RESEARCH PAPER

"THE EFFECT OF ORAL ZINC SUPPLEMENTATION ON SERUM BILIRUBIN LEVELS IN TERM NEONATES WITH HYPERBILIRUBINEMIA UNDERGOING PHOTOTHERAPY-DOUBLE BLINDED RCT"

Dr Harsha Gopinath[1], Dr Narendra K.S[2]*, Dr K.B Mahendrappa[3], Dr Nandakumar[4], Dr Meghana S K[5], Dr Keerthi R[6]

[1]Junior Resident, 3rd Year, Department of Paediatrics, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, Mandya District, Karnataka – 571448, India.

[2]Associate Professor, Department of Paediatrics, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, Mandya District, Karnataka – 571448, India.*

[3]Professor and Head, Department of Paediatrics, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, Mandya District, Karnataka – 571448, India.

[4]Associate Professor, Department of Paediatrics , Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, Mandya District, Karnataka – 571448, India.

[5]Assistant Professor, Department of Paediatrics, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, Mandya District, Karnataka – 571448, India.

[6]Assistant Professor, Department of Community Medicine, Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, B.G. Nagara, Mandya District, Karnataka – 571448, India.

Corresponding author: Dr. K. S Narendra, narendraks@yahoo.com

ABSTRACT

Background: Neonatal hyperbilirubinemia is a common condition that may require the phototherapy or other interventions to the prevent complications. Zinc has been explored for its potential antioxidative and enterohepatic interrupting effects on bilirubin metabolism.

Objectives: To determine the effect of oral zinc supplementation on hyperbilirubinemia in term neonates undergoing phototherapy.

Methods: This prospective, randomized placebo-controlled study included term neonates with hyperbilirubinemia who received either oral zinc supplementation or placebo. Maternal and neonatal baseline characteristics were recorded, including gestational age, birth weight, sex and Apgar scores. Serum total bilirubin levels was measured at baseline and at 24, 48, and 72 hours. Duration of phototherapy and the incidence of the adverse effects were also evaluated.

Results: Baseline maternal and neonatal characteristics were comparable between groups, except for gestational age, which was significantly higher in the zinc group ($p = 0.033$). Baseline total serum bilirubin (TSB) levels were similar ($p = 0.945$), but were significantly lower in the zinc group at 24 hours ($p = 0.011$), 48 hours ($p < 0.001$), and 72 hours ($p < 0.001$). Phototherapy duration was significantly shorter in the zinc group (29.54 ± 7.66hours) than placebo (41.18 ± 9.70 hours; $p < 0.001$).

Adverse events such as vomiting, diarrhoea, rash, and irritability were mild and comparable between groups, with no statistically significant difference ($p > 0.05$), indicating good tolerability of zinc.

Conclusion: Oral zinc supplementation in term neonates with hyperbilirubinemia significantly accelerated the reduction in serum bilirubin levels and reduced the duration of phototherapy without increasing adverse effects, suggesting that zinc may be a beneficial adjunct in the management of neonatal jaundice. Here the sample size is small, so future studies should aim to include a larger and more neonatal population across multiple centres to validate and strengthen the findings.

Keywords: Neonatal hyperbilirubinemia, zinc supplementation, bilirubin, phototherapy, jaundice, neonates, randomized controlled trial, adverse effects

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INTRODUCTION

Neonatal hyperbilirubinemia (NNHB) is a common clinical concern, affecting approximately 60% of term and 80% of preterm neonates during the first week of life. It manifests as a yellowish discoloration of the skin and sclera, resulting from bilirubin deposition in tissues. [1] Almost all neonates develop unconjugated serum bilirubin levels exceeding 30 mmol/L (1.8 mg/dL) in this period. [2] While most cases are benign and self-limiting, it is crucial to identify infants at risk of severe NNHB to prevent complications such as kernicterus and irreversible neurological injury. [3]

The physiological rise in bilirubin levels is attributed to increased breakdown of fetal haemoglobin, immature hepatic conjugation pathways, and enhanced enterohepatic circulation. [4,5] Bilirubin levels typically peak between days 5 and 7 before declining. In pathological conditions, however, bilirubin can accumulate

excessively, and due to its lipid solubility, unconjugated bilirubin crosses the blood–brain barrier at high concentrations, leading to bilirubin-induced neurologic dysfunction (BIND).[6] NNHB can be classified into unconjugated (indirect) and conjugated (direct) forms, with unconjugated hyperbilirubinemia (UHB) being more common. Physiologic jaundice appears after 24 hours, peaks at 48–96 hours, and usually resolves within two to three weeks in term infants. [7] In contrast, pathologic UHB presents within the first 24 hours of life, with rapid rises in bilirubin exceeding age-specific thresholds. [2]

Although phototherapy is the cornerstone of NNHB management, it is not without limitations. Prolonged exposure may result in dehydration, thermal instability, retinal injury, and longer hospital stays, all of which increase healthcare costs. [8,9] These challenges highlight the importance of exploring adjunctive therapies that could enhance bilirubin clearance while reducing the intensity and duration of phototherapy.

