CLINICAL RESEARCH

Effect of serum vitamin D, calcium, and phosphorus on mandibular residual ridge resorption in completely edentulous participants: A clinical study

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Retention and stability are important factors in the success of a complete denture. They are primarily dependent on the structural integrity displayed by the underlying residual ridge. However, structural integrity is transient because residual ridges undergo progressive resorption.[1] The rate of residual ridge resorption can be measured by using biochemical markers such as deoxypyridinoline, N-telopeptides, and C-telopeptides.[2] However, the methods available to quantify these markers are expensive, and a cost-effective method is needed to predict bone resorption. Moreover, the degree of bone resorption is not uniform among individuals because the process is influenced by anatomic, metabolic, functional, and prosthetic factors.[3,4]

ABSTRACT

Statement of problem. Published data regarding association between edentulous mandibular residual ridge resorption and nutritional status of geriatric patients is limited.

Purpose. The purpose of this clinical study was to evaluate the degree of mandibular residual ridge resorption in completely edentulous participants and to investigate the role of dietary nutrients in the resorption process.

Material and methods. Three hundred (55% men and 45% women; aged between 35 and 85 years) completely edentulous participants with specific inclusion and exclusion criteria were enrolled for the study. A standardized panoramic radiograph was made, measurements were made digitally, and the amount of resorption was calculated using the Wical and Swoope method. The blood plasma levels of vitamin D3 were analyzed by using the direct competitive chemiluminescence immunoassay (CLIA) method, whereas the total calcium and phosphorus were determined by using spectrophotometer method. Statistical data of serum nutrient levels (calcium, phosphorus, and vitamin D3), age, sex, and residual ridge resorption were subjected to the Mann-Whitney U test, the Spearman correlation test, and a stepwise multiple linear regression analysis (α=.05).

Results. Calcium (*P*=.003) and phosphorus (*P*<.001) levels were significantly increased in the female participants as compared with the male participants. Vitamin D3 levels were similar in all the participants. Moreover, metabolic levels of calcium (rho=-0.09), phosphorus (rho=-0.10), and vitamin D3 (rho=-0.02) were found to be reduced with increasing age. However, male participants had increased mandibular residual ridge resorption (*P*<.001) with positive correlation (rho=0.06) when compared with female participants. Mandibular ridge resorption was increased with a decrease in levels of serum nutrients.

Conclusions. Increased levels of mandibular residual ridge resorption were observed in participants with decreased levels of systemic biochemical parameters, including calcium, phosphorus, and vitamin D3. Moreover, male participants showed increased residual ridge resorption when compared with female participants, who showed a significantly higher level of serum nutrient levels. Serum nutrient levels decreased, whereas mandibular residual ridge resorption increased with age. (J Prosthet Dent 2022;127:93-9)

Clinical Implications

Total calcium, phosphorus, and vitamin D3 levels play an important role in the oral health of individuals with complete edentulism. Understanding the degree of residual ridge resorption will help the clinician to effectively modify the diet and prescribe nutritional supplements for improved treatment.

Skeletal growth depends on factors including vitamins, minerals, and hormones. Calcium, the principal constituent of bone, is actively absorbed from the small intestine in the presence of vitamin D3, which plays a pivotal role in increasing intestinal calcium absorption, calcium homeostasis, and bone metabolism.[5,6] In addition, phosphorus forms hydroxyapatite crystals along with calcium that will mineralize and strengthen bones. Subclinical vitamin D3 deficiency and low dietary calcium intake are important risk factors for reduced bone mineral density, osteoporosis, and fractures. Therefore, a diet containing optimal calcium, phosphorus, and vitamins is important for the proper mineralization of bone.[7,8]

When the dietary sources of calcium are depleted, trabecular bone, including the jaws and the ribs, becomes the primary source of calcium.[9] Furthermore, the prevalence of varying degrees of vitamin D3 deficiency because of low dietary calcium intake in an Indian population has been reported, especially with women after the menopause.[10] In addition, predicting the degree of the residual ridge resorption process has a clinical significance in fabricating dentures.[11] The purpose of this clinical study was to evaluate whether the serum vitamin D3, calcium, and phosphorus levels are associated with residual ridge resorption in completely edentulous participants. The null hypothesis was that no interrelations would be found between serum levels of vitamin D3, calcium, phosphorus, and mandibular residual ridge resorption.

