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Article

Chromium Dose Dependent Kidney Changes Morphological, Histological and Morphometrical Parameters

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Abstract: Background: Chromium is a common toxic heavy metal used in many industries and has been shown to have toxic effects in many organs; the kidneys have a nephrotoxic effect, largely due to oxidative effects and cell damage. Aims: The current study aims to examine the gross anatomical, morphometric and histopathological changes in the renal tissue after exposure to chromium, in varying doses. Methods: control group and groups exposed to various doses of chromium. Gross, morphometric (length, width, weight) and histopathological changes were analysed. Result: gross changes were observed in treated groups such as; lighter kidney colour with mottling and thinning cortex. There was no significant Morphometric alteration in kidney length, kidney width was increased, and kidney weight was decreased in a dose dependent manner. Histopathologically exposed groups revealed expansion of the urinary space, glomerulus and tuft size and degeneration in the proximal convoluted tubule. Conclusion: In conclusion chromium induces significant dose-dependent renal damage at both structural and cellular levels. The findings highlight the nephrotoxic potential of chromium.

Keywords: chromium, nephrotoxicity, kidney, oxidative stress, histopathology.

Introduction

The kidney is the primary organ for metabolism, detoxification, storage, and excretion of many medications and supplements and their metabolites, the kidney is especially vulnerable to injury from agents such as chrome supplements [1].

The histological organization of the filtering units (renal corpuscles) is critical for this function. Renal corpuscles can only be found in the kidney cortex, and there are approximately 1 million renal corpuscles per kidney although this figure is variable depending on race. Renal injury alterations observed in kidney biopsy specimens encompass augmented arteriosclerosis, glomerulosclerosis, interstitial fibrosis, tubular atrophy, increased nephron size, infiltration, and diminished nephron count. The renal alterations are challenging to evaluate by visual inspection but can be effectively assessed using morphometry [2]. Oxidative stress (OS) occurs when there is an imbalance between the generation and accumulation of reactive oxygen species (ROS) and the organism's ability to neutralize them via enzymatic and non-enzymatic antioxidant defense systems. While low levels of ROS are essential for activating signaling pathways and regulating various biological and physiological processes, including cellular proliferation and host defense mechanisms, excessive ROS can lead to detrimental effects. [3].

Current chromium supplements exhibit significant variability in recommended dosages (typically around 500 μg per serving) and formulations (including Brewer's yeast, chromium picolinate, chromium chloride, and various proprietary blends). [4]. Trivalent chromium is a trace element believed to positively influence oxidative stress parameters and inflammation. It is well tolerated, with no major side events directly associated with high consumption from food or commercially accessible supplements. [5]. A total of 58.3% of people reported consuming a dietary supplement in the previous 30 d, 28.8% reported consuming a dietary supplement that contained chromium, and 0.7% consumed supplements that had "chromium" in the title, Over one-half the adult US population consumes nutritional supplements, and over one-quarter consumes supplemental chromium. [6].

Materials and Methods

Experimental animals and housing:

The current study was conducted on thirty (males) albino rats, experimental animals were acquired from the collage of science, Kufa University from Spet. - Nov. 2025. rats with body weight ranging between 250- 370 gm and age 8-12 weeks. They were kept under conventional condition in acclimatized room with free access to tap water & food (standard pellet diet) and maintained under a 12h light.

Animal and study design

In this study 30 males albino rats were enrolled, rats were divided into three groups: Control group, low dose group and high dose group each formed of 10 rats. Daily dose were adjusted and calculate according to body weight, 0.5 mg/kg per day of chromium for low dose and 2 mg/kg per day for high dose group.

Oral Gavage Procedure

Rats received the prepared chromium solution by oral gavage once daily using a metal gavage needle attached to a 5 mL syringe.

Animal anesthesia and tissue sampling

All animals were anaesthetized with an intramuscular injection of a ketamine and xylazine combination at dosages of 80–100 mg/kg body weight and 10–12.5 mg/kg xylazine . Removed of the right kidney after 5weeks was done, An inverted T-shaped incision was performed on the ventral aspect, In order to get access to the kidney location, and facilitate sample collection (kidney). animals returned to the animal house after undergoing tissue sampling. Each kidney was cut into 2 identical halves. Running through the hilum region.

Tissue preparation for paraffin section and staining:

Kidney specimens were processed for paraffin section in accordance with (Suvarna et al. 2018). Fixation,dehydration,clearing paraffin embedding and then blocking was performed 4μ thsickness section were collect on glass slide then staind by H&E.

