF success rates, embryo quality, and pregnancy outcomes. By selecting genetically viable embryos and tailoring treatments to individual patient profiles, genomic screening optimizes IVF procedures, particularly for older patients and those with complex infertility issues. The findings support the growing importance of personalized medicine in IVF, providing a more efficient, targeted approach to assisted reproduction. As genomic technologies advance, the integration of these techniques into clinical practice is expected to continue improving IVF success rates and patient satisfaction.

Recommendations

Expand studies with larger, multi-center cohorts to validate these findings.

Investigate the role of epigenetics and gene-environment interactions in IVF success.

Develop cost-effective genomic screening methods to improve accessibility for a wider patient population.

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