Zinc supplementation has emerged as a promising option in this context. Zinc plays a vital role in enzyme function, cellular repair, and antioxidant defence. It is hypothesized to aid bilirubin excretion by binding unconjugated bilirubin in the intestinal lumen, thereby reducing its enterohepatic circulation. [10] Preclinical studies demonstrated reductions in serum bilirubin following zinc administration, encouraging clinical trials in neonates.

The clinical evidence, however, remains mixed. Some randomized controlled trials (RCTs) have reported significant benefits. For instance, Nikouei et al. (2024)11 found greater bilirubin reduction, shorter hospitalization, and fewer phototherapy hours with zinc supplementation, while Mandlecha et al. (2023)12 demonstrated decreased bilirubin levels and phototherapy needs in term neonates. Likewise, Hashemian et al. (2017)13 and Ibrahim et al. (2020)14 observed improvements in bilirubin decline and phototherapy duration. In contrast, studies by Kumar et al.[15],16(2014, 2024) and systematic reviews such as Yang et al. (2018)17 and Almarhoon & Aljarwan (2024)18 concluded that zinc does not consistently reduce serum bilirubin, though it may shorten phototherapy. Yang et al. (2018),17 Almarhoon & Aljarwan (2024)18, and Ghadirzadeh et al. (2025)19 concluded that zinc supplementation does not significantly reduce hyperbilirubinemia incidence or the need for phototherapy but is consistently associated with a shorter phototherapy duration and minimal adverse effects.

Given this background, the role of zinc supplementation in NNHB management remains clinically relevant but scientifically uncertain. Its potential as an adjunct therapy is particularly important in low- and middle-income countries, where prolonged phototherapy burdens healthcare systems. This thesis seeks to add to the existing body of evidence by evaluating the impact of zinc supplementation on neonatal hyperbilirubinemia, with particular focus on serum bilirubin levels, phototherapy duration, and associated clinical outcomes.

MATERIALS AND METHODS

- **STUDY DESIGN**: Hospital-based randomized, double-blind, controlled clinical trial
- **STUDY PLACE :** Department of Paediatrics – Post Natal Ward and Neonatal Intensive Care Unit at AIMS, Mandya
- **SAMPLING METHOD:** Purposive sampling
- **STUDY POPULATION**: A minimum of 100 term neonates with hyperbilirubinemia admitted to the neonatal intensive care unit. The sample size was calculated from a study conducted by Ashok Kumar et al., using the formula:

$$\sqrt{\frac{(n1-1)SD1+(n2-1)SD2}{n1+n2-2}}$$

$$(40-1)2+(39)(1.2)40+40=78+46.878=1.2$$

$$N=2\times(1.2)2\times(Z\alpha/2\times Z\beta/2)2/d2=2\times1.44\times(2.8)2/(0.6)2=62.72$$

STUDY PERIOD: The study was carried out over a period of 18 months, from May 2024 to December 2025

Inclusion Criteria:

- Term neonates delivered at Adichunchanagiri Institute of Medical Sciences, B G Nagara, diagnosed with neonatal hyperbilirubinemia requiring phototherapy (based on Bhutani chart).

Exclusion Criteria:

- Preterm neonates
- Neonates with systemic illness or severe sepsis
- Neonates with direct hyperbilirubinemia
- Severe respiratory disease requiring mechanical ventilation
- Major congenital anomalies (gastrointestinal malformations, heart defects, neural tube defects)
- Patients who refused to stay for the study duration, the one who has not given the consent.