MATERIAL AND METHODS

Completely edentulous participants visiting the Department of Prosthodontics, D.A. Pandu Memorial. R.V. Dental College, Bangalore, India, were enrolled in this study. The participants had been completely edentulous for more than 1 year and were aged between 35 and 85 years. Exclusion criteria were those with maxillary and mandibular defects, known neurologic deficits, known osteoporosis, osteopenia, or osteoarthritis, hypertension taking calcium channel blockers, autoimmune diseases, including rheumatoid arthritis, metabolic syndromes, and those receiving nutritional supplements. The purpose of the study was explained, and consent was obtained after ensuring that the purpose of the study was completely understood. The study protocol was approved by the Ethics Committee of D.A. Pandu Memorial. R.V. Dental College, Bangalore, India (IEC/IRB NO:116/VOL-1/2015).

Three hundred participants were enrolled as per the inclusion and exclusion criteria. Written consent was obtained after which a panoramic radiograph was made. Blood was obtained and sent to a clinical laboratory for analysis. All the blood reports were provided to the participants free of cost, and they were counseled to seek a physician to improve their nutritional status. This was in addition to the complete denture that was provided by predoctoral or postgraduate students at the dental school.

A total of 5 mL of blood was obtained from each participant, the blood samples were centrifuged, and serum samples were stored at -80 °C until further assays were completed. Serum 25-hydroxy vitamin D3 levels were assayed by using fully automated chemiluminescent immunoassay (Siemens ADVIA Centaur). Serum calcium was measured with the Arsenazo III method: a metallochromic indicator, chemically stable, with high affinity for calcium (II) at neutral pH, and not affected by magnesium ions. It formed a purple violet Arsenazo III-calcium complex, which was destroyed by ethylenediaminetetraacetic acid (EDTA).[12] The absorbance of the intense purple-colored Ca-Arsenazo III complex was measured by spectrophotometry at 660 to 700 nm. The resulting absorbance of the reaction mixture was directly proportional to the calcium concentration in the sample.[12,13] The total phosphorus level was measured by spectrophotometry with the unreduced phosphomolybdate method. Phosphate was determined in serum without deproteinization as the phosphomolybdic acid complex by UV spectrophotometry. For each participant, a digital panoramic radiograph (8000C digital panoramic and cephalometric system; Kodak) was made by using standard exposure parameter settings (74 kV, 10 mA for 12 seconds) to assess the degree of residual ridge resorption. By using digital panoramic images (MasterView software), the original height of the mandible and the amount of resorption was calculated using the Wical and Swoope formula.[14,15] Based on the radiographic findings, the participants were divided into 3 categories: mild resorption, up to one third of the original vertical height resorbed; average resorption, from one third to two thirds of the original vertical height resorbed; and severe resorption: more than two thirds of the original mandibular height resorbed.[14,15]

The participants were divided into 2 subgroups as per their sex. A statistical software program (IBM SPSS Statistics, v22.0; IBM Corp) was used to analyze the data. The relationship between mandibular resorption and calcium, phosphorous, and vitamin D3 levels were investigated with the Spearman correlation test. A sex

Table 1. Age and sex distribution among participants

Variable	Category	Number	Percentage Distribution
Age	41-50 y	17	5.7
	51-60 y	64	21.3
	61-70 y	116	38.7
	71-80 y	79	26.3
	81-90 y	24	8.0
Sex	Male	165	55.0
	Female	135	45.0

comparison of serum calcium, phosphorus, and vitamin D3 with resorption levels was studied by using the Mann-Whitney U test (α=.05). The relationship between the mandibular resorption with metabolic markers was predicted by using a stepwise multiple linear regression analysis.

RESULTS

The present study was performed to evaluate the effect of metabolic nutrients including calcium, vitamin D3, and phosphorus with residual ridge resorption and its relationship with the age and sex of 300 completely edentulous participants. The age and sex distributions of the participants are presented in Table 1. The mean ±standard deviation age of the participants was 65 ±18.7 years, with the youngest participant being 35 years and the oldest being 85 years of age.

The levels of calcium (P=.003) and phosphorus (P<.001) were significantly higher in female participants than in male participants, whereas residual ridge resorption (P<.001) was significantly higher in male participants than in female participants (Fig. 1, Table 2). No differences in the levels of vitamin D3 were observed in male and female participants (Fig. 1B).

Comparing the levels of metabolic nutrients such as calcium, phosphorus, and vitamin D3 with the age of the participants by using the Spearman correlation test showed a very weak and negative correlation with rho values -0.09, -0.10, and -0.02 respectively. Conversely, mandibular resorption showed a very weak positive correlation (rho=0.06) with age (Table 3). However, the rho values were not significantly different.

