

Serum Trace Element Profiles in Women with Gynecological Disorders: An ICP-MS-Based Comparative Study

Jinekolojik Rahatsızlıkları Olan Kadınlarda Serum İz Element Profilleri: ICP-MS Tabanlı Karşılaştırma Çalışması

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ABSTRACT

Aim: Trace elements serve critical functions in cellular homeostasis and are rapidly becoming recognized for their role in carcinogenesis and gynecologic disorders. However, the serum trace element profiles of individuals with endometriosis, ovarian cancer (OCA), and endometrial cancer (ECA) are not fully known. The purpose of this study is to examine the levels of trace element profiles in the blood serum of healthy people and individuals with gynecological disorders.

Materials and Method: The study group comprised 40 women divided into four groups (n=10 each): endometriosis, endometrial cancer, ovarian cancer, and a control group who were obstetrically and demographically similar. Inductively coupled plasma-mass spectrometry (ICP-MS) was used to assess serum trace element levels of lead, beryllium, vanadium, chromium, manganese, iron, cobalt, nickel, arsenic, selenium, molybdenum, cadmium, antimony, and phosphorus.

Results: Significant differences were observed in the serum levels of Be, P, V, Cr, Mn, Co, As, Se, Cd, and Sb among the groups ($p<0.05$). Notably, the highest concentrations of most elements were detected in the endometrial cancer group, followed by the ovarian cancer, endometriosis, and control groups, respectively. No significant difference was found between the groups in terms of Pb, Fe, Ni, and Mo levels ($p>0.05$).

Conclusion: This study demonstrates differences in serum trace element profiles between gynecologic malignancies and endometriosis. The observed alterations suggest a potential association between trace element imbalance and disease-related metabolic changes in gynecological conditions. These findings indicate that trace element homeostasis may be affected in these disorders and highlight the need for further studies to clarify their clinical and biological significance.

Keywords: Trace element, Endometrial Cancer, Ovarian Cancer, Endometriosis

ÖZ

Amaç: İz elementler hücresel homeostazda kritik işlevlere sahiptir. Karsinogenez ve jinekolojik rahatsızlıklardaki rolleri önem kazanmaya başlamıştır. Ancak endometriozis, ovaryum kanseri (OCA) ve endometrial kanseri (ECA) olan bireylerin serum eser element profilleri tam olarak bilinmemektedir. Bu çalışmanın amacı, sağlıklı ve jinekolojik rahatsızlıkları olan bireylerin kan serumunda eser element profillerinin seviyelerini incelemektir.

Gereç ve Yöntem: Çalışma grubu 40 kadının dahil edildiği dört gruptan oluşmaktadır (her biri n=10): endometriozis, endometrial kanser, ovaryum kanseri ve obstetrik ve demografik olarak benzer olan kontrol grubu. Serum eser elementlerinin kurşun, berilyum, vanadyum, krom, manganez, demir, kobalt, nikel, arsenik, selenyum, molibden, kadmiyum, antimon ve fosfor düzeyleri indüktif olarak eşleştirilmiş plazma-kütle spektrometrisi (ICP-MS) kullanılarak ölçüldü.

Bulgular: Gruplar arasında Be, P, V, Cr, Mn, Co, As, Se, Cd ve Sb serum düzeyleri arasında anlamlı farklılıklar gözlemlendi ($p<0,05$). Özellikle, çoğu elementin en yüksek konsantrasyonları endometrial kanser grubunda, ardından sırasıyla ovaryum kanseri, endometriozis ve kontrol gruplarında tespit edildi. Pb, Fe, Ni ve Mo düzeyleri açısından ise gruplar arasında anlamlı bir fark belirlenmemiştir ($p>0,05$).

Sonuç: Bu çalışma, jinekolojik maligniteler ve endometriozis arasında serum eser element profillerinde farklılıklar olduğunu göstermektedir. Gözlemlenen değişiklikler, eser element dengesizliği ile jinekolojik rahatsızlıklardaki hastalıkla ilişkili metabolik değişiklikler arasında potansiyel bir ilişki olduğunu düşündürmektedir. Bu bulgular, eser element homeostazının bu bozukluklarda etkilenebileceğini ve klinik ve biyolojik önemlerini açıklığa kavuşturmak için daha fazla çalışmaya ihtiyaç duyulduğunu vurgulamaktadır.