Method of Collection of Data

This study was designed as a randomized, double-blind, placebo-controlled clinical trial conducted in term neonates diagnosed with neonatal hyperbilirubinemia requiring phototherapy. Written and informed consent was obtained from the parents or guardians of all neonates. Eligible neonates were randomized into two groups—the zinc group and the placebo group—using generalized random sequences in permuted blocks of two to ensure allocation concealment. Blinding and randomization was done, all enrolled neonates received phototherapy using identical, calibrated Brilliance PRO Phoenix phototherapy devices, each equipped with 9 LED bulbs, delivering a minimum irradiance of 30 μW/cm²/nm from a fixed distance of 25 cm. In addition to phototherapy, neonates in the zinc group received 5 mg of elemental zinc once daily (0.25 mL of syrup containing 20 mg/mL zinc sulphate), while those in the placebo group received 0.25 mL of a 5% sucrose solution (using 22.5 g sucrose in 450 mL of distilled water). The zinc and placebo solutions were identical in colour, volume, and packaging, and administration was done using syringes, with all syrups coded and blinded to participants, caregivers and investigators until study completion. Breastfeeding was allowed on demand throughout the treatment period. Phototherapy was provided according to unit policy, and treatment was discontinued if serum bilirubin levels dropped below the threshold defined by the American Academy of Paediatrics (AAP) guidelines. Bilirubin levels were measured at baseline at 24, 48, and 72 hours, and as clinically indicated as per NICU guidelines. Neonates were assessed twice daily for clinical stability and any adverse effects. Outcome measures included total bilirubin reduction rates, duration of phototherapy, length of hospital stay, and the incidence of adverse effects such as vomiting, diarrhoea, rash, excessive crying, or irritability, which were documented for both groups. Guardians were informed that the intervention would be discontinued if any of these side effects were observed.

Statistical Data Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 24.0. Differences between groups were compared using Student's t-test and ANOVA for numerical variables, and the Chi-square test for categorical variables. Differences were considered statistically significant at $p < 0.05$.

RESULTS

Table 1. Maternal Age Distribution by Group

Maternal Age (Years)	Zinc Group	Placebo Group	p-value
19-20 years	5 (10.0%)	3 (6.0%)	**0.474**
21–25 years	14 (28.0%)	13 (26.0%)	
26–30 years	17 (34.0%)	20 (40.0%)	
31–35 years	12 (24.0%)	11 (22.0%)	
35-40 years	2 (4.0%)	3 (6.0%)	
Total	**50 (100%)**	**50 (100%)**	

The maternal age distribution shows a fairly balanced pattern between the zinc and placebo groups, with no statistically significant difference ($p = 0.474$). In the zinc group, the majority of mothers fell within the 26–30-year age range (34%), followed by those aged 21–25 (28%) and 31–35 (24%). The placebo group showed a similar distribution, with the highest proportion also in the 26–30-year range (40%), then 21–25 (26%), and 31–35 (22%). Smaller proportions were observed in the youngest (19–20 years) and oldest (35–40 years) age categories in both groups.

Table 2. Gestational Age (weeks) × Group

Gestational Age	Zinc Group	Placebo Group	p-value
37 weeks	2 (4.0%)	13 (26.0%)	0.033
38 weeks	21 (42.0%)	14 (28.0%)	
39 weeks	18 (36.0%)	15 (30.0%)	
40 weeks	5 (10.0%)	6 (12.0%)	
41 weeks	4 (8.0%)	2 (4.0%)	
Total	50 (100.0%)	50 (100.0%)	

There was a statistically significant difference in gestational age distribution between the groups ($p = 0.033$). A notable proportion of the placebo group delivered at 37 weeks (26%) compared to only 4% in the zinc group. Conversely, more neonates in the zinc group were born at 38 weeks (42%) versus 28% in the placebo group. Distributions for 39 and 40 weeks were comparable, and 41-week gestation was more frequent in the zinc group (8%) than in the placebo group (4%).

Table 3. Birth Weight

Parameter	Zinc Group	Placebo Group	p-value
Birth Weight (g)	3194.72 ± 310.51	3194.34 ± 294.93	0.995

Birth weights between the two groups were nearly identical, with a mean of approximately 3194 grams in both groups and no statistically significant difference ($p = 0.995$), indicating comparable neonatal weight status at birth.

Table 4. Sex × Group

Sex	Zinc Group	Placebo Group	p-value
Female	27 (54.0%)	28 (56.0%)	0.841
Male	23 (46.0%)	22 (44.0%)	
Total	50 (100.0%)	50 (100.0%)	

The sex distribution of neonates was nearly equal across both groups, with females comprising 54% in the zinc group and 56% in the placebo group. Males made up 46% and 44% respectively. This distribution was not statistically significant ($p = 0.841$), confirming gender balance between the groups.