The rate of mandibular resorption increased with the decreasing levels of metabolic nutrients. The Spearman correlation test showed a significant weak negative correlation between mandibular resorption and metabolic nutrients, namely calcium (rho=-0.34; P=.001), phosphorus (rho=-0.35; P<.001), and vitamin D3 (rho=-0.23; P<.001) (Table 4). Moreover, the tangent line in the scatter plot confirms the negative correlation between mandibular residual ridge resorption and metabolic nutrients (Fig. 2).

An increase in the levels of vitamin D3 was observed in the serum with increased levels of calcium and
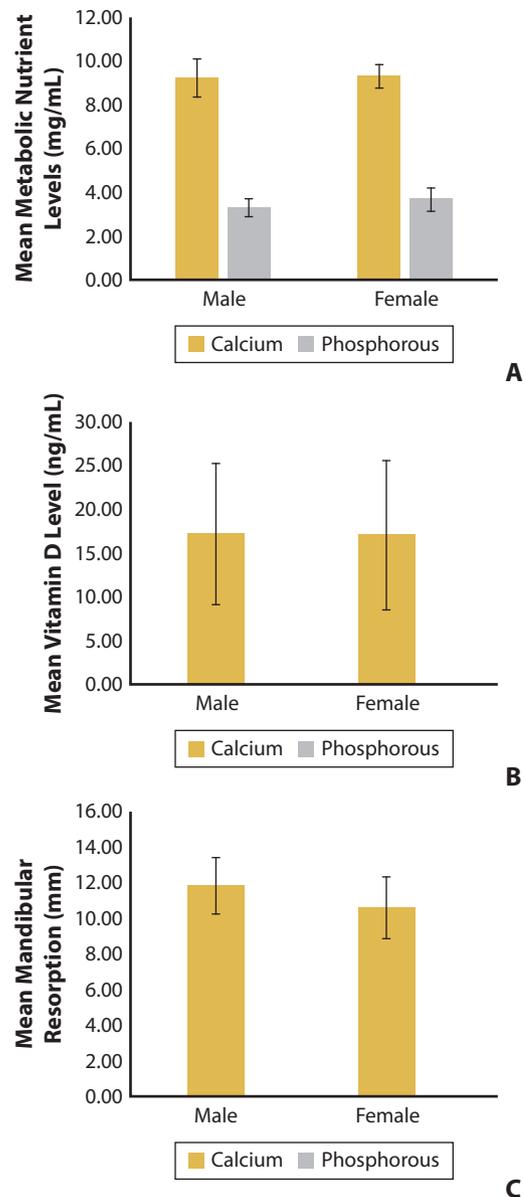

Figure 1. Sex-wise comparison of A, mean calcium and phosphorus level; B, vitamin D; C, mandibular resorption among study participants.

phosphorus. The Spearman correlation test showed a weak positive correlation between vitamin D3 and calcium (rho=0.40), as well as with phosphorus (rho=0.37) (Table 4).

Based on the levels of mandibular residual ridge resorption, all the participants were categorized into various groups as described in the methods. A Mann-Whitney U test categorized 158 participants into the mild resorption group (up to one third of the original vertical height resorbed) and 142 participants into the average resorption group (from one third to two thirds of the original vertical height resorbed). No participants were found to be a part of the severe resorption group. It was

Table 2. Sex-wise comparison of variables using Mann-Whitney *U* test

Variables	Sex	N	Mean Ranks	Z	P
Calcium	Male	165	137.13	-2.951	.003*
	Female	135	166.84		
Phosphorus	Male	165	123.55	-5.959	<.001*
	Female	135	183.44		
Resorption	Male	165	180.27	-6.571	<.001*
	Female	135	114.12		

N, number of participants; *P*, probability value; Z, standard score. *Statistically significant.

Table 3. Age-wise comparison. Spearman correlation statistics to estimate relationship between age and other study variables

Variables	Values	Calcium	Phosphorus	Resorption
Age	rho	-0.09	-0.10	0.06
	P	.130	.100	.290
	N	300	300	300

N, number of participants; *P*, probability value; rho, correlation coefficients (minus sign denotes negative correlation); Correlation coefficient range: 0.0, no correlation; 0.01-0.20, very weak correlation; 0.21-0.40, weak Correlation; 0.41-0.60, moderate correlation; 0.61-0.80, strong correlation; 0.81-1.00, very strong correlation.