Anahtar Kelimeler: Eser element, Endometrial kanser, Ovaryum kanseri, Endometriozis

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INTRODUCTION

Endometriosis, as well as ovarian and endometrial malignancies, is among the most serious gynecological illnesses affecting women (1). Endometrial cancer (ECA) is one of the most prevalent genital system cancers in women, particularly in industrialized nations, and early detection and biomarkers are crucial. Ovarian cancer (OCA), on the other hand, is typically detected at a late stage and has a dismal prognosis (2). Endometriosis is a benign illness, although it offers several biological features with neoplastic processes due to its active engagement in inflammation, oxidative stress, and cellular proliferation processes.

Trace elements are ionic substances that exist in extremely low quantities in the body yet play important roles in metabolic, enzymatic, redox, signal transduction, and DNA maintenance processes (3). These elements can have both beneficial and detrimental effects; some operate as cofactors for antioxidant enzymes, while excesses can cause oxidative stress, DNA damage, and cell cycle disruption. Some elements, particularly arsenic, cadmium, and chromium, have been linked to cancer (4). Furthermore, certain elements, such as selenium, have been shown to have a deleterious impact on cellular health at both low and high doses (5), which can lead to impaired cellular function and increased susceptibility to diseases, including cancer.

The latest research indicates that trace element abnormalities may have a role in gynecological illnesses. For example, it has been proposed that the levels of various trace elements (such as nickel, cadmium, and lead) differ between women with endometriosis and those in the control group (6). Furthermore, trace element levels in gynecological disorders have the potential to serve as biomarkers. In a review of research on the association between trace element imbalances and the female reproductive system and gynecological malignancies, Dring et al. identified gaps in the literature (7).

Cancer and other neoplasias are considered to cause changes in systemic microelement levels, which may be linked to tumor metabolism, oxidative stress response, metal transport routes, and immune system interactions. Lossow et al. found that serum selenium and iron levels varied depending on the cancer type, although copper levels were typically raised (8). Furthermore, several studies have found that blood zinc and selenium levels may be significantly lower in women with endometrial disease than in healthy individuals (6).

Considering these findings, the literature has few studies that extensively compare trace element levels, particularly among gynecological illnesses. This results in a considerable gap in our understanding of the roles of necessary and harmful trace elements

in these disorders. The purpose of this study is to compare directly individuals with endometriosis, ovarian, and endometrial cancer to a healthy control group by measuring serum levels of trace elements such as lead, beryllium, vanadium, chromium, manganese, iron, cobalt, nickel, arsenic, selenium, molybdenum, cadmium, antimony, and phosphorus. Furthermore, the study intends to determine whether there are any significant changes in trace element levels across the groups.

MATERIALS AND METHOD

Study Population

This study included patients who were newly diagnosed with endometrial cancer, ovarian cancer, or endometriosis and enrolled at the Department of Obstetrics and Gynecology, Sivas Cumhuriyet University Faculty of Medicine Hospital, between May 2025 and October 2025, before beginning any treatment. Healthy volunteers who visited the same clinic for control purposes were also included. All participants were selected from individuals living in the same geographic region and having similar socio-demographic characteristics. Additionally, individuals with potential occupational heavy metal exposure and those using mineral/vitamin supplements were excluded from the study. Informed consent forms were obtained from all individuals included in the study. Approval for this study was obtained from the Sivas Cumhuriyet University Health Sciences Research Ethics Committee (Decision No: 2025-04/145). The Helsinki Declaration guidelines were followed at every stage of the study.

A power analysis was performed using G*Power software (version 3.1) to determine the sample size of the study. The power analysis assumed a large effect size ($f = 0.58$), a significance threshold of $\alpha = 0.05$, and statistical power ($1 - \beta$) = 0.80. The total sample size is calculated as 40, with 10 individuals in each group.

Sample Collection

All participants in the research group had 5 mL of venous blood taken from their right or left forearm and placed in sterile, trace element analysis-specific blood tubes. Blood samples were centrifuged at 3000 rpm for 15 minutes. Serums were separated and kept in microcentrifuge tubes at -80°C until the research day.

