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ORIGINAL ARTICLE

Evaluation of renal osteodystrophy in the dental clinic by assessment of mandibular and phalangeal cortical indices

Bruna Corrêa Massahud[1] · João César Guimarães Henriques[1] · Reinhilde Jacobs[2] ·
Rafaela Rangel Rosa[3] · Caio Vinícius Bardi Matai[3]

Abstract

Objectives Secondary hyperparathyroidism (SHPT) is a disease that affects patients with chronic kidney disease, and is characterized by mineral disturbance and bone loss, known as renal osteodystrophy. The aim of this study was to assess the validity of using intraoral phosphor storage plates to take radiographs of the middle phalanges to evaluate bone loss resulting from SHPT during follow-up of these patients.

Methods The sample consisted of 24 patients with chronic kidney disease, 12 with parathyroid hormone (PTH) levels ≥ 500 pg/ml, and 12 with PTH levels <500 pg/ml, who underwent hemodialysis weekly. For each patient, a panoramic radiograph and digital radiographs of the ring, index, and middle fingers of both hands were taken. The Mandibular Cortical Index (MCI) and the Trabecular Bone Pattern Index (TBP) were applied to the panoramic radiographs, while the Phalangeal Cortical Index (PCI) was applied to the digital radiographs of the phalanges. Three evaluators performed all analyses.

Results Significant correlations were found between the PTH levels and the MCI ($p = 0.023$), the PCI ($p = 0.039$)

and the TBP index ($p = 0.032$). These parameters were also significantly interrelated (MCI $\times$ PCI = 0.001; MCI $\times$ TBP = 0.004 and PCI $\times$ TBP = 0.009). The PCI was shown to have the highest correlation with PTH levels.

Conclusion In patients with chronic renal disease, it is clinically relevant to use panoramic and digital radiographs using intraoral storage plates to assess a number of quantitative parameters that can be linked to PTH levels.

Keywords Chronic kidney disease · Secondary hyperparathyroidism · Renal osteodystrophy · Dental radiography · Phalanges of the fingers

Introduction

Secondary hyperparathyroidism (SHPT) is a disease characterized by an increase in parathyroid hormone (PTH) resulting from reduced excretion of phosphorous and diminished secretion of the active form of vitamin D (calcitriol), resulting in hypocalcemia in patients with chronic renal disease [1–5]. Generalized bone loss and the mineral imbalance of calcium and phosphorous culminate in so-called renal osteodystrophies and metastatic calcifications in these individuals [6–12].

The middle phalanges of the middle and index fingers are the first bone sites to undergo the osteoporotic processes resulting from SHPT [9, 13–20]. Recently, a marked correlation was demonstrated between PTH levels and the state of resorption of the middle phalanges of the middle and index fingers of the right and left hands, by means of applying the Phalangeal Cortical Index (PCI) to hand and wrist radiographs [7, 8]. Furthermore, a direct correlation was demonstrated between the osteoporotic action of SHPT in the cortical bone of the middle phalanges of the hands

✉ João César Guimarães Henriques
  joaocesarhenriques@yahoo.com.br

1 Diagnosis and Stomatology Department, Universidade
   Federal de Uberlândia, Avenida Pará, 1720. Bloco 2G, Sala
   08. Bairro Umuarama, Uberlândia, Minas Gerais 38405-320,
   Brazil

2 Oral Imaging Center, Katholieke Universiteit Leuven,
   Kapucijnenvoer 7, 3000 Louvain, Belgium

3 Faculdade de Odontologia, Campus de São José dos Campos,
   Universidade Estadual Paulista Julio de Mesquita Filho,
   Avenida Engenheiro Francisco José Longo, No. 777-Bairro:
   Jardim São Dimas, São Paulo 12245-000, Brazil

and that occurring in the basal cortex of the mandible, evaluated by means of the Mandibular Cortical Index (MCI) [9–11].

The main aim of this study was to assess the clinical applicability and diagnostic value of using intraoral phosphor storage plates to take radiographs of the phalanges of the hand to evaluate bone loss resulting from SHPT. In countries with limited healthcare access, screening for diseases with the use of digital radiographs in the dental clinic may help in directing affected subjects to the appropriate primary care.