Table 4. Spearman correlation test to estimate relationship between mandibular resorption and calcium, phosphorous, and vitamin D_3 levels

Variables	Values	Resorption	Calcium	Phosphorus	Vitamin D_3
Resorption	rho	1	-0.34	-0.35	-0.23
	P	—	.001*	<.001*	<.001*
	N	300	300	300	300
Calcium	rho	-0.34	1	0.51	0.40
	P	.001*	—	.001*	.001*
	N	300	300	300	300
Phosphorus	rho	-0.35	0.51	1	0.37
	P	<.001*	.001*	—	<.001*
	N	300	300	300	300
Vitamin D3	rho	-0.23	0.40	0.37	1
	P	<.001*	.001*	.001*	—
	N	300	300	300	300

*Statistically Significant. N, number of participants; *P*, probability value; rho, correlation coefficients (minus sign denotes negative correlation); Correlation coefficient range: 0.0, no correlation; 0.01-0.20, very weak correlation; 0.21-0.40, weak Correlation; 0.41-0.60, moderate correlation; 0.61-0.80, strong correlation; 0.81-1.00, very strong correlation. *Statistically Significant.

also observed that the levels of calcium, phosphorus, and vitamin D3 between the mild and average resorption groups were significantly (P<.001) different (Table 5).

A stepwise multiple regression linear analysis showed a significant linear relation between the phosphorus levels and the mandibular resorption in the overall sample at P<.001 (adj R^2=0.11). For every 1 mg/dL of phosphorus level increase, 1.06 mm of mandibular ridge resorption decreased. A similar significant linear relation was observed among men (adj R^2=0.06) at P<.001. In men, for every milligram of phosphorus level increase, the mandibular ridge resorption decreased by 0.76 mm. Among the women participants, a significant linear relationship was observed between mandibular ridge resorption and calcium level (adj R^2=0.09) at P<.001. In women, for every 1 mg/mL of calcium level increase, the mandibular ridge resorption decreased by 1.24 mm. The results demonstrated a significant linear relation between vitamin D3 levels and mandibular residual ridge resorption in the overall sample at P<.001 (adj R^2=0.05), and for every 1 nanogram of increase in vitamin D3, resorption decreased by 0.05 mm (Table 6). A regression equation was drawn from the results to predict the mandibular residual ridge resorption by using calcium and phosphorus levels (y=ax+b). In accordance with this regression equation, mandibular residual ridge resorption could be predicted by analyzing serum calcium or phosphorus levels in a South Indian population with edentulous ridges (Table 7).

DISCUSSION

Mandibular residual ridge resorption rates have been reported to vary among and within individuals at different ages.[16] Regardless of the broad understanding of the resorption process, knowledge of the metabolic factors that influence resorption is still inadequate. In the present study the effect of calcium, vitamin D3, and phosphorus levels was compared with the incidence of residual ridge resorption in completely edentulous participants. An association was found between serum vitamin D3, calcium, phosphorus, and mandibular residual ridge resorption. Hence, the null hypothesis was

partially rejected. The mean ±standard deviation age of the participants was 65 ±18.7 years, with the youngest participant being 35 years and the oldest 85 years of age.