Results and Discussion

Result

General Anatomical and Morphological assessment

Assessment of anatomical locations and general morphological criteria in all groups by necked eyes revealed that kidneys are bilaterally positioned on the posterior abdominal wall lateral to the vertebral column, no abnormal displacement or any other anatomical variation was observed in either groups.Grossly the kidneys have been shaped with deep brown pinkish color in control group and showed light pinkish brown color in experimental groups, some of showed light patches appeared grossly in both experimental groups, the patches seems to be less in low does group and extensively distributed in high dose group.Grossly the bean shaped kidney show clear concave medial border for the passage of blood vessels and renal pelvis which represent hilum region.

In both groups the kidneys showed smooth and firm texture for farther examination of the kidneys midsagittal plan reveal presence of very thin capsule surrounding the whole kidneys in both groups (Figure 1).

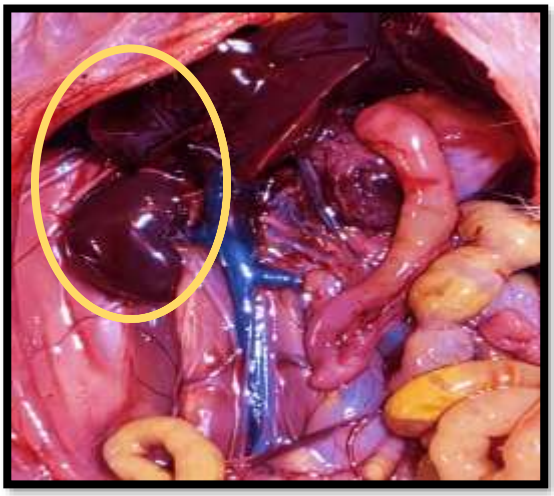


Figure 1. gross anatomical view of the kidney (inside the circle) and its position within abdominal cavity.

Regarding renal capsule grossly it was a transparent outer membrane and although was very thin but still it was tough layer and easily peel able below which a thin dark brown area obviously recognized which represent cortex region. The medulla was seen below the cortical region and appeared lighter in color ranging between light brown to pinkish color, major calyces and renal pelvis were clearly identified as a white conical area piercing the hilum region. Comparison between the three groups regarding gross morphological appearance it was noted that cortical region seems to be thinner in experimental groups than that of control group.in experimental group the color of cortical and medullary region seems to be light pinkish if compared to control group which showed a deep brown color.(Figure 2)

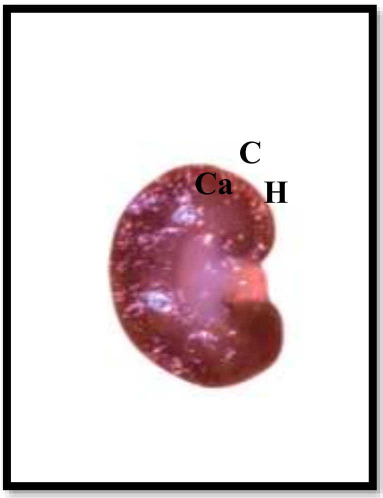


Figure 2. Gross morphological appearance of the kidney showing cortical region(c), medulla, major calyces(ca) and renal pelvis were clearly to identified as a white conical area piercing the hilum region(H).

Morphometrical changes of kidney dimensions

Assessment of kidneys dimension in all groups using Vernier clipper recorded that the mean length of control group was (11.50 ± 0.34960) mm while the mean lengths of low dose group (10.21 ±0.56223) mm the length measurement of high dose group was (10.88 ±0.32924) mm.The mean width of all groups showed (5.70 ±0.23523) mm for control group, (6.39 ±0.38541) mm for low dose group and (6.95 ±0.22913) mm for high dose group.

There was no significant difference between the length kidneys in all groups.Regarding the width of the kidneys there was a significant increase in width regarding the high dose group when compared to low dose and control groups (Table 1, 2). The mean is significant at the 0.05 level

Table 1. Show the difference in the length of the kidney in three groups

dimension of kidney (k)	dimension of kidney(k)	Mean /mm	Std. Error(SE)	p-value
length of control	length of low dose	10.2100	0.56223	0.101
	length of high dose	10.8800	0.32924	0.567
length of low dose	length of control	11.5000	0.34960	0.101
	length of high dose	10.8800	0.32924	0.516
length of high dose	length of control	11.5000	0.34960	0.567
	length of low dose	10.2100	0.56223	0.516

