ORIGINAL ARTICLE

The Effects of Sperm Quality on Embryo Development: An Experience in an IVF Centre in Benin City

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ABSTRACT

Background: The introduction of intracytoplasmic sperm injection (ICSI) has brought hope to cases of severe male factor infertility. Despite widely reported success rates with ICSI, studies have shown that poor semen quality is associated with a reduced blastocyst formation rate, which may impair embryogenesis and lead to implantation failure. **Methods:** This was a cohort study of all couples undergoing ICSI at our Centre from 1 January 2024 to 31 December 2025. Couples were classified into three groups based on the WHO 2010 semen criteria. Group 1 (Grade 1 semen; normal parameters); group 2 (Grade 2 semen; mild OAT syndrome) with sperm concentration < 20×10^6/ml, motility < 50%, and morphology < 30% normal forms; and group 3 (Grade 3 semen; severe OAT syndrome) with sperm concentration < 1×10^6/ml, motility < 25%, and morphology < 10%. Oocyte retrieval was performed after standard ovarian stimulation using a short protocol. ICSI was used to inseminate the retrieved oocytes, and fertilization was confirmed 16-20 hours post-ICSI by the presence of pronuclei. Embryo cleavage was assessed 42-49 hours post-ICSI and graded based on shape, size, and degree of fragmentation. Embryo transfers were performed on days 3 to 5. Data are presented as mean ± standard error of the mean (SEM). Comparisons among the groups were performed using ANOVA for numerical parameters and the chi-square test for categorical variables. Data analysis was conducted using SPSS 11, with significance set at $p<0.05$. **Results:** A total of 65 couples were enrolled. Grade 1 semen accounted for 3.6% of samples, while the majority (96.4%) were grade 2, with no grade 3 cases. Although grade 1 semen exhibited a higher mean number of fertilized oocytes (71.0) than grade 2 semen (67.3), this difference was not statistically significant ($p=0.794$). There was no significant difference in the mean cleavage rate between the semen groups; however, grade 1 had a higher mean cleavage rate (75%) than grade 2 (46.2%). Grade 1 semen demonstrated a higher mean blastocyst formation rate (75.0%) than grade 2 (47.4%). **Conclusion:** The use of ICSI for male infertility is associated with high fertilization rates but lower cleavage and blastocyst rates. This may affect embryo quality, potentially leading to implantation failure. Therefore, we recommend that infertile males undergo thorough investigation and receive appropriate treatment to improve sperm quality before IVF.

Keywords: Intracytoplasmic Sperm Injection (ICSI), Embryo, Sperm quality, Fertilization

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Introduction

The success of in vitro fertilization (IVF) largely depends on embryo quality, which is determined primarily by nuclear content, mitochondrial function, and cytoplasmic maturity. [1] Oocyte quality remains central to female fertility. [2] Fertilization and subsequent embryo development are crucial and are influenced by age, the follicular microenvironment, and the cause of infertility. [3, 4]

Emerging evidence has demonstrated the importance of oocytes for embryo quality. The role of

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spermatozoa remains debated in the literature.[5-7] However, studies [8-10] have shown an inverse relationship between fertilization rate, embryo quality, and the presence of low-quality spermatozoa. Furthermore, sperm DNA fragmentation has been shown to negatively impact embryo quality, leading to reduced implantation rates and pregnancy outcomes.[11] Nevertheless, meta-analyses and the American Society for Reproductive Medicine practice guidelines do not currently recommend routine sperm DNA integrity testing in patients undergoing IVF.[1,12] Therefore, routine sperm DNA integrity testing is not offered to patients undergoing IVF at most centres.

Spermatozoa were previously thought to provide only genetic material for embryo formation. Recent studies [12, 13] have demonstrated that spermatozoa contribute not only their DNA but also structural components during embryo development. After fertilization, sperm-specific proteins and factors trigger Ca2+ oscillations that activate the oocyte, initiating a complex process of embryonic development that results in the formation of a zygote. [13] The zygote's nuclei are guided by sperm centrioles. The behaviour of sperm DNA structures, chromatin, and free RNAs tends to turn gene expression on or off during embryonic development. [14] These interactions highlight the important role of spermatozoa in oocyte activation, zygote formation, and the phenotype of the subsequent embryo.

