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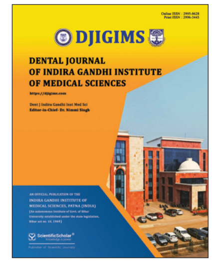

Original Article

Assessment of Nickel Ion Release from NiTi Orthodontic Archwire After Using Magnetized Water as a Mouth Rinse

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ABSTRACT

Objectives: This study was to detect whether the magnetized water (MW), when used as a mouth rinse, can influence the release of Nickel (Ni) ions from NiTi (nickel-titanium) archwires.

Material and Methods: One hundred fifty (0.016" *0.022") as received orthodontic NiTi archwires were grouped into three chief groups based on the used mouth rinse into MW, Ortho Kin (control positive) (OK) and distilled water (control negative) (DW) groups. Every group contained intervals of five points (24 h, 1 week, 2 week, 3 week and 4 week). Ten archwires were used for each interval. The release Ni was detected at each interval using an atomic absorption spectrometer. The topographic features of orthodontic archwires were examined with a scanning electron microscope and an atomic force microscope. SPSS Statistics software (V.19) was used for statistical analysis. One-way Analysis of Variance (ANOVA) and post hoc Duncan's multiple range test were used for data analysis with $P \leq 0.05$.

Results: Significantly less amount of Ni ion released in the MW group was recorded from NiTi archwires in comparison with the OK group for all studied intervals.

Conclusion: MW may be indicated as a suitable adjunct for further commercially available mouth rinses (as OK) throughout orthodontic therapy.

Keywords: Corrosion, Orthodontics, Mouthwash, NiTi

INTRODUCTION

There has been augmented attention among biomedical and dental specialists on the drawbacks of biomaterials usage, particularly metallic materials, especially in the latest decade. Biocompatibility of materials is the most central selection factor regarding orthodontic materials.[1] The corrosion resistance of biomaterials in orthodontics is the utmost essential characteristic.[2] In the oral environment, all metal components suffer from corrosion as a result of thermal, microbiological, mechanical, chemical and enzymatic alterations, which leads to ions release.[3] Prolonged use of any orthodontic appliance placed in the oral cavity should confirm no significant release of toxic ions.[4]

Nickel titanium (NiTi) archwire is one of the most common clinically-applied orthodontic archwires owing to their unique mechanical properties.[5] NiTi alloys consists of 55% Ni and 45% Titanium.[6] A metal used as components of this alloy, i.e., Ni, has been known as allergenic, mutagenic, and cytotoxic.[7]

Oral health insult is a drawback relating to orthodontic therapy, leading to enamel demineralization, white spots formation, and caries.[8] Additionally, some patients develop periodontal disease during orthodontic therapy and must use mouth rinses to reduce plaque buildup. Therefore, it is suggested to use a diverse mouthwash throughout orthodontic therapy.[9] Using mouth rinses, and prophylactic agents can modify the oral atmosphere, which may result in continued exposure of the orthodontic archwire to these agents. A prior study directed that orthodontists should be careful when prescribing mouth rinses for patients with orthodontic devices.[10] The usage of fluoride ion in different mouth rinses and prophylactic agents for orthodontic patients can alter the oral environment, leading to increased brackets and archwires' corrosion. This destroys the protective titanium oxide layer, which is found on titanium alloys' surface, and results in hydrogen absorption, leading to reduced corrosion resistance and degradation of the mechanical properties of NiTi archwires.[11]

Magnetically treated water also called magnetized water (MW), is water that has been managed with a magnet, and is demarcated as water which exposed to a magnetic field of definite strength.[12] MW is a cheap natural alternative agent which have many applications, prominent advantages, and no side effects.[13–15] A previous study[16] disclosed that MW exhibited superior activity in dental plaque compared to saliva, hence, MW has just been used effectively as a mouth rinse against *S. mutans*. A recent study[17] revealed that MW is effective against *Candida albicans*. Thus, MW can be used as an adjunct to commercially available mouth rinses.[16, 17] The effect of MW may occur due to inhibition of the bonding process by which plaque attaches to teeth and by which bacteria colonizes. This inhibition can be explained by the principle of "magnetohydrodynamics."[16] A study showed that there is a significant reduction in gingival scores as well as plaque was observed after using MW.[18]

Still, there is no previous study in the literature, and no information exists concerning the influence of MW as a mouth rinse on Ni ions released from NiTi orthodontic archwires. Therefore, the purpose of this study was to determine if the usage of MW as a mouth rinse affects Ni ion release from NiTi archwires and to detect the topographic features of orthodontic NiTi archwire rinsed with MW by atomic force microscope (AFM) and scanning electron microscope (SEM).