Table 2. Show the difference in the width of the kidney in three groups

dimension of kidney	dimension of kidney	Mean /mm	Std. Error	p-value
width of control	width of low dose	6.3900	0.38541	0.235
	width of high dose	6.9500	0.22913	0.015*
width of low dose	width of control	5.7000	0.23523	0.235
	width of high dose	6.9500	0.22913	0.378
width of high dose	width of control	5.7000	0.23523	0.015*
	width of low dose	6.3900	0.38541	0.378

*It indicates that the value is significant

Morphometrical analysis of kidney weight change

Analysis of kidneys weight was performed using post-hoc Tukey test for analysis, in the control group it was (1.2780 ±0.04541) gram, low dose group (1.1810g ±0.10044) gram, high dose group was (0.8460g ±0.07276) gram, there was a significant differences between control and high dose and between low dose and high dose, while there was no significant differences between control and low dose the overall parts reduction in the weight of the kidney (Table 3).

Table 3. Show the difference of the weight of the kidney in three groups

Weight of kidney	Weight of kidney	Mean / gram	Std. Error (SE)	p-value
high dose	low dose	1.1810	0.10044	0.012*
	control	1.2780	0.04541	0.001*
low dose	high dose	0.8460	0.07276	0.012*
	control	1.2780	0.04541	0.645
control	high dose	0.8460	0.07276	0.001*
	low dose	1.1810	0.10044	0.645

General architecture of renal tissue histological analysis of kidney tissue

Histological analysis of kidney tissue showed that the kidney is surrounded by a thin tough delicate fibrous capsule which was easily peel able from the cortical tissue below it.

At higher magnification the capsule composition was mainly of fine connective tissue elements including thin collagen bundles and elastic fibers at the hilum region the capsule was easily recognized where blood vessels enters and leave together with the renal pelvis.

There were no evident differences in the Shape and constituent of the capsule between the three groups, the arrangement was the same so was the thickness and constituent (Figure 3).

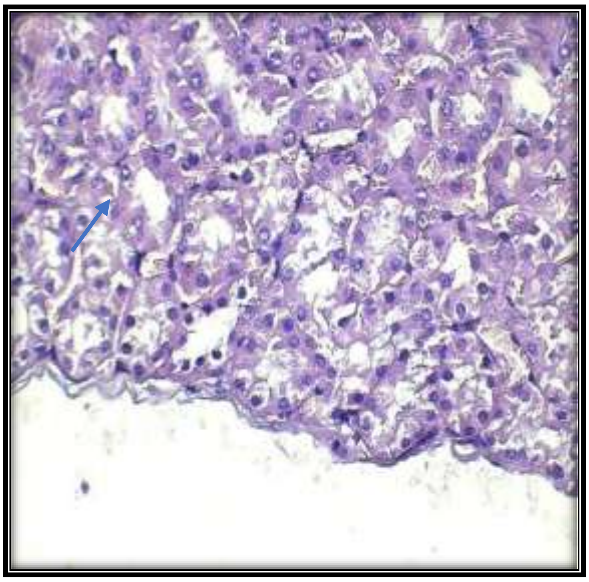


Figure 3. showing renal capsule (arrow) in control group, H&E, X40.

Histological architecture of renal Cortex and Medulla

General examination of the parenchyma of the kidneys in control group under light microscope showed a clear demarcation between two distinct areas and outer narrow region occupied by small rounded numerous glomeruli of different sizes interposed with different types of tubules of different size and variant diameter and presenting the proximal convoluted tubule the and distal convoluted tubules it seems that the number of a proximal convoluted is more than the distal convoluted tubule at the region surrounding the renal corpuscles(Figure4).

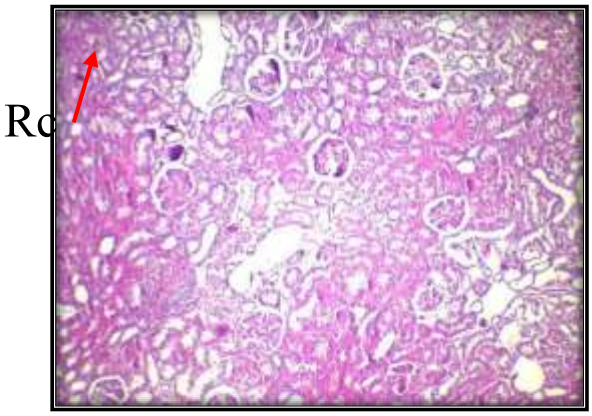


Figure 4. Histological architecture of renal cortex showing small renal corpuscles (RC) in control group, H&E, X10

The medullary region which appeared paler than the Cortex but less cellular composition than the cortex, the medulla tubular constituent was seen as parallel rays which is mainly formed collecting duct and different parts of loop of Henle these medullary rays arrange themselves to be collected at certain point to form what is called renal papillae which a project into the lumen of minor calyces (Figure5).