Table 5. Apgar Score at 1 Minute × Group

Apgar Score (1 min)	Zinc Group	Placebo Group	p-value
6	11 (22.0%)	14 (28.0%)	0.549
7	12 (24.0%)	16 (32.0%)	
8	12 (24.0%)	10 (20.0%)	
9	15 (30.0%)	10 (20.0%)	
Total	50 (100.0%)	50 (100.0%)	

At one minute after birth, Apgar scores were comparable between groups (p = 0.549). In both groups, most neonates scored between 6 and 9. The zinc group had a slightly higher proportion of neonates scoring 9 (30%) than the placebo group (20%), while the placebo group had more neonates scoring 7 (32%) compared to the zinc group (24%).

Table 6. Apgar Score at 5 Minutes × Group

Apgar Score (5 min)	Zinc Group	Placebo Group	p-value
8	22 (44.0%)	21 (42.0%)	0.84
9	28 (56.0%)	29 (58.0%)	
Total	50 (100.0%)	50 (100.0%)	

Apgar scores at five minutes post-birth were slightly better but not significantly different between groups (p = 0.840). In both groups, the majority of neonates scored 9 (56% in the zinc group and 58% in the placebo group), with the rest scoring 8.

Table 7. Total Serum Bilirubin (TSB)

Time Point	Zinc Group	Placebo Group	p-value
Baseline	16.25 ± 2.08	16.28 ± 2.23	0.945
24 hours	12.72 ± 2.08	13.84 ± 2.23	0.011
48 hours	10.51 ± 2.07	12.34 ± 2.26	<0.001
72 hours	8.77 ± 2.14	11.24 ± 2.37	<0.001

A significant finding in this study was the progressive reduction in TSB levels in the zinc group compared to the placebo group, beginning from 24 hours post-baseline. At baseline, levels were similar (16.25 vs.[16].28 mg/dL, p = 0.945), but at 24 hours, the zinc group showed significantly lower TSB (12.72 vs.[13].84 mg/dL, p = 0.011), with the difference widening further at 48 hours (10.51 vs.[12].34 mg/dL, p < 0.001) and 72 hours (8.77 vs.[11].24 mg/dL, p < 0.001), suggesting that zinc supplementation may accelerate bilirubin clearance.

Table 8. Phototherapy Duration

Parameter	Zinc Group	Placebo Group	p-value
Phototherapy (hrs)	29.54 ± 7.66	41.18 ± 9.70	<0.001

The zinc group required significantly less phototherapy compared to the placebo group, with an average duration of 29.54 hours versus 41.18 hours (p < 0.001). This reinforces the clinical relevance of the bilirubin reduction findings, indicating a potential therapeutic benefit of zinc in reducing the burden of phototherapy.

Table 9. Adverse Event × Group

Adverse Event	Zinc Group	Placebo Group	p-value
Yes	8 (16.0%)	5 (10.0%)	0.372
No	42 (84.0%)	45 (90.0%)	
Total	50 (100.0%)	50 (100.0%)	

Overall, 16% of neonates in the zinc group experienced at least one adverse event, compared to 10% in the placebo group. While slightly higher in the zinc group, this difference was not statistically significant (p = 0.372), indicating that zinc supplementation was generally well tolerated.

Table 10. Adverse effects spectrum × Group

Adverse effects spectrum	Zinc Group	Placebo Group	p-value
Vomiting	3 (6.0%)	2 (4.0%)	0.646
Diarrhea	2 (4.0%)	0 (0.0%)	0.153
Rash	1 (2.0%)	1 (2.0%)	1.00
Irritability	2 (4.0%)	2 (4.0%)	1.00

Adverse events were infrequent and generally mild, with no statistically significant differences between the two groups for any of the events recorded. Vomiting occurred in 6% of the zinc group vs. 4% of the placebo group (p = 0.646), diarrhea in 4% vs. 0% (p = 0.153), and rash in 2% of both groups (p = 1.000). Irritability was reported in 4% of neonates in each group (p = 1.000).

DISCUSSION

Neonatal hyperbilirubinemia is one of the most frequently encountered clinical conditions in the neonatal period and remains a major cause of neonatal hospitalization worldwide. Approximately 60% of term and 80% of preterm infants develop jaundice during the first week of life, although only a subset requires therapeutic intervention. Despite the widespread availability and effectiveness of phototherapy, prolonged treatment duration, increased hospitalization, separation of mother and infant, and healthcare costs continue to pose challenges. Consequently, there has been growing interest in identifying safe, inexpensive, and effective adjunctive therapies that can enhance bilirubin elimination and reduce the duration of phototherapy. Zinc supplementation has emerged as a potential therapeutic option because of its ability to interfere with the enterohepatic circulation of bilirubin. The present randomized placebo-controlled study was undertaken to evaluate the efficacy and safety of oral zinc supplementation as an adjunct to phototherapy in term neonates with unconjugated hyperbilirubinemia.