The tested null hypotheses were:

1. The released Ni ions concentration from NiTi archwires rinsed with MW is not different from Ortho Kin (OK) mouth rinse.
2. The topographic features of NiTi archwires rinsed with MW via SEM and AFM are not different from OK mouth rinse.

MATERIAL AND METHODS

Material

The sample comprised of one hundred fifty (0.016" *0.022") as received orthodontic NiTi archwires (Dentarum, Germany). The archwires were divided into three chief groups based on the used mouth rinse as follows: MW group prepared at 3000 Gauss magnetic field, OK (OrthoKin mouth rinse, LABORATORIES KIN S.A.- Spain contains 500 ppm sodium fluoride) group (control positive) and DW group (control negative). Every chief group contained intervals of five points (24 h, 1 week, 2 week, 3 week and 4 week). For each time interval, ten archwires were used; thus, every chief group had 50 archwires. A pilot study was done on five randomly selected NiTi archwires incubated in artificial saliva at 37 °C and rinsed for 1 min twice daily with DW for one week. The obtained standard deviation of means of the Ni ion release of these archwires was 0.2. The sample size in each sub-group was calculated by using a single mean formula $[n = (Z\ r/D)^2]$. Where (n) represents the number of samples, Z (constant) equals to 1.96 for 95 % confidence, (r) represents the standard deviation equals 0.20 (from the pilot study), and D (precision) equals 0.2 units. The final sample size in every group was approximately = 4. Nevertheless, 10 archwires were included in each sub-group for a more accurate result.

Preparation of MW

A locally made device was used to magnetize (100 ml) DW and 3000 Gauss magnetic field neodymium-type magnets (K&J Magnetics, China) were utilized. The Gauss meter (LakeShore 455 DSP, USA) determined the magnetic strength. The magnets were placed below the glass beaker for 72 h with the north pole facing up. MW was used for 1 minute twice a day.[18]

Artificial saliva

Components of artificial saliva are CaCl2 · 2H2O 0.79, NaH2 PO4.2H2O 0.78, KCl 0.40, NaCl 0.40, CO(NH2)2 Urea 0.1 and Na2S.9H2O 0.005, in 1000 ml distilled water, pH of 7 (concentration g\L).[19]

Methods

The NiTi archwire was wiped with acetone, cleaned with DW, and dried with an absorbent towel. Each archwire was divided into four equal parts and placed in a glass container (volume 30 ml). Each container contained 25 ml of respective artificial saliva solution. The samples were incubated at 37°C for 24 h, 1 week, 2 week, 3 week, and 4 week. At 12 h intervals corresponding to using of mouth rinse (twice a day), the wires were removed from the incubator (nüve EN 400, Turkey), washed in DW, then rinsed with 25 ml of solution sample (MW, OK or DW) contained in distinct 30-ml glass containers. The rinsing time was 1 min, two times daily.[18] Then the wires were washed by DW before they were returned back to their artificial saliva containers in the incubator at 37°C until the following mouth rinse rinsing period. This procedure was recurrent at the same rhythm till the end of four weeks. At the end of each five-time-points (24hrs, 1wk, 2wk, 3wk, and 4wk), the archwire pieces were detached from the artificial saliva solution then an addition of one drop of nitric acid with a concentration of 65% was done to stabilize the ions released.[3]

Ni ion Release Analysis

The artificial saliva samples were withdrawn after shaking[20], and then the Ni ion was analyzed via an atomic absorption spectrometer (AAS) (BUCK Scientific, USA).

Topographic Features of NiTi Orthodontic Archwires

One piece of each NiTi archwire representing every chief group was used for descriptive evaluation of the surface characteristics of NiTi archwires before and after 4 week experiment using a scanning electron microscope (SEM) (TESCAN MIRA3, French) and atomic force microscope (AFM) (NaioAFM Nanosurf Switzerland).