Resorption of residual ridges may continue for years and can extend below the mucobuccal fold, the muscle attachments, the genial tubercles, the mylohyoid line, and to the level of the periapical bone, leaving grossly mutilated jawbones.[14] Moreover, the occurrence and resorption of the mandibular residual ridge varies with age and sex.[17] Residual ridge resorption has been reported to be multifactorial and influenced by factors including genetics.[18] According to Baylink et al,[19] there is a strong suspicion that genetic factors influence bone density; however, only a few conclusive quantitative studies have dealt with this issue, supporting the concept that individuals of African origin have higher maximum bone density in young adulthood and less age-related bone loss than those of European origin. A number of different mutations have been identified in humans that lead to hereditary vitamin D resistance. Hence, genetic defects in the vitamin D receptors may lead to vitamin D deficiency. Sometimes severe liver or kidney diseases can interfere with the generation of the biologically active form of vitamin D. Fortification of staple foods with
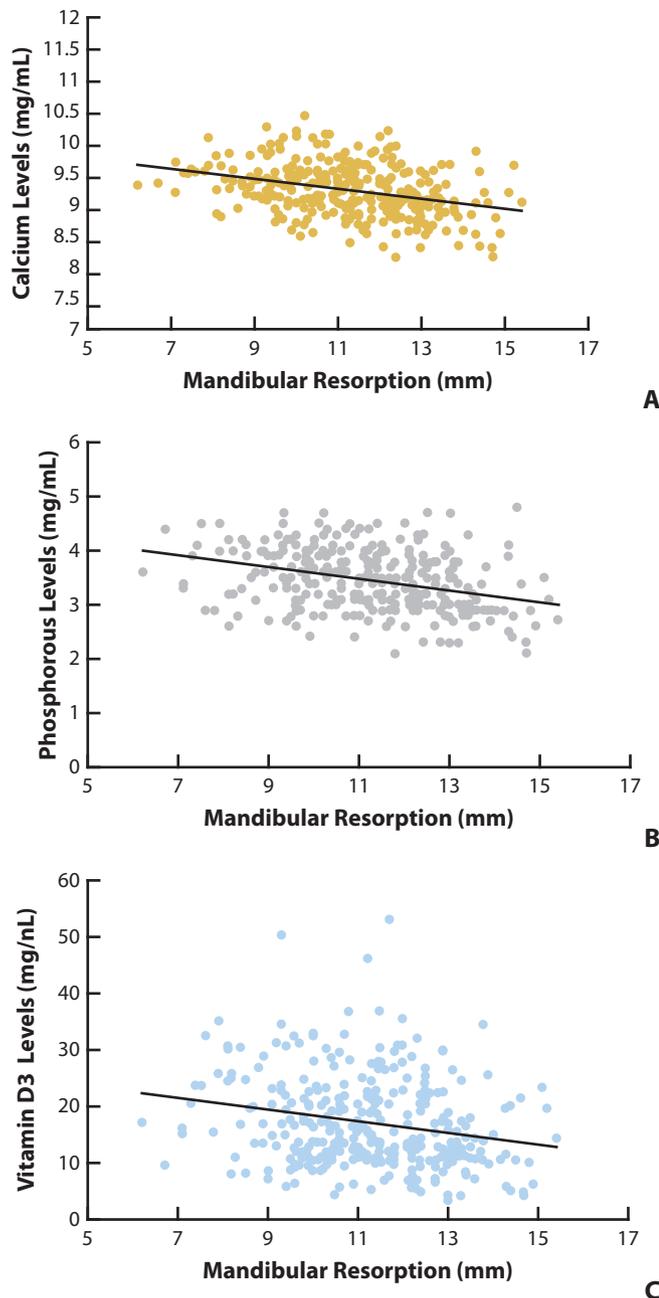
Table 5. Group-wise comparison with calcium, phosphorous and vitamin. D₃ levels. Comparison of different study variables based on different resorption grades by using Mann-Whitney U Test

Variables	Group	N	Mean	SD	Mean Rank	Z	P
Calcium	MR	158	9.38	0.41	179.61	-6.132	<.001*
	AR	142	9.16	0.91	118.11		
Phosphorus	MR	158	3.62	0.52	176.77	-5.541	<.001*
	AR	142	3.28	0.55	121.27		
Vitamin D3	MR	158	19.79	8.12	181.84	-6.600	<.001*
	AR	142	14.04	7.30	115.63		

AR, average resorption – one third to two thirds of original vertical height resorbed; MR, mild resorption – up to one third of original vertical height resorbed; N, number of participants; P, probability value; SD, standard deviation; Z, standard score. *Statistically significant.

Figure 2. Scatter plot depicting relationship between A, mandibular resorption and calcium levels (mg/mL); B, mandibular resorption and phosphorus levels (mg/mL); C, mandibular resorption and vitamin D3 Levels (ng/mL) among study participants.

vitamin D may prove to be a more viable solution to attaining vitamin D sufficiency in India.[20]

Calcium and vitamin D play a major role in maintaining bone health. Recently, it has been documented that 90% of the population are living with calcium deficiency and 50% with vitamin D deficiency.[20] Moreover, varying degrees of vitamin D deficiency occur among the Indian population because of low dietary calcium intake.[7,21]

In the present study, calcium and phosphorus levels in men were significantly lower than in women, with significantly higher levels of residual ridge resorption. These findings are not in agreement with those of studies reporting that women have more alveolar residual ridge resorption than men.[22-26] Furthermore, the data confirmed that lower levels of metabolic nutrients such as calcium and phosphorus might be responsible for the increased resorption of residual ridges. These findings are consistent with those of Wical and Swoope,[15] who reported a correlation between excessive resorption of alveolar bone and inadequate dietary levels of calcium and phosphorus. A decrease in residual ridge resorption in women could be because of improved nutritional intake.