Measurement of Serum Trace Element Levels

Before undergoing elemental analysis, the serum samples were subjected to microwave digestion (Milestone-ETHOS Easy SK-10, Italy) with acid to eliminate the organic phase. After digestion, the samples were diluted to an appropriate ratio, and an internal standard (internal standard mix Tb, Bi, Sc) was added following calibration with multi-element standard solutions and periodic

verification. Inductively coupled plasma mass spectrometry (ICP-MS, ThermoScientific iCAPQ, Germany) was used to determine the trace element levels of the samples. The ICP-MS operating conditions were optimized before analysis, and the detailed instrumental parameters are summarized in Table 1. Results were calculated from standard curve plots at the ppb level, taking the dilution factor into account.

Statistical Analysis

Statistical analysis and graphical visualizations of the study were carried out with IBM SPSS Statistics (version 27.0) and R Studio software. Continuous variables are reported as mean $\pm$ SD or median (0.25-0.75 quartiles). Categorical variables are represented as frequencies (n) and percentages (%). The normality of the data distribution was determined using the Shapiro-Wilk test. For variables with a normal distribution, one-way analysis of variance (ANOVA) was employed to compare more than two groups. The Levene test was used to determine variance homogeneity; when variances were homogenous, Scheffé post-hoc tests were used, and when they were not, Tamhane T2 post-hoc tests were used.

The Kruskal-Wallis H test was used to compare more than two groups of variables that did not have a normal distribution, whereas

the Dunn test with Bonferroni correction was used to compare groups of variables when significant differences were detected. The Chi-square (χ^2) test was used to evaluate relationships among categorical variables. The statistical significance criterion for all analyses was $p < 0.05$, unless otherwise noted.

RESULTS

The demographic characteristics associated with the study groups are shown in Table 2. There was no statistically significant difference in average age between the groups ($p = 0.375$). Similarly, there was no significant difference in smoking rates across the groups ($p = 0.911$). These data suggest that the research groups are similar in terms of fundamental demographics.

Because there were no significant variations in demographic factors across the groups, the distribution of serum trace element levels was investigated (Table 3).

There were ten participants in each of the following groups: endometriosis, OCA, ECA, and a healthy control group. When the groups' serum trace element levels were compared, beryllium (Be), phosphorus (P), vanadium (V), chromium (Cr), manganese (Mn), cobalt (Co), arsenic (As), selenium (Se), cadmium (Cd), and antimony (Sb) levels showed statistically significant differences ($p < 0.05$) (Table 3).

Beryllium levels differed significantly among the groups according to the Kruskal-Wallis test ($p < 0.001$). Bonferroni-corrected Dunn post-hoc analysis revealed significant differences between the Endometriosis group and both the OCA (adjusted $p = 0.016$) and ECA groups (adjusted $p < 0.001$), as well as between the control and ECA groups (adjusted $p = 0.001$). In contrast, no significant differences were observed between the Endometriosis-Control, Control-OCA, or OCA-ECA comparisons. As shown in Table 3, Be levels were highest in the ECA group [0.53 (0.43–0.75)], followed by the OCA [0.20 (0.17–0.24)], Control [0.11 (0.08–0.19)], and Endometriosis [0.05 (0.03–0.09)] groups. These findings indicate that the overall difference among groups was mainly driven by the marked

Table 1. Operating parameters of the ICP-MS instrument

Parameters	
RF Power (W)	1548.6
Nebulizer	PFA-ST MicroFlow Nebulizer
Spray Chamber	Cyclonic Quartz
Plasma Gas Flow Rate (L/min)	14
Auxiliary Gas Flow Rate (L/min)	0.8021
Nebulizer Gas Flow Rate (L/min)	0.8
Sample Uptake Rate (mL/min)	0.5
Scanning mode	Peak hopping
Sampler and Skimmer Cones	Nikel
Dwell time (s)	0.01
Number of Replicates	3
Sampling Depth (mm)	5
Number of Sweeps	10
Time Per Sweep (s)	0.14
Time Per Main Run (s)	1.4

Table 2. Comparison of research groups based on age and smoking behaviours.