The baseline demographic characteristics of the study population were generally comparable between the zinc and placebo groups. Maternal age distribution did not differ significantly between groups (p = 0.474), with most mothers belonging to the 21–30-year age category. Maternal age is an important demographic variable because extreme maternal ages have been associated with adverse neonatal outcomes; however, the similarity observed between groups indicates that maternal age was

unlikely to influence the study outcomes. Similarly, birth weight was almost identical between the groups (3194.72 ± 310.51 g vs. 3194.34 ± 294.93 g, p = 0.995). Birth weight has been recognized as a determinant of bilirubin metabolism and neonatal adaptation; therefore, comparable birth weights further strengthen the internal validity of the study.

The sex distribution was also balanced, with females accounting for 54% of neonates in the zinc group and 56% in the placebo group (p = 0.841). Previous studies have suggested that male neonates may have a slightly higher risk of significant hyperbilirubinemia, although the evidence remains inconsistent. The nearly equal sex distribution observed in this study minimizes the possibility of sex-related confounding. Likewise, Apgar scores at both one and five minutes were comparable between the groups, indicating similar perinatal adaptation and neonatal health status at birth. These findings suggest that the two groups were well matched with respect to important baseline characteristics.

A statistically significant difference was observed in gestational age distribution (p = 0.033), with a greater proportion of neonates in the placebo group being born at 37 weeks and more neonates in the zinc group being born at 38–39 weeks. Gestational age is a recognized determinant of bilirubin metabolism because relatively less mature infants may exhibit delayed hepatic conjugation and increased enterohepatic circulation. Nevertheless, all enrolled neonates were term infants, and the overall gestational age range was narrow. Therefore, although this difference should be acknowledged, its clinical impact on the study outcomes is likely limited.

The most important finding of the present study was the significantly greater reduction in total serum bilirubin (TSB) levels among neonates receiving zinc supplementation. At baseline, mean bilirubin concentrations were nearly identical between the groups (16.25 ± 2.08 mg/dL vs.[16].28 ± 2.23 mg/dL, p = 0.945), confirming comparable disease severity at enrollment. Following initiation of treatment, bilirubin levels declined in both groups as expected due to phototherapy; however, the decline was significantly more rapid in the zinc group. At 24 hours, mean TSB levels were significantly lower in the zinc group than in the placebo group (12.72 ± 2.08 mg/dL vs.[13].84 ± 2.23 mg/dL, p = 0.011). The difference became more pronounced at 48 hours (10.51 ± 2.07 mg/dL vs.[12].34 ± 2.26 mg/dL, p < 0.001) and persisted at 72 hours (8.77 ± 2.14 mg/dL vs.[11].24 ± 2.37 mg/dL, p < 0.001).

The progressive widening of the difference in bilirubin levels over time suggests a sustained therapeutic effect of zinc supplementation. While phototherapy converts bilirubin into water-soluble photoisomers that can be excreted without conjugation, zinc appears to act through a complementary mechanism. Experimental studies have demonstrated that zinc salts can bind unconjugated bilirubin within the intestinal lumen, thereby preventing its reabsorption and reducing enterohepatic circulation. Since enterohepatic recycling contributes substantially to neonatal hyperbilirubinemia, particularly during the first few days of life, interruption of this cycle may accelerate bilirubin elimination. Zinc may also reduce intestinal β-glucuronidase activity, thereby limiting the deconjugation of bilirubin and further decreasing its reabsorption. These mechanisms provide a biologically plausible explanation for the enhanced bilirubin reduction observed in the zinc-treated group.

The findings of the present study are in agreement with several previous investigations. Kumar et al. reported a significantly greater decline in serum bilirubin levels among neonates receiving oral zinc supplementation compared with controls. Ahmadpour-Kacho et al. similarly demonstrated accelerated bilirubin reduction in zinc-treated neonates, supporting the hypothesis that zinc enhances bilirubin elimination. Rana et al. also observed lower bilirubin concentrations and improved treatment outcomes among infants receiving adjunctive zinc therapy. Furthermore, systematic reviews and meta-analyses have suggested that zinc supplementation may contribute to faster bilirubin decline and shorter treatment duration, although the magnitude of benefit varies across studies.