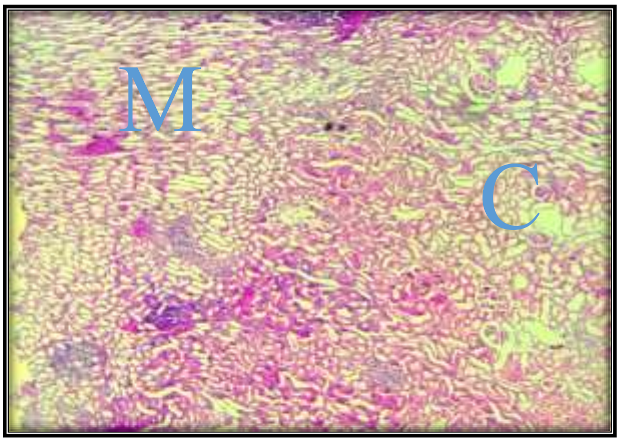


Figure 5. Showing histological architecture of renal medulla (M) and cortex(C) in control group,H&E ,X10 .

The arrangement of the medullary rays to form the papillary region forms what called renal pyramids which identified as a conical part formed by medullary rays and separated by cortical tissue columns (column of Morgagni)(Figure6)

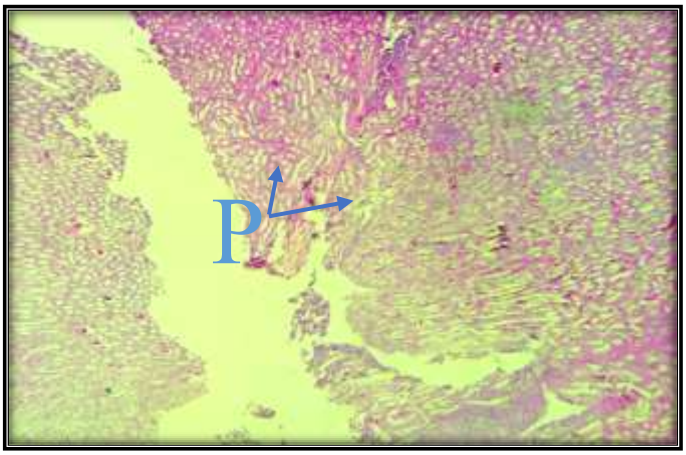


Figure 6. showed the renal papilla (P) in control group, H&E,X10.

Examination of the field in the low dose group at higher magnification give more evidence of congestion of blood vessels and it was very obviously also seen in the tuft (Figure7).

Another criteria was the infiltration of small highly basophilic cells in between the tubules which was sign lymphocyte infiltration (inflammation) (Figure8).

All the above feature was also seen in high dose group.

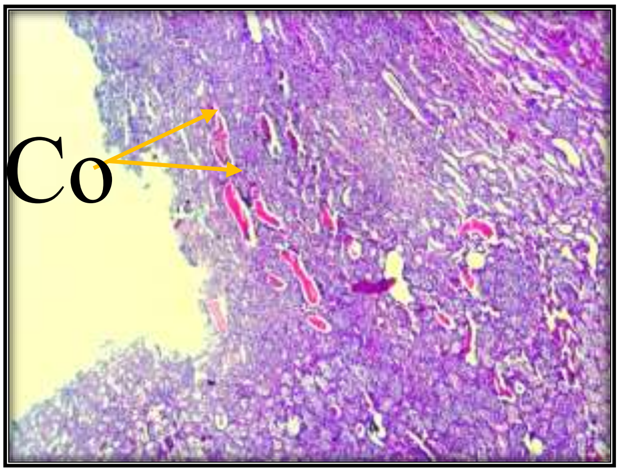


Figure 7. Illustrate bleeding between parenchyma and congestion of renal blood vessels (Co) in low dose group,H&E,X10.

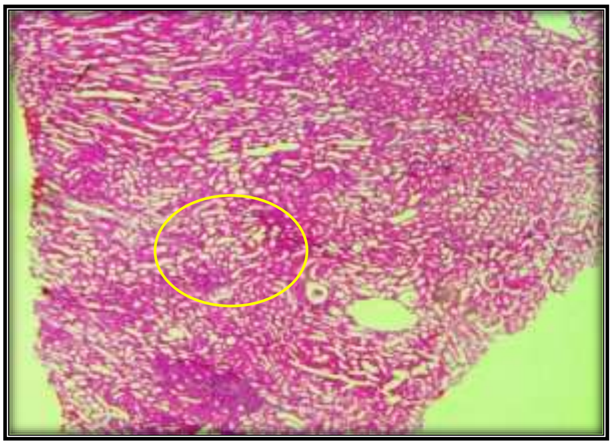


Figure 8. renal section showing lymphocyte infiltration (inside circle)in form of lymphocyte nodule in low dose group, H&E, X10.