Statistical Analysis

The data were analyzed using SPSS Statistics (version 19.0, USA). The normality of data was assessed via Shapiro–Wilk's test. Descriptive statistics of the Ni ions released for the study groups were reported. Statistical differences between the experimental and control groups were assessed using the One Way Analysis of Variance (ANOVA) test to identify any statistical significance at ($P \leq 0.05$) among the study groups, and post-hoc Duncan's Multiple Range test was done to detect the significant differences among the groups.

RESULTS

Results of Ni ion release from NiTi archwire

The descriptive statistics of Ni ion release (measured in part per billion, ppb) from NiTi archwire are demonstrated in Table 1. These data revealed that at 24 h, 1 week, 2 week, 3 week, and 4 week intervals, OK exhibited the maximum Ni ions release, but DW presented the lowermost Ni ions release value.

Table 1: Descriptive statistics for the Ni ion release from NiTi archwire for the study groups.

Groups	N	Mean	SD	R	Min.	Max.
Ni DW NiTi 24hrs	10	1.96	0.11	0.30	1.80	2.10
Ni OK NiTi 24hrs	10	4.40	0.22	0.60	4.10	4.70
Ni MW NiTi 24hrs	10	2.14	0.20	0.50	1.90	2.40
Ni DW NiTi 1wk	10	2.34	0.20	0.50	2.10	2.60
Ni OK NiTi 1wk	10	8.30	0.55	1.20	7.70	8.90
Ni MW NiTi 1wk	10	2.42	0.22	0.60	2.10	2.70
Ni DW NiTi 2wk	10	7.20	0.41	1.00	6.70	7.70
Ni OK NiTi 2wk	10	300	13.35	31.30	284.70	316
Ni MW NiTi 2wk	10	19	0.83	2.20	17.90	20.10
Ni DW NiTi 3wk	10	18.64	0.46	1.10	17.90	19.00
Ni OK NiTi 3wk	10	460	18.93	51	431	482
Ni MW NiTi 3wk	10	21.60	0.33	0.80	21.20	22
Ni DW NiTi 4wk	10	28.80	0.79	2.10	27.90	30
Ni OK NiTi 4wk	10	900	30.26	70.80	867.20	938
Ni MW NiTi 4wk	10	55.80	1.20	3	54	57

N: number, R: range, Min.: minimum, Max.: maximum, SD: Standard deviation, Ni: nickel ion release (ppb), DW: distilled water, OK: Ortho Kin mouth rinse, MW: magnetized water, NiTi: nickel titanium archwire, hrs: hours and wk: week.

The results of ANOVA were presented in Table 2, showing that at all the studied intervals, there was a significant difference at ($P \leq 0.05$) among the groups. Duncan's multiple range test was made among all the groups [Table 3], detecting that at 24 h, 1 week, 3 week, and 4 week intervals, Ni ion release value was significantly higher in an OK group than in MW and DW. In contrast, DW and MW groups showed non-significant Ni ion release differences. At a 2 week interval, the OK group showed the highest significant difference in Ni ion release followed by MW. However, the DW group revealed a significantly lowest difference value in Ni ion release.

SEM results

The new, as received NiTi archwire displayed considerably a smooth surface devoid of any signs of corrosion, as observed in Figure 1, but with a small amount of surface roughness when increasing the magnification power [Figures 1-Ia and 1-Ib]. After the 4 week immersion period in DW, the NiTi archwire exhibited small and few areas of surface irregularities [Figures 1-IIa and 1-IIb]. After the 4 week immersion period in OK mouth rinse, the surface of the archwire displayed abundant and diffused surface defects and signs of corrosion [Figures 1-IIIa and 1-IIIb]. Whereas after a 4 week immersion period in MW, the archwire showed small and localized areas of surface roughness as shown in Figures 1-IVa and 1-IVb.

AFM results

Table 4 signifies the values of the arithmetic mean height of surface roughness (Sa = which is the extension of the

Table 2: One way (ANOVA) for the mean values of Ni ion release from NiTi archwires after rinsing in different mouth rinse groups at various intervals.