Materials and methods

This research was approved by the Research Ethics Committee of Federal University of Uberlândia (Protocol 112.646).

Subjects were selected from the clinical charts of 400 patients with chronic kidney disease and secondary hyperparathyroidism, who were undergoing hemodialysis in the hospital nephrology clinic. One evaluator approached the patients during their hemodialysis sessions, and 24 patients aged between 27 and 66 years agreed to participate in the research after providing informed consent. The subjects agreed to attend the dental, oral, and maxillofacial imaging department of the university to undergo the necessary examinations.

The PTH values of the subjects were measured and 2 groups were formed: 12 individuals with PTH levels <500 pg/ml and 12 considered to have severe secondary hyperparathyroidism, with PTH levels ≥500 pg/ml.

All patients underwent the following imaging examinations conducted by the same radiologist: one panoramic radiograph (Orthopantomograph OP 200 D; Instrumentarium Oy, Tuusula, Finland) and four radiographs of the middle phalanges of the index and middle fingers of both hands, using size 2 phosphor storage plates for intraoral imaging (VistaScan, Dürr Dental GmbH & Co. KG, Bietigheim-Bissingen, Baden-Württemberg, Germany).

After a 14-day training period with a radiologist with 15 years of professional experience, three researchers were calibrated for the observational task. They independently and randomly applied the following evaluations to the digital radiological images acquired:

1. Panoramic radiographs (70 KVp, 10–16 mAs) were used to assess the Mandibular Cortical Index (Fig. 1) [12] and the Trabecular Bone Pattern Index (TBP), a qualitative parameter used to classify the mandibular trabecular bone pattern as dense, heterogeneous, sparse, or sparse with ground glass appearance [8, 10, 11] (Fig. 2). The presence of soft tissue calcifications and brown tumors was also evaluated in the panoramic radiographs.

2. Digital radiographs with size 2 phosphor storage plates for intraoral imaging were used to assess the PCI applied to the middle phalanges of the index and middle fingers of both hands. This index is correlated with the MCI and is used to evaluate the cortical osseous loss on the hand phalanges [7] (Fig. 3). The patient placed the palm of each hand on a smooth flat surface, and the phosphor storage plate was placed over the middle phalanx. A paralleling technique was applied with the X-ray cylinder (Time-X 70, Gnatus Equipamentos Médico-Odontológico LTDA, Ribeirão Preto, Brazil) positioned perpendicular to the sensor handset with exposure parameters of 70 KVp/7 mA and at a distance of approximately 20 cm (Fig. 4).

The degree of resolution of the radiographic images obtained with the use of the intraoral phosphor plate sensor was verified for the purpose of applying the PCI. The intra- and inter-examiner agreement were verified by means of the kappa coefficient. The Spearman's correlation was used to evaluate the correlation of the PTH levels with the indices applied, and to evaluate the correlation between these indices.

In addition, the frequency distribution of the different grades of these indices was evaluated for both groups (PTH <500 and ≥500 pg/ml).

Results

Digital radiographs taken with size 2 intraoral phosphor storage plates provided sufficient coverage for visualization of the middle phalanges of the index and middle fingers. The images were of high resolution and detail, allowing excellent precision for evaluating the PCI (Fig. 2).

Inter-observer agreement was assessed by comparing the results obtained by each of the three evaluators. Kappa values (κ) were 0.80 ($p < 0.01$) for the MCI, 0.80 ($p < 0.01$) for the PCI, and 0.81 ($p < 0.01$) for the TBP. Therefore, inter-examiner agreement was very favorable. For the intra-examiner agreement, the κ value was 0.90 ($p < 0.01$).

The PTH levels of the subjects were significantly correlated with the MCI, PCI, and TBP (Table 1).

The frequency distribution tables for the MCI, PCI, and TBC showed that the group with PTH values ≥500 pg/ml had higher concentrations in the more severe classifications of the indices when compared with the group with PTH values <500 pg/ml (Tables 2, 3, 4).

Fig. 1 The mandibular cortical index (MCI) is a qualitative parameter that classifies, by bilateral inspection, the morphological appearance of the mandibular cortical bone distal to the mental foramen as normal cortex (C1), moderately eroded cortex (C2), and severely eroded cortex (C3)