General arrangement of Architecture in the renal corpuscle

The corpuscle showed that it is oval to spherical structure with a tuft of capillaries(glomerulus) surrounded by a cavity which represent the urinary space, urinary space separate the glomerulus and Bowman's capsule. The glomerulus was found to be covered by cells (podocytes) which represent the visceral epithelial layer of Bowman's capsule and the vascular pole, this layer will be reflected to form the parietal epithelial of Bowman's capsule as lined by simple squamous epithelial of Bowman's capsule as lined by simple squamous epithelial, in many location of urinary space to be continuous with the lumen of a proximal convoluted tubule (PCT) (Figure 9).

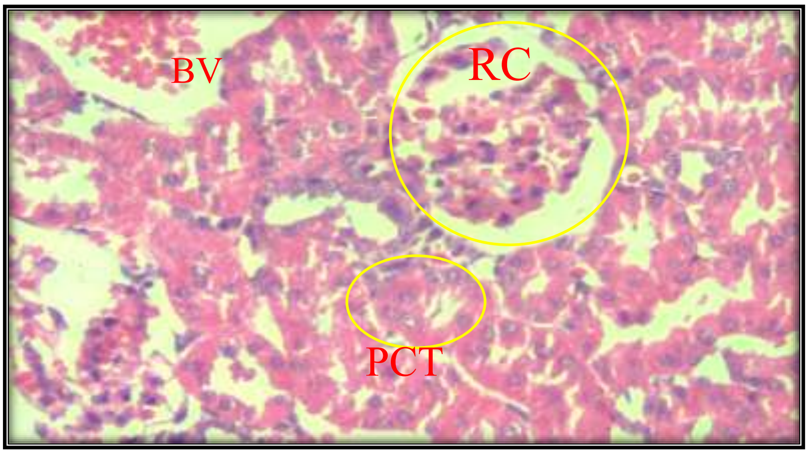
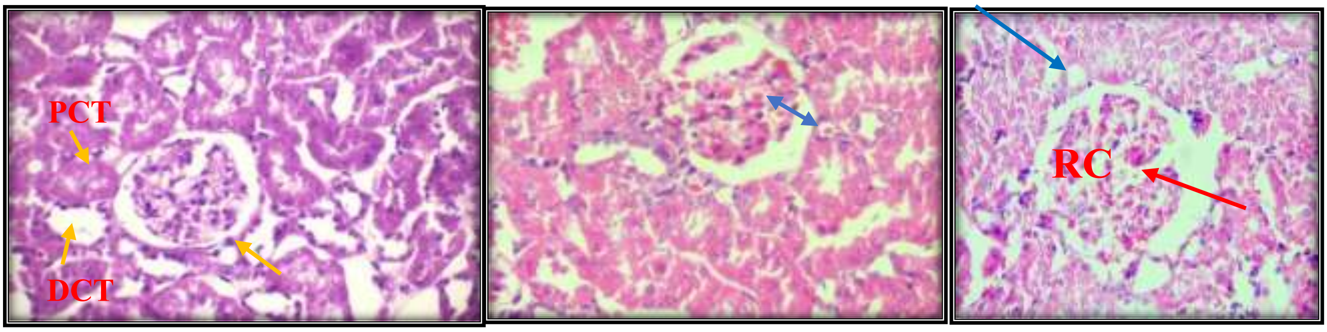


Figure 9. showing renal corpuscle(RC) and some proximal tubule(renal corpuscle showing congestion of blood vessel(BV) and proximal tubule with high cuboidal cells in control group ,H&E,X40

All the mention criteria above was seen in both control group and experimental groups, but the experimental groups showed some corpuscles change as follows; the size of the renal corpuscle seems to be larger than what was seen in the control group, a blood vessels congestion was seen between glomeruli a future which was not seen in control group, the tuft inside the renal corpuscles was frequently seen destructed, aggregation of clustered of corpuscle was not seen in experimental groups ,urinary space seems to be wider than that of



(Figure10A). **(Figure10B)** **(Figure10C)**

Figure 10. Showing the cortical area

A: Section in control group showing renal corpuscle (RC) and surrounding PCT &DCT in normal configuration ,B:widening of renal space (Bowman's space) (→) sign of tubule injury and congestion(→).C: Sever congestion of blood vessel (→) with change in PCT lining and loss of brush border(→).