		Sum of Squares	df	Mean Square	F	Sig.*
At 24hrs	Between Groups	18.489	2	9.245	261.642	0.000
	Within Groups	0.424	24	0.035		
	Total	18.913	26			
At 1wk	Between Groups	116.837	2	58.419	438.140	0.000
	Within Groups	1.600	24	0.133		
	Total	118.437	26			
At 2wk	Between Groups	274337.733	2	137168.867	2235.598	0.000
	Within Groups	736.280	24	61.357		
	Total	275074.013	26			
At 3wk	Between Groups	645003.285	2	322501.643	2696.292	0.000
	Within Groups	1435.312	24	119.609		
	Total	646438.597	26			
At 4wk	Between Groups	2453986.800	2	1226993.400	4010.328	0.000
	Within Groups	3671.500	24	305.958		
	Total	2457658.300	26			

df: degree of freedom, Sig*.: significant at $P \leq 0.05$, F:F test, hrs: hours, and wk: week, ANOVA: Analysis of Variance, Ni: Nickel, NiTi: nickel-titanium.

Table 3: Duncan's multiple range test for multiple comparisons of the Ni ion release from NiTi archwires after rinsing in different mouth rinses at various intervals.

	Mouth rinse	N	Mean ± SE	Duncan Groups*
At 24 hrs	DW	10	1.96 ± 0.050	A
	OK	10	4.40 ± 0.100	B
	MW	10	2.14 ± 0.092	A
At 1wk	DW	10	2.34 ± 0.092	A
	OK	10	8.30 ± 0.246	B
	MW	10	2.42 ± 0.101	A
At 2wk	DW	10	7.20 ± 0.184	A
	OK	10	300 ± 5.970	C
	MW	10	19 ± 0.374	B
At 3wk	DW	10	18.64 ± 0.206	A
	OK	10	460 ± 8.467	B
	MW	10	21.60 ± 0.151	A
At 4wk	DW	10	28.80 ± 0.356	A
	OK	10	900 ± 13.533	B
	MW	10	55.80 ± 0.537	A

N: number, SE: standard error, *Different litters mean significant difference at the same interval ($P \leq 0.05$), DW: distilled water, OK: Ortho Kin mouth rinse, MW: magnetized water, hrs: hours, wk: week, Ni: Nickel, NiTi: nickel-titanium.

Table 4: Surface roughness values of NiTi archwires.

	Sa value (nm)
New archwire	2.160
DW	2.850
OK	3.813
MW	3.135

Sa: arithmetic mean height, nm: nanometer, DW: distilled water, OK: Ortho Kin mouth rinse, and MW: magnetized water, NiTi: nickel-titanium.

arithmetical mean height of a line to a surface; this parameter is measured by nanometer (nm)) of new as received NiTi archwire and for NiTi archwires after rinsing in the studied mouth rinses, it demonstrates that the highest Sa value was for archwire rinsed with OK, followed by archwire rinsed with MW, then followed by archwire rinsed with DW. In contrast, the least Sa value was for new archwire.

Figures 2a, 2b, 2c, 2d signify the AFM topographical images of new, DW, OK and MW regularly, the overall look of all AFM images conforming to the arithmetic mean height (Sa) values. The surface of the new archwire had a generalized shallow pit, as found in Figure 2a. The depth of the pits increased obviously [Figure 2b], after 4 week archwire rinsing with DW. The surface of the archwire rinsed with OK showed a large and deep cavity [Figure 2c]. While in MW, the archwire surface showed shallow grooves, as seen in Figure 2d.

DISCUSSION

Many factors may influence metal corrosion in a water environment, including water temperature, duration of immersion, pH value, and oxygen saturation.[21] In this study, mouth rinses were used in a static state; however, in fact, more metal release could occur because of oxide layers' removal by brushing of teeth and similarly owing to the flowability of saliva in the mouth,[22] in addition to changing oral environment due to changing food and fluid intake.

The Ni ions released from NiTi archwires after rinsing with OK occurred due to corrosion. When NiTi archwire is in a low pH (acidic environment), the corrosion process may occur because of an oxidation and reduction reaction. In an acidic environment, "hydrogen ions (H+) will form. A higher acid