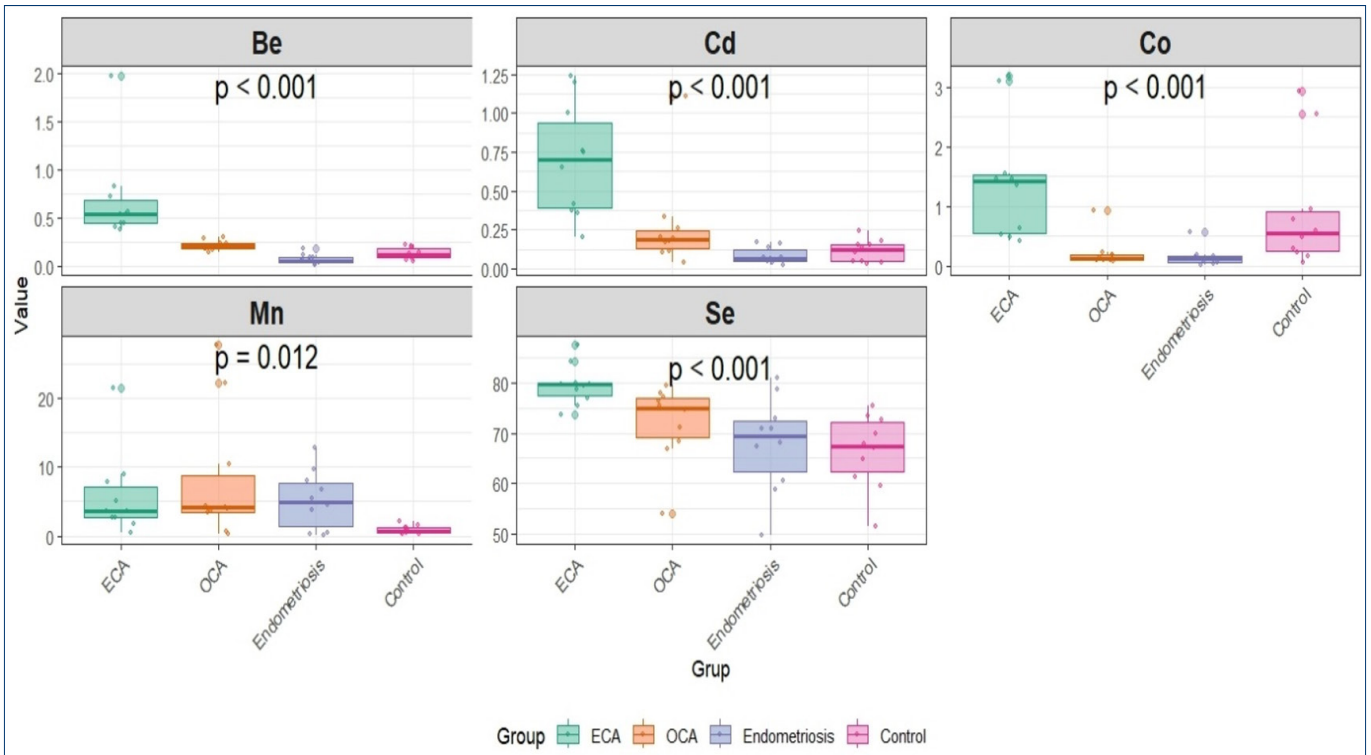
Group	Smoking n(%)	No Smoking n(%)	Age ($\bar{x} \pm SD$)
ECA	8 (80.0)	2 (20.0)	39.60 $\pm$ 4.30
OCA	7 (70.0)	3 (30.0)	40.00 $\pm$ 3.74
Endometriosis	8 (80.0)	2 (20.0)	40.20 $\pm$ 4.70
Control	7 (70.0)	3 (30.0)	36.90 $\pm$ 5.82
	$p=0.911$		$p=0.375$

The data is provided as mean $\pm$ standard deviation ($\bar{x} \pm SD$) and number (%). Intergroup comparisons were conducted using appropriate parametric or nonparametric tests. $p < 0.05$ was deemed statistically significant. (ECA: endometrial cancer, OCA: ovarian cancer)