The study compared the levels of metabolic nutrients such as calcium, phosphorus, and vitamin D3 with the ages of the participants, and the results showed a very weak and negative correlation. Dawson-Hughes et al[27] reported that dietary supplementation with calcium and vitamin D reduced bone loss moderately in men and women 65 years of age or older. Jowsey[28] reported that low dietary calcium intake, low calcium-to-phosphorus ratio, and vitamin D3 deficiency were significant factors in general skeletal bone loss. Conversely, mandibular resorption showed a very weak and insignificant positive correlation. These findings are consistent with those of a study with 55 patients with edentulism,[29] where a strong association was found between severe ridge resorption and a combination of low calcium intake and low dietary calcium-to-phosphorus ratio. A significant association was also reported between minimal ridge resorption and a combination of high calcium intake and a high calcium-to-phosphorus ratio in the diet.

The present study supports the physiologic importance of calcium, phosphorus, and vitamin D3 on bone health. The direct relation of these

Table 6. Regression analysis. Stepwise multiple linear regression analysis to predict mandibular resorption using biochemical parameters in overall samples and between sexes

Samples	DV	IV	Unstd. Coef	SE	t	P	R^2_{adj}	F	P
Overall	Resorption	Constant	14.89	0.60	24.83	<.001*	0.12	21.402	<.001*
		Phosphorus	-0.93	0.18	-5.048	<.001*			
		Vitamin D3	-0.03	0.01	-2.027	.040*			
Male	Resorption	Constant	14.32	0.76	18.848	<.001*	0.06	11.121	<.001*
		Phosphorus	-0.76	0.23	-3.335	.001*			
Female	Resorption	Constant	19.64	3.29	5.967	<.001*	0.11	9.277	<.001*
		Calcium	-0.90	0.37	-2.470	.020*			
		Vitamin D3	-0.04	0.02	-2.130	.040*			

DV, dependent variable; F, ratio of mean regression sum of squares divided by mean error sum of squares; IV, independent variable; P, probability value; R^2_{adj}, adjusted coefficient of determination; SE, standard error; t, size of difference relative to variation in sample data; Unstd. Coef., unstandardized coefficients. *Statistically significant.

Table 7. Regression equation (y= ax+b)

y	ax+b
Overall mandibular resorption	Serum phosphorus level x-1.06+14.93
Mandibular resorption in men	Serum phosphorus level x-0.76+14.32
Mandibular resorption in women	Serum calcium level x-1.24+22.09

nutrients to the resorption of bone could be an important diagnostic tool for studying resorption. Limitations of the present study included the age range of the participants. In addition, the reason for tooth loss, diabetes, deleterious habits (smoking, alcoholism), and parafunctional habits was not considered.

The acquisition and maintenance of bone mass and strength are influenced by environmental factors, including physical activity and nutrition. The mineral phase of bone is an analog of the naturally occurring mineral hydroxyapatite. The total amount of calcium and phosphorus in an adult human weighing 70 kg is about 1300 g and 700 g, respectively. Bone contains about 99% of the whole body's supply of calcium and 80% of its phosphorus. The Ca/P mass ratio in bone is 2.2. Vitamin D3 is essential as it is required for the absorption of dietary calcium from the gut. Therefore, all 3 nutrients are interrelated, apart from hormonal influence. Apart from the factors discussed in the study indicating a negative correlation between the serum levels of vitamin D3, calcium, and phosphorous and the resorption of residual ridges, the correlation between these study variables and genetic factors (specific gene) should be determined. Identifying the gene specific to the resorption of residual ridges can lead to gene therapy being an adjunct to the prosthesis. This type of outcome can enhance the prognosis of any type of prosthetic rehabilitation in patients with complete edentulism .

CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. A strong influence of serum vitamin D3, calcium, and phosphorus levels was found on mandibular residual ridge resorption.
2. Mandibular residual ridge resorption increased as the level of serum vitamin D3, calcium, and phosphorus decreased.
3. No association was found between age and serum vitamin D3, calcium, and phosphorus levels.
4. No association was found between sex and serum vitamin D3, calcium, and phosphorus levels.
5. Age and sex were found to be least associated with mandibular residual ridge resorption.

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