The introduction of intracytoplasmic sperm injection (ICSI) in 1992 brought renewed hope to men with infertility who were otherwise considered to have untreatable conditions. [8, 15] The aim is to achieve fertilization despite numerous biological barriers. However, Loeb's principle has demonstrated that spermatozoa play a major role in cell division after fertilization. [16]

Despite the widely reported success rate of ICSI, studies have shown that poor semen quality is associated with a lower blastocyst formation rate, [8, 18] indicating that sperm quality significantly affects embryo development. Furthermore, studies have demonstrated that blastocyst formation rates are lower in ICSI than in IVF embryos.[14, 19] These findings, together with a broader understanding of sperm biology, have prompted detailed investigations into the mechanisms by which sperm influence embryo quality and development.

Although several researchers have demonstrated the role of sperm in embryo development, the debate continues over whether sperm quality can influence this process. This study aimed to establish a relationship between sperm quality and embryo development.

Methods

This cohort study included all couples who underwent ICSI at our centre between January 2023 and December 2024. Couples were grouped by sperm parameters using the WHO criteria. Grade 1: semen with normal parameters—sperm concentration (20 × 10^6/ml), motility (50%), and morphology (30% normal forms). Grade 2: semen with mild OAT syndrome—sperm concentration < 20 × 10^6/ml, motility < 50%, and morphology < 30% normal forms. Grade 3: semen with severe OAT syndrome—sperm concentration < 1 × 10^6/ml, motility < 25%, and morphology < 10%.

Semen was collected on the day of oocyte retrieval and allowed to liquefy. Origi gradients reagent (Cooper Surgical, Inc., USA) was then added at 80% and 55%, and the mixture was centrifuged at 1500 rpm for 20 min. The subsequent pellet was washed with 5 mL of sperm preparation medium at 1100 rpm for 5 min. The final solution was maintained at 37°C until insemination.

Oocyte retrieval was performed after standard ovarian stimulation with a short regimen. The retrieved oocytes were stripped of their surrounding cumulus cells with hyaluronidase. ICSI was then performed, and fertilization was confirmed 16-20 hours later by the presence of pronuclei. The cleavage stage was assessed 42-49 hours post-ICSI and graded according to shape, size, and degree of fragmentation. Embryo transfers were performed on day 3 and day 5, depending on the number and quality of available embryos. Data are presented as mean ± standard error of the mean (SEM). Comparisons between groups were performed using ANOVA for numerical data and the chi-square test for categorical data. Data analysis was conducted using SPSS 11 at the 0.05 significance level. Ethical approval was obtained from the Ethical and Research Committee of the University of Benin Teaching Hospital.

Results

A total of 65 couples who underwent ICSI during the study period were included.

Table 1: Age and Semen characteristics of participants

Variables	Semen Characteristics Mean(SEM)		
Age (years)	Count (x 10^6/ml)	Motility(%)	Morphology (%)
20-30	8.3 (5.8)	10.3 (2.3)	9.0 (1.5)
31-40	16.1 (1.9)	21.6 (2.1)	13.0 (4.5)
41-50	17.1 (2.9)	20.9 (2.4)	14.0 (1.1)
>50	10.6 (3.7)	19.5 (4.5)	11.4 (2.0)
P-value	0.552	0.561	0.723

Table 1 presents the age range of the study participants, along with semen parameters (count, morphology, and motility). There was no statistically significant difference in the mean semen parameters across the age groups.

Table 2: Semen grade of participant

Variables	Frequency	Percentage (%)
Grade 1	2	3.6
Grade 2	53	96.4
Grade 3	0	0.0

Considering the semen grade of the study participants (Table 2), over 95% had grade 2 semen parameters, and none had grade 3.