Table 3. Comparison of serum trace element levels (ppb) between study groups

	ECA (n=10)	OCA (n=10)	Endometriosis (n=10)	Control (n=10)	p
Be	0.53 (0.43-0.75)	0.20 (0.17-0.24)	0.05 (0.03-0.09)	0.11 (0.08-0.19)	<0.001*
Pb	7.68±2.94	6.57±3.13	7.81±4.02	4.67±1.92	0.105
P	23922.3±6473.1	17291.9±3643.5	15799.7±4240.4	19670.6±3130.5	0.002*
V	2.45±0.13	2.24±0.24	2.13±0.30	2.03±0.23	0.003*
Cr	0.81±0.07	0.67±0.09	0.62±0.08	0.70±0.09	<0.001*
Mn	3.56 (2.42-8.06)	4.08 (2.68-13.29)	4.93 (0.49-8.42)	0.66 (0.36-1.33)	0.012*
Fe	371.9 (252.6-710.0)	328.1 (205.2-405.3)	629.2 (205.7-744.5)	622.5 (356.4-793.4)	0.280
Co	1.40 (0.51-1.93)	0.12 (0.09-0.19)	0.12 (0.04-0.16)	0.54 (0.20-1.33)	<0.001*
Ni	0.01 (0.004-0.07)	0.02 (0.01-0.03)	0.024 (0.01-0.027)	0.01 (0.001-0.03)	0.604
As	1.98±0.08	1.82±0.17	1.70±0.23	1.6±0.19	0.001*
Se	79.66 (76.63-81.02)	75.01 (67.93-77.41)	69.47 (60.19-74.40)	67.41 (60.2-72.99)	<0.001*
Mo	1.65 (1.38-1.68)	1.04 (0.56-1.57)	1.02 (0.70-2.65)	0.86 (0.62-1.86)	0.071
Cd	0.69 (0.37-1.05)	0.18 (0.11-0.28)	0.06 (0.04-0.14)	0.12 (0.04-0.15)	<0.001*
Sb	1.86±1.39	0.79±0.44	0.86±0.31	0.09±0.04	<0.001*

All trace element concentrations are expressed as ppb. Data is shown as the median (0.25-0.75 quartiles) or mean ± standard deviation. For regularly distributed data, one-way ANOVA was utilized, whereas non-normally distributed data was subjected to the Kruskal-Wallis H test. Significant comparisons were performed using appropriate post-hoc analyses (Scheffe, Tamhane T2, Dunn test). A p-value of <0.05 qualifies as statistically significant


Figure 1. Distribution of serum Be, Cd, Co, Mn, and Se levels across study groups

elevation in the ECA group and the higher Be levels observed in the OCA group compared with the Endometriosis group (Figure 1).

Phosphorus levels were considerably greater in the ECA group than in the OCA and endometriosis groups, whereas the endometriosis group showed an increase above the control group ($p=0.002$) (Figure 2).

Vanadium levels were considerably greater in the ECA group than in the endometriosis and control groups, as well as in the OCA group compared to the control group ($p=0.003$) (Figure 2).

Chromium levels were considerably higher in the ECA group compared to the OCA, endometriosis, and control groups ($p<0.001$) (Figure 2).

Manganese levels differed significantly among the groups ($p=0.012$). Dunn–Bonferroni post-hoc analysis demonstrated that Mn levels were significantly higher in the OCA group compared with the control group (adjusted $p=0.026$). Although Mn levels in the ECA group were also higher than those in the control group,