However, not all published studies have reported a significant therapeutic effect of zinc. Some investigators have found no meaningful differences in bilirubin reduction between zinc-treated and placebo-treated neonates. The discrepancies among studies may be attributable to differences in study design, sample size, dosage and formulation of zinc, timing of initiation, severity of hyperbilirubinemia, duration of treatment, and inclusion criteria. Variations in feeding practices and ethnic differences in bilirubin metabolism may also contribute to inconsistent findings. Nevertheless, the significant reductions observed consistently at multiple time points in the present study provide strong evidence supporting a beneficial role of zinc supplementation.

An equally important finding was the significant reduction in phototherapy duration among neonates receiving zinc supplementation. The mean duration of phototherapy was 29.54 ± 7.66 hours in the zinc group compared with 41.18 ± 9.70 hours in the placebo group (p < 0.001). This represents a reduction of approximately 11.6 hours, which is clinically meaningful. Shortening the duration of phototherapy has several potential benefits. Reduced exposure to phototherapy may decrease fluid loss, thermal instability, skin rash, and disruption of maternal–infant interaction. Additionally, shorter treatment duration may facilitate earlier discharge, improve bed availability in neonatal units, reduce healthcare expenditure, and lessen parental anxiety. In resource-limited settings, where the burden of neonatal jaundice remains substantial, such reductions may have important public health implications.

The safety profile of zinc supplementation observed in this study was reassuring. Although adverse events were reported in 16% of neonates in the zinc group compared with 10% in the placebo group, the difference was not statistically significant (p = 0.372). Furthermore, the adverse events documented were mild and self-limiting. Vomiting occurred in 6% of neonates receiving zinc and 4% receiving placebo, while diarrhea was reported only in two neonates in the zinc group. Rash and irritability occurred infrequently and with equal frequency in both groups. Importantly, no serious adverse events attributable to zinc supplementation were observed. These findings are consistent with previous clinical trials demonstrating that oral zinc is generally safe and well tolerated in neonates. Given that zinc is an essential micronutrient with an established safety profile, its use as an adjunctive therapy appears attractive from a clinical perspective.

The present study possesses several strengths. The randomized placebo-controlled design minimizes selection bias and enhances the validity of the findings. Baseline comparability of most demographic and clinical variables ensures that differences in outcomes are likely attributable to the intervention. Serial bilirubin measurements at predefined intervals allowed detailed assessment of treatment response over time. Furthermore, both efficacy and safety outcomes were evaluated, providing a comprehensive assessment of zinc supplementation in neonatal hyperbilirubinemia.

Despite these strengths, certain limitations should be acknowledged. The study was conducted at a single center, which may limit the generalizability of the findings. The sample size, although adequate to demonstrate significant differences in primary outcomes, remains relatively modest. Serum zinc levels were not measured before or after supplementation; therefore, the relationship between zinc status and treatment response could not be evaluated. Long-term neurodevelopmental outcomes were not assessed. Additionally, the significant difference in gestational age distribution between groups may have introduced some degree of confounding, although all neonates were term infants. Future multicenter randomized controlled trials involving larger populations, standardized zinc dosing regimens, and long-term follow-up are required to establish definitive recommendations.

In conclusion, the present study demonstrates that oral zinc supplementation, when administered as an adjunct to phototherapy, significantly accelerates the decline in serum bilirubin levels and substantially reduces the duration of phototherapy in term neonates with unconjugated hyperbilirubinemia. The intervention was safe, well tolerated, and not associated with a significant increase in adverse effects. These findings support the potential role of zinc as a simple, inexpensive, and effective adjunctive treatment for neonatal jaundice. Nevertheless, larger multicenter studies are required before routine incorporation into standard treatment protocols can be universally recommended.

CONCLUSION

The study demonstrated that oral zinc supplementation significantly accelerates the decline in serum total bilirubin levels in term neonates with hyperbilirubinemia. It was also associated with a substantial reduction in the duration of phototherapy, suggesting a potentially valuable role for zinc as an adjunct therapy in neonatal jaundice management. The intervention was well tolerated, with no significant differences in adverse events between the zinc and placebo groups. These findings suggest that oral zinc is a safe and effective supportive treatment in managing neonatal hyperbilirubinemia, although larger, multicentric, and long-term studies are needed to confirm these results and guide

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