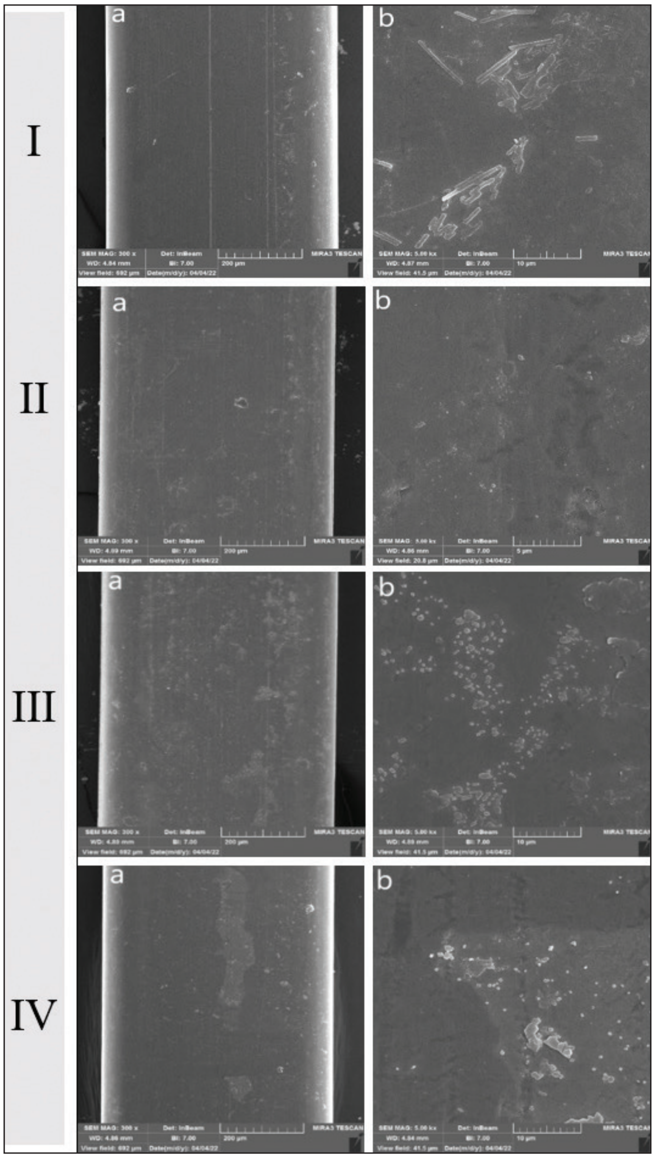

Figure 1: SEM images for NiTi archwires I: new, II: after 4 week rinsing in DW, III: after 4 week rinsing in OK and IV: after 4 week rinsing in MW, at magnification power of (a) 300x and (b) 5000x. SEM: scanning electron microscope, NiTi: nickel-titanium, OK: Ortho Kin, MW: magnetized water, MW: magnetized water, DW: distilled water.

concentration leads to more H+ ions released from the acid, which reacts and experiences reduction. Thus, more metal ions suffer from oxidation, which accelerates the process of corrosion, resulting in Ni ions release".[22]

NiTi archwire contains a titanium element that will form titanium oxide (TiO_2) on the surface of the archwire and acts as a thin passive protective layer to protect NiTi archwire from the process of corrosion. However when this passive layer is damaged, it will cause Ni ions release on the surface of NiTi archwire. Acidic pH is one of the factors that can damage TiO_2 layer of NiTi archwire through a corrosion process,

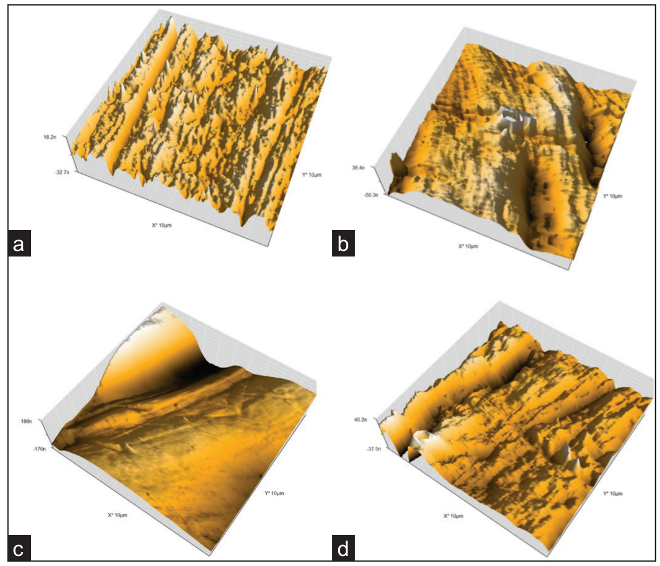

Figure 2: 3D AFM images for: (a) new NiTi archwire, (b) NiTi archwire after 4 week rinsing in DW, (c) NiTi archwire after 4 week rinsing in OK and (d) NiTi archwire after 4 week rinsing in MW, AFM: atomic force microscope, NiTi: nickel-titanium, DW: distilled water, MW: magnetized water, OK: Ortho Kin.