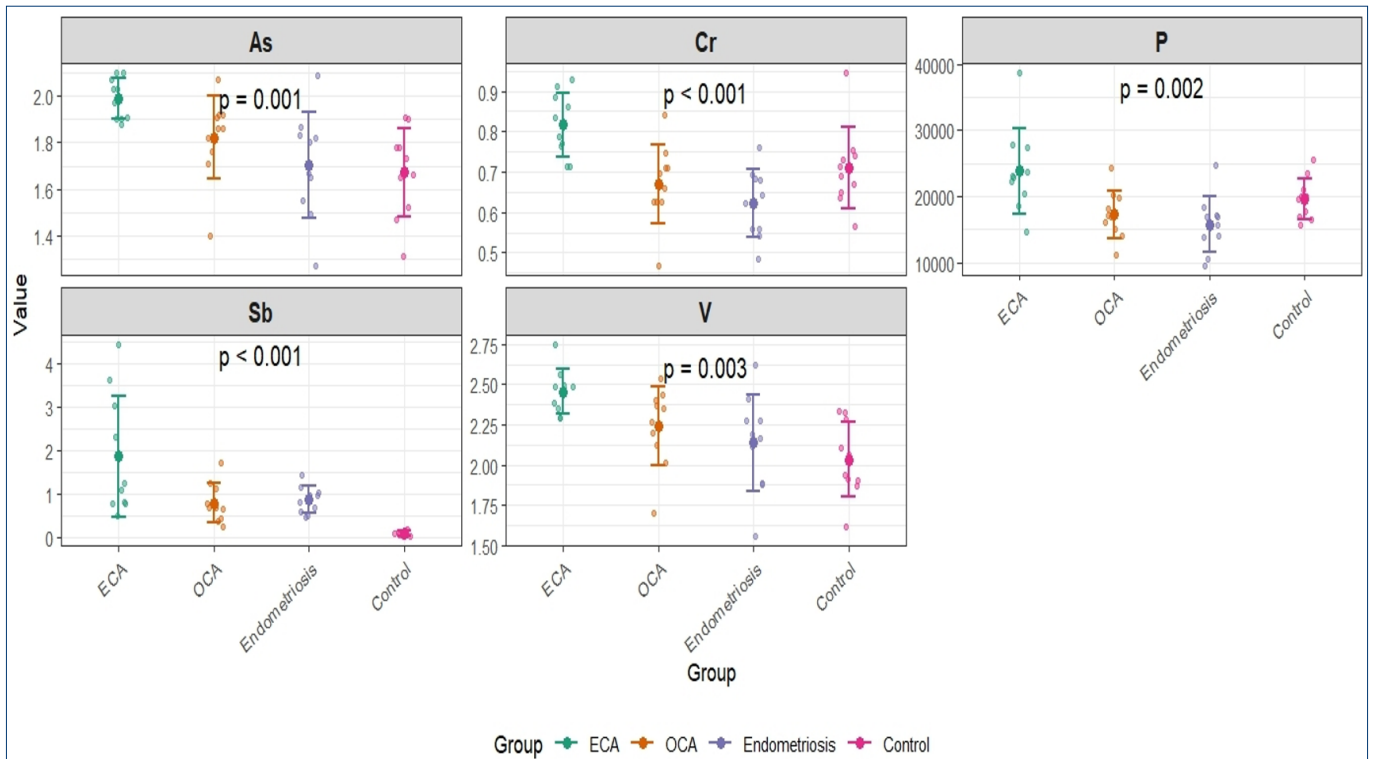


Figure 2. Distribution of serum As, Cr, P, Sb, V levels across study groups

this difference was at the threshold of statistical significance (adjusted $p=0.050$). Similarly, Mn levels appeared elevated in the endometriosis group compared with the control group; however, this difference did not reach statistical significance after Dunn–Bonferroni correction (adjusted $p=0.066$), possibly due to the small sample size and the wider distribution range within the endometriosis group. No statistically significant differences in Mn levels were observed among the patient groups (endometriosis, OCA, and ECA) ($p>0.05$) (Figure 1).

Cobalt levels differed significantly among the groups ($p<0.001$). The highest Co levels were observed in the ECA group [1.40 (0.51–1.93)], followed by the control [0.54 (0.20–1.33)], endometriosis [0.12 (0.04–0.16)], and OCA [0.12 (0.09–0.19)] groups (Table 3). Dunn–Bonferroni post-hoc analysis demonstrated that Co levels were significantly higher in the ECA group compared with both the endometriosis (adjusted $p<0.001$) and OCA groups (adjusted $p=0.003$). In addition, Co levels in the control group were significantly higher than those in the endometriosis group (adjusted $p=0.040$). No statistically significant differences were observed in the remaining pairwise comparisons (adjusted $p>0.05$) (Figure 1).