Morphometrically evaluation of renal corpuscles changes

Image analysis software program (image J) was used in this study to identify specific measurable changes of renal corpuscle between the three groups.

Renal corpuscle size

Morphometrical differences was observed in the renal corpuscle size of experimental groups ,there was elevated total corpuscle size in the high dose group and to a lesser extent in the low dose experimental group in comparison with the control group, suggestive adaptive changes in the corpuscle morphology in experimental group.

Control group showed a mean corpuscle area (204.74±18.94514) μ^2 while in low dose experimental group the mean area recorded (1190.19±33.01004) μ^2 , high does experimental group area measurement was (1410.83±52.53331) μ^2.

A significant p-value (0.05) was estimated between control group and the two experimental groups and there was a significant differences recorded between the two experimental groups regarding renal corpuscle size (Table 4).

Table 4. Show the difference of the mean area of corpuscle in three groups

group	area of corpuscle	Mean μ^2	Std. Error	P-value.
area of corpuscle control group	**low dose group**	**1190.1943***	**33.01004**	**0.000**
	high dose group	**1410.8352***	**52.53331**	**0.000**
area of corpuscle low dose group	**control group**	**204.7483***	**18.94514**	**0.000**
	high dose group	**1410.8352***	**52.53331**	**0.000**
area of corpuscle high dose group	**control group**	**204.7483***	**18.94514**	**0.000**
	dose group	**1190.1943***	**33.01004**	**0.000**

* The mean is significant at the 0.05 level

Estimation of the area of urinary space in all groups

Bowman's space (urinary space) in control group showed a mean area (38.520 ± 3.70984) μ^2 while in low dose experimental group the mean area recorded (316.74 ± 15.68035) μ^2, high does experimental group area measurement was (323.02 ± 36.35227) μ^2 .

A significant p-value (0.05) was estimated between control group and the two experimental groups while there was no significant differences recorded between the two experimental groups Regarding Bowman's space size (Table 5).

Table 5. Show the difference of urinary space area between the three groups

group	area of urinary space	Mean/μ^2	Std. Error	p-value
area of urinary space control group	**low dose group**	**316.7435***	**15.68035**	**0.000**
	high dose group	**323.0243***	**36.35227**	**0.000**
area of urinary space low dose group	**control group**	**38.5203***	**3.70984**	**0.000**
	high dose group	**323.0243**	**36.35227**	**0.980**
area of urinary space high dose group	**control group**	**38.5203***	**3.70984**	**0.000**
	low dose group	**316.7435**	**15.68035**	**0.980**

*. The mean is significant at the 0.05 level.

Glomerular size

Tuft (glomerulus) in control group showed a mean area (168.6187±17.05094) μ^2 while in low dose experimental group the mean area recorded (839.6395±38.09689) μ^2,high does experimental group area measurement was(1094.0918±49.98915) μ^2.

There was a significant difference between the three group regarding glomerular size with a significant p-value of (0.05) (Table 6).

Table 6. Show the difference of the area of the tuft in three groups

area of tuft	area of tuft	Mean /μ²	Std. Error	p-value
area of tuft control group	low dose group	839.6395*	38.09689	0.000
	high dose group	1094.0918*	49.98915	0.000
area of tuft low dose group	control group	168.6187*	17.05094	0.000
	high dose group	1094.0918*	49.98915	0.000
area of tuft high dose group	control group	168.6187*	17.05094	0.000
	low dose group	839.6395*	38.09689	0.000

* The mean is significant at the 0.05 level.

Proximal convoluted tubule (PCT) morphological study

Proximal convoluted tubule as a part of nephron representing the first part that is attached to renal corpuscle and start as a continuation of parietal layer of Bowman's capsule by changing the height of epithelial lining gradually from simple squamous to cuboidal epithelial, it is a lumen is continuation of the urinary space in the renal corpuscle , proximal convoluted tubule appeared as rounded to oval with the eosinophilic appearance large cuboidal cells with abundant eosinophilic cytoplasm and a rather large rounded a nuclei with distinctive a nucleolus was seen ,the lumen of proximal convoluted tubule was rather narrow and filled with the microvilli. The high cuboidal cells forming proximal convoluted tubule was distinctive feature in the area, surrounding renal corpuscles, the brush border occupying the lumen was seen as long interdigitating eosinophilic network like structure with it is distinctive glycocalyx, vacculation of the cytoplasm was a common feature of the proximal convoluted tubule in control group specifically around the nuclei and apical cytoplasmic part. (Figure11).Regarding the experimental groups changes in the proximal convoluted tubule started with noticed increase in the size of PCT gradually, cells forming the PCT although is a still cuboidal but it became a low form of cuboidal cells ,the lumen was wider and free brush border was lost in most cases ,cytoplasmic component of the cells forming proximal convoluted was still eosinophilic, some cells nuclei showed no nucleoli a feature which was highly distinctive in the control group, vaculation which was seen in control group was lost. (Figure12)