Table 3: Semen characteristics and number of M11 Fertilized

Variables	Number of M11 Fertilized Mean (SEM)
Semen characteristics	
Grade 1	71.0 (4.0)
Grade 2	67.3 (2.7)
Grade 3	0.0 (0.0)
P-value	0.794

Table 3 compares the semen grades with the mean number of M11 fertilized. There was no statistically significant difference in semen grade between M11 fertilization. Grade 1 semen parameters had a higher mean of approximately 71.0 compared with grade 2 semen parameters (67.3).

Table 4: Semen characteristics and number of embryos cleaved

Variables	Number embryo cleaved Mean (SEM)
Semen characteristics	
Grade 1	75.0 (0.0)
Grade 2	46.2 (3.3)
Grade 3	0.0 (0.0)
P-value	0.096

Table 4 shows the relationship between semen grade and the cleavage stage following fertilization. There was no statistically significant difference between the semen grade and the mean cleavage rate. However, the

grade 1 group had a mean cleavage rate of 75, which was higher than that of the grade 2 group, which was 46.2

Table 5: Semen characteristics and blastocyst formation of participants

Variables	Blastocyst formation Mean (SEM)
Semen characteristics	
Grade 1	75.0 (0.0)
Grade 2	47.4 (3.3)
Grade 3	0.0 (0.0)
P-value	0.214

The Grade 1 group had a higher blastocyst formation rate (mean 75.0), whereas the Grade 2 group had a lower rate (mean 47.4), Table 5. However, this difference was not statistically significant.

Discussion

This study, within the limits of the available data, has shown that spermatozoa not only provide genetic material during fertilization but are also fundamental to oocyte activation, and that their genome is crucial for embryogenesis.[18] In this study, there was no statistically significant difference in sperm parameters or participants' age, as in the study by Aghajanova et al.[1, 22] Furthermore, a recent meta-analysis found no association between paternal age and embryonic development.[18] Instead, sperm quality and the ability to initiate intracellular Ca+ oscillations culminate in oocyte activation. However, reduced fertilization and cleavage rates are associated with poor semen parameters, highlighting the importance of the paternal role in embryonic development.

Similarly, Loutradi et al.[8] reported that their current research supports earlier observations that poor semen parameters are associated with reduced fertilization and cleavage rates. However, the reduction observed was not comparable to that observed at the late embryonic stage. This is because the early embryo's genomic activity relies on inherited maternal mRNA, whereas the paternal contribution becomes fully involved from the 8-cell stage onwards [4, 19]

While in early embryogenesis, the paternal factor only exhibits a slight transcriptional influence on the oocyte machinery in modifying sperm chromatin in the development of the pronuclei after fertilization. [12, 20] Furthermore, the paternal epigenetic factor phospholipase C-zeta (PLCζ) regulates the Ca+ oscillations required for oocyte activation.[21] Failure of these factors and the inability of the sperm to produce a functional centrosome may lead to abnormal spindle formation and cleavage arrest in early embryogenesis.[8, 10, 22]

As demonstrated in previous studies,[1, 8, 22] our study identified a lower blastocyst development rate in patients with poor semen parameters. This underscores the vital role of paternal influence on the genome during the later stages of embryogenesis. This critical function is preserved by the DNA quality in the sperm head, which is often affected by protamine deposition during spermiogenesis[18]. Inadequate protamine levels lead to DNA fragmentation, which has been observed to be significantly higher in low-quality sperm.[8,22]

Limitations of the Study

This was a hospital-based study and may not be representative of the general population. A multicenter study with a larger dataset may be required to strengthen this assertion.

Conclusion

The use of ICSI to treat male infertility is promising; however, it presents several challenges that must be carefully considered in future studies. This process may yield a high fertilization rate, but cleavage and blastocyst rates may be compromised. These overall effects may compromise embryo quality, leading to implantation failure. Therefore, the cause of male infertility should be investigated, and appropriate treatment should be sought to forestall the short-lived hope that may be associated with ICSI and low-quality semen.

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