Levels of selenium differed significantly among the groups ($p<0.001$). The highest Se levels were observed in the ECA group [79.66 (76.63–81.02)], followed by the OCA [75.01 (67.93–77.41)], endometriosis [69.47 (60.19–74.40)], and control [67.41 (60.20–

72.99)] groups (Table 3). Dunn–Bonferroni post-hoc analysis demonstrated that Se levels in the ECA group were significantly higher than those in the control (adjusted $p=0.001$) and endometriosis groups (adjusted $p=0.007$). However, no statistically significant differences were observed in the control–endometriosis, control–OCA, endometriosis–OCA, or OCA–ECA comparisons after Bonferroni correction ($p>0.05$).

Significant differences were found between the groups in terms of arsenic levels ($p=0.001$). The highest arsenic level was observed in the ECA group, followed by the OCA and endometriosis groups, respectively. The lowest value was observed in the control group (Table 3). These findings indicate that arsenic levels are higher in the ECA group compared to the other groups (Figure 2).

Significant differences in Cadmium levels were observed among the study groups ($p<0.001$). According to Table 3, the highest Cd level was detected in the ECA group [0.69 (0.37–1.05)], followed by the OCA group [0.18 (0.11–0.28)], the control group [0.12 (0.04–0.15)], and the endometriosis group [0.06 (0.04–0.14)]. According to the Dunn–Bonferroni post-hoc analysis, Cd levels in the ECA group were significantly higher than those in the endometriosis (adjusted $p<0.001$) and control groups (adjusted $p<0.001$) (Figure 1). No statistically significant differences were found in the other pairwise comparisons (endometriosis–control, endometriosis–OCA, control–OCA, and OCA–ECA) after Bonferroni correction ($p>0.05$).

Antimony levels considerably increased in the ECA, OCA, and endometriosis groups compared to the control group ($p < 0.001$) (Figure 2).

But when it came to the levels of lead (Pb), iron (Fe), nickel (Ni), and molybdenum (Mo), there was no statistically significant difference between the groups ($p > 0.05$).

DISCUSSION

In this study, substantial differences were detected between endometriosis, OCA, ECA, and control groups in terms of trace element levels assessed in serum using ICP-MS. Significant variations were discovered between groups in the levels of beryllium (Be), phosphorus (P), vanadium (V), chromium (Cr), manganese (Mn), cobalt (Co), arsenic (As), selenium (Se), cadmium (Cd), and antimony (Sb) (Table 3, Figures 1-2). These findings are consistent with emerging data in the literature linking trace element metabolism to gynecological diseases.

When the demographic parameters of the study groups were compared, there was no statistically significant difference in terms of average age or smoking status (Table 2, $p > 0.05$). This data suggests that the groups are similar in terms of fundamental demographic features, allowing variations in trace element levels in the serum to be assessed independently of potential confounding factors such as age or smoking. The closeness in smoking rates among the groups, in particular, limits the possibility that variations in blood levels of elements such as cadmium and lead are caused by smoking exposure.

In our study, endometrial cancer patients had the highest concentrations of numerous elements. The ECA group showed substantially greater levels of As, Cr, and V compared to the control and other patient groups (Table 3, $p < 0.05$). These data provide support for various types of cancer research in the literature. Metal genotoxicity, particularly that of arsenic and chromium, has been linked to cellular DNA damage and oxidative stress (9, 10). It has been proposed that arsenic exposure increases the incidence of ovarian and endometrial cancer; our data support this theory (11).

Similarly, the considerably greater Cd levels seen in the ECA group compared to the control group (Figure 1) can be attributable to cadmium's estrogenic properties and putative effects on hormone receptor activation (12). According to the literature, cadmium promotes the pro-oxidative response, particularly in gynecological malignancies, and may promote tumor growth (13). The greater amounts of this element in the endometriosis group compared to

the control group may indicate that Cd causes imbalances not only in malignant pathways but also in chronic inflammation.

Even for elements such as Se, whose biological activity is predominantly related to antioxidant defense mechanisms, the research yields inconsistent conclusions (14). The ECA group had the highest Se levels in our research (Table 3). This finding is consistent with previous data indicating that elevated Se levels may be a prognostic factor in some forms of cancer. However, because a lot of studies have found that Se deficiency is linked to a variety of cancer risks, our findings could be associated with both deficiency and excess of this element, which may have pathological consequences (15). As a result, selenium's relationship role should be examined within a biological context rather than just based on a one-way increase/decrease.