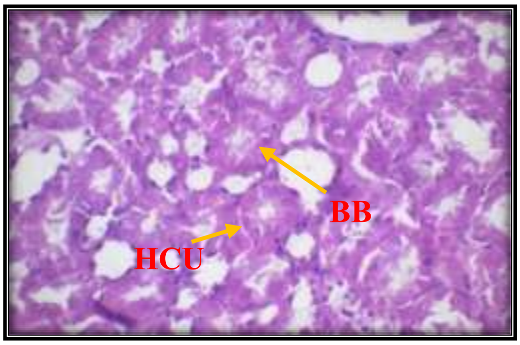


Figure 11. renal section showing high cuboidal cells (HCU) forming PCT and brush border (BB) occupying lumen in control group,H&E,X10.

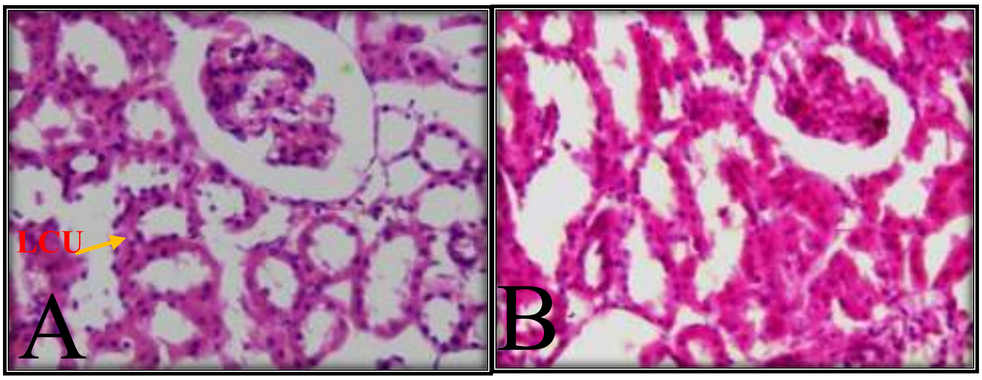


Figure 12 (A&B) renal section showing low cuboidal cells (LCU) forming PCT and No brush border(BB) in the lumen in experimental groups(A low dose group ,B high dose group) group,H&E,X40.

Statistical assessment of proximal convoluted tubule changes

Morphometrical measurement of the size of PCT was performed using image J software ,control group area of PCT was recorded (457.73 ± 15.00149) μ² ,area of proximal convoluted tubule in low dose group was(500.62 ± 12.55738) μ²while area of PCT in high dose group was (529. 97 ±12.53530) μ²,These results have significant p-value (0.05) between control group and high dose group while there was no significant difference between control group and low dose group and no significant difference between two experimental groups(table 7)

Table 7. Show the difference in the area of proximal convoluted tubule between three groups

group	area of PCT	Mean/ μ²	Std. Error	P-value.
area of PCT control group	low dose group	500.62	12.55738	0.066
	high dose group	529.97*	12.53530	0.001
area of PCT low dose group	control group	457.73	15.00149	0.066
	high dose group	529.97	12.53530	0.273
area of PCT high dose group	control group	457.73*	15.00149	0.001
	low dose group	500.62	12.55738	0.273