which causes Ni ion release.[23] Therefore, it can be considered that there is an inversely proportional relation between pH and corrosion. The lower the pH of the media, the greater the corrosion rate. Hence that the pH of the immersion media can help explain the cause of corrosion if all other factors remain constant. Fluoridated mouth rinses in the current study OK could also create acidic environment.[3]

"Aggressive ions present in the solution (fluoride) can lead to the formation of an acid (hydrofluoric acid) which can infiltrate through the undermined areas of a passive film and lead to regional breakdown and starting of corrosion. This corrosion failure cannot be seen by the naked eye but by microscopic observation".[24] An important fact to be considered is that fluoride has an acidic pH, which is regarded as a significant factor in the split of the protective oxide layer (titanium-based alloy), resulting in corrosion.[25]

The results of this study showed that Ni ion released value from NiTi archwire was significantly the highest when rinsed with OK mouth rinse at all-time intervals, as OK has low pH value and high concentration of fluoride ion that increased Ni ion release. Moreover, the results were in agreement with the former studies concerning OK mouth rinse; since it was found that acidic environment and fluoride ion can lead to corrosion. Kang *et al.*[26] stated that an acidic NaF solution could influence surface morphology and microhardness by damaging Ti-based orthodontic brackets. Erdogan *et al.*[27] studied the effect of different types of mouth rinses on the metal ion release and concluded that the greatest amount of release occurs in alcohol and NaF containing mouth rinses.[26] Likewise, OrthoKin mouth rinse (fluoridated) has a higher concentration of metallic ion release than Kin Forte and DW. In an acidic environment, corrosion could easily occur even with low fluoride concentrations.[28] Anions, such as fluoride and chloride ions, attack the protective oxide layer, leading to pitting type of corrosion.[10] The resistance to corrosion of some metals, specifically titanium, as reported by some studies, is reduced in a fluoridated, acidic atmosphere.[29] A study[21] reported that chromium and Ni ions release were the highest in ALOF mouth rinse. This could be due to the fluoride anion in its composition.[30]

In this study, the MW had a non-significantly higher difference value of Ni ion release from DW at 24h, 1week, 3week and 4week intervals. At a 2week interval, MW showed a significantly higher value of Ni ion release than DW. This may attributed to the fact that exposure of the water to the magnetic field and its properties such as its pH, salinity, conductivity, evaporating temperature, dissolved oxygen, organic matter, minerals, total dissolved solids, and the account of bacteria will considerably change.[21] Water becomes an electrical conductor, increasing in soluble oxygen percentage having more solubility for acids and minerals after passing through the magnetic field, which could accelerate biochemical reactions.[31] Furthermore, the physical characteristics of the water will be enhanced by reducing its surface tension.[32] Mghaiouini *et al*.[33] confirmed that the dielectric constant and resistance of treated water will be reduced, and its electric conductivity will be increased under the influence of the electromagnetic field.

Thus the corrosion that occurred in MW may be due to increasing in water conductivity, resulting in increasing the rate of corrosion. Gas that dissolve in water, such as carbon dioxide and oxygen are the most critical gas from the corrosion risk standpoint. "Oxygen acts as a depolarizer in the cathodic half-cell, enhancing corrosion risk."[34]

The proposed null hypotheses were rejected, as the released Ni ions concentration from NiTi archwires in the existence of MW was significantly less than OK, accompanied by little changes in surface characteristics after immersion in MW when compared with OK, as confirmed by SEM and AFM.

CONCLUSION

MW may be indicated as a suitable adjunct to other commercially available mouth rinses (as OK) throughout orthodontic therapy, especially in Ni- allergic patients.

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Ethical approval

The research/study was approved by the Institutional Review Board at the University of Mosul/College of Dentistry, number UoM.Dent/ DM.H.28/22, dated 19-4-2022.

Declaration of patient consent

Patient consent is not required as there are no patients in this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of Artificial Intelligence (AI)-Assisted Technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI.

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