In terms of phosphorus (P) levels, the ECA group showed significantly higher levels compared to the OCA, endometriosis, and control groups (Figure 2). This difference may be associated with altered metabolic activity and changes in cellular processes within the ECA group. Previous studies have reported that phosphate metabolism can be dysregulated in rapidly proliferating cells, particularly in malignant conditions (16). Therefore, the observed increase in P levels may reflect underlying metabolic alterations associated with disease activity rather than serving as a specific indicator of malignant transformation.

Disruptions in the levels of cofactor elements such as Mn and Co were also observed between the study groups. Mn levels were significantly higher in the OCA group compared to the control group, which may indicate alterations in oxidative stress related biochemical processes. Similarly, Co levels were significantly elevated in the ECA group compared to the control and other groups. Cobalt has been implicated in cellular responses to hypoxia and angiogenesis-related pathways (17), suggesting that increased Co levels in ECA patients may reflect disease-associated metabolic alterations. Interestingly, the control group also demonstrated higher Co levels than the OCA and endometriosis groups. Since cobalt is an essential trace element involved in vitamin B₁₂ metabolism and various enzymatic processes (18), serum levels may be influenced by physiological, nutritional, and metabolic factors. In addition, altered trace element utilization or redistribution associated with chronic inflammatory or neoplastic processes may contribute to the relatively lower Co levels observed in certain patient groups.

The significantly higher levels of Sb observed in both the ECA and OCA groups compared to the control group are in line with previous studies suggesting that Sb may be associated with alterations in endocrine-related processes and cellular signaling pathways (19).

However, the evidence regarding the relationship between Sb exposure and gynecological tumors remains limited. Therefore, the present findings may contribute to a better understanding of this association and warrant further investigation.

In the present study, significantly higher vanadium levels were observed in the endometrial cancer group compared to the endometriosis and control groups (Table 3, Figure 2). Vanadium is a trace element that has been reported to interact with various enzymatic systems and to influence multiple biological processes. Previous studies have suggested that V compounds may exhibit antiproliferative and anticancer properties in different tumor models (20). However, the clinical significance of altered serum V levels in cancer patients remains unclear. Therefore, the increased levels observed in the present study may reflect disease-associated metabolic alterations, although further studies are needed to clarify the underlying mechanisms.

One of the advantages derived from this is that none of the patient groups had received prior therapy before diagnosis, allowing for a controlled comparison in which the detected trace element differences were not confounded by variables such as treatment or metastatic progression. Furthermore, the employment of a highly sensitive analytical method such as ICP-MS improved the dependability of the results. In addition, the observed differences in trace element profiles, particularly the consistent elevation in the endometrial cancer group, may indicate a potential role for these elements as diagnostic or prognostic biomarkers. However, due to the cross-sectional design and limited sample size, these findings should be interpreted cautiously and require validation in larger, prospective studies before clinical application.

However, the study has certain limitations. The modest sample size (n=10 per group) may not fully represent the biological variability across the study population and may limit the statistical power for detecting smaller effect sizes, thereby affecting the generalizability of the findings. The sample size in this study was determined based on a large effect size assumption; however, smaller effect sizes may require larger cohorts. Notably, several elements, such as As and Cr, demonstrated substantial differences between groups relative to within-group variability, supporting the presence of large effect sizes. In addition, certain potential confounding variables, including dietary habits and body mass index (BMI), were not systematically recorded due to the preliminary nature of the study, and this is acknowledged as a limitation that may have influenced serum trace element levels. Although participants with known occupational heavy metal exposure and those using mineral or vitamin supplements were excluded, the inability to comprehensively assess all relevant factors may have resulted

in residual confounding. These limitations should be considered when interpreting the findings and need to be addressed in larger, prospective studies.

CONCLUSION

Finally, our findings reveal that serum trace element patterns vary between gynecological disorders. The observation that several elements were higher in the ECA group compared to the other groups highlights the need for further investigation into their potential as biomarkers and their contribution to disease pathogenesis. In addition, these findings may indicate a possible clinical utility of trace elements in diagnosis or disease monitoring; however, larger and prospective studies are required to validate these results before clinical application.

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