Discussion

The human kidney is a bilateral excretory organ crucial for regulating fluid balance, maintaining electrolyte homeostasis, and expelling metabolic waste. Each kidney exhibits a highly unique anatomical configuration that facilitates its functions in filtration, secretion, and reabsorption. . Histologically, the renal cortex contains the numerous renal corpuscles along with the proximal and distal convoluted tubules, whereas the renal medulla consists mainly of loops of Henle and collecting ducts arranged within renal pyramids. The renal corpuscle is composed of the glomerulus and Bowman's capsule, which together form the filtration unit of the nephron [7]. The proximal convoluted tubule is lined with the sample, a cuboidal epithelium characterized by a prominent brush border that increases the surface area for reabsorption. Due to its high metabolic activity and rich blood supply, renal tissue is particularly vulnerable to toxic substances and heavy metals that may induce structural and functional alterations [8]. Gross examination revealed that kidneys in the control group maintained normal morphology, including their characteristic bean shape, deep brown pinkish color, and intact cortical-medullary differentiation. In contrast, treated groups exhibited a light pinkish brown color with patchy light areas, which were more prominent in the high-dose group. Such discoloration may be attributed to oxidative stress induced cellular injury, where increased production of (ROS) lead to impaired renal perfusion, hypoxia, and early degenerative changes in renal parenchyma. Similar gross alterations have been reported following heavy metal exposure, where vascular compromise and oxidative stress lead to visible tissue pallor and patch formation [9].Cortical thinning observed in treated groups further supports the presence of structural damage, as the renal cortex is highly susceptible to toxic injury due to its high metabolic activity and dense concentration of glomeruli and proximal tubules. Loss of cortical thickness has been linked to nephron loss and progressive degeneration in experimental nephrotoxicity models [10]. Morphometric analysis showed no significant change in kidney length among groups, suggesting that longitudinal growth is less affected by toxic exposure. However, kidney width increases with higher doses, likely reflecting interstitial edema, inflammatory infiltration, or vascular congestion. Such findings are consistent with previous studies indicating that toxic renal injury may lead to organ swelling due to fluid accumulation [11]. In contrast, kidney weight showed a dose-dependent decrease, particularly in the high-dose group. This reduction may be attributed to cellular loss, tubular degeneration, and tissue atrophy resulting from sustained toxic insult. Decreased organ weight has been widely associated with chronic nephrotoxicity and progressive structural damage [12].

Chromium-induced renal toxicity

The results of the present study demonstrated significant structural alterations in renal tissues following exposure to chromium, these findings, such as that chromium exerts a toxic effect on renal cells and tissues. Chromium compounds are known to introduce cellular damage primarily through oxidative stress mechanisms. During intracellular reduction of hexavalent and trivalent chromium, reactive oxygen species (ROS) are generated, which can damage cellular proteins, lipids, and DNA. [13]. Similar findings were reported by [14], who observed significant histopathological alterations in renal tissues of rats exposed to potassium dichromate, including tubular degeneration, necrosis, and vascular congestion. In the present study, noticeable structural alterations were observed in the renal corpuscle of the treated groups. These changes may reflect impairment in the glomerular filtration process. Heavy metals such as chromium can induce a glomerular injury through oxidative damage to glomerular cells, leading to structural distortion of the glomerular tuft. Similar glomerular alterations were reported by [15]), who observed glomerular degeneration and disruption of renal architecture in chromium-treated rats.

One of the significant findings in the present study was the enlargement of the urinary space in treated groups compared with the control group. The current study showed a progressive increase in the urinary space despite the apparent enlargement of the glomerular tuft particularly in the higher dose group, these results clarify that expansion of the urinary space is not related to shrinkage, but rather to complex structural alterations within the glomerulus may be due to glomerular hypertrophy which is associated with toxic or metabolic stress. Enlargement of the tuft may result from capillary dilation, mesangial expansion and increased interaglomerular pressure. The proximal convoluted tubules showed degenerative alterations in the treated groups. These included epithelial cell degeneration and disruption of tubular architecture. The proximal tubule is particularly susceptible to toxic injury because it plays a major role in the reabsorption of filtered substances and contains a high concentration of mitochondria, making it highly sensitive to oxidative stress [16][17][18][19][20]. Similar tubular degeneration following the chromium exposure has been reported by [17], who observed necrosis damage in the renal tubules of rats treated with chromium. The progressive increase in renal alterations observed with increasing chromium doses in the present study suggests a dose-dependent toxic effect. Higher chromium concentrations may result in increased oxidative stress and enhanced cellular injury. Dose-dependent nephrotoxic effects of chromium have also been documented in experimental studies where increasing doses of chromium resulted in progressively severe renal damage [18][21][22][23][24].

Conclusion

Chromium exposure leads to significant alterations in renal structure and function, as evidenced by both gross and histomorphometrical findings. Changes including cortical thinning, discoloration, increase kidney width, reduce kidney weight, reflect underlying pathological processes such as edema, vascular disturbance and cellular degeneration. Morphometrical findings further confirmed renal injury through glomerular and the tubular alterations, particularly in the proximal convoluted tubules which are highly susceptible to toxic insult. Importantly these effects where dose-dependent with more pronounced alterations observed at higher levels of exposure.

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Declaration of Conflicting Interests

The author(s) declared that there is no conflicts of interest regarding the research, authorship, and/or publication of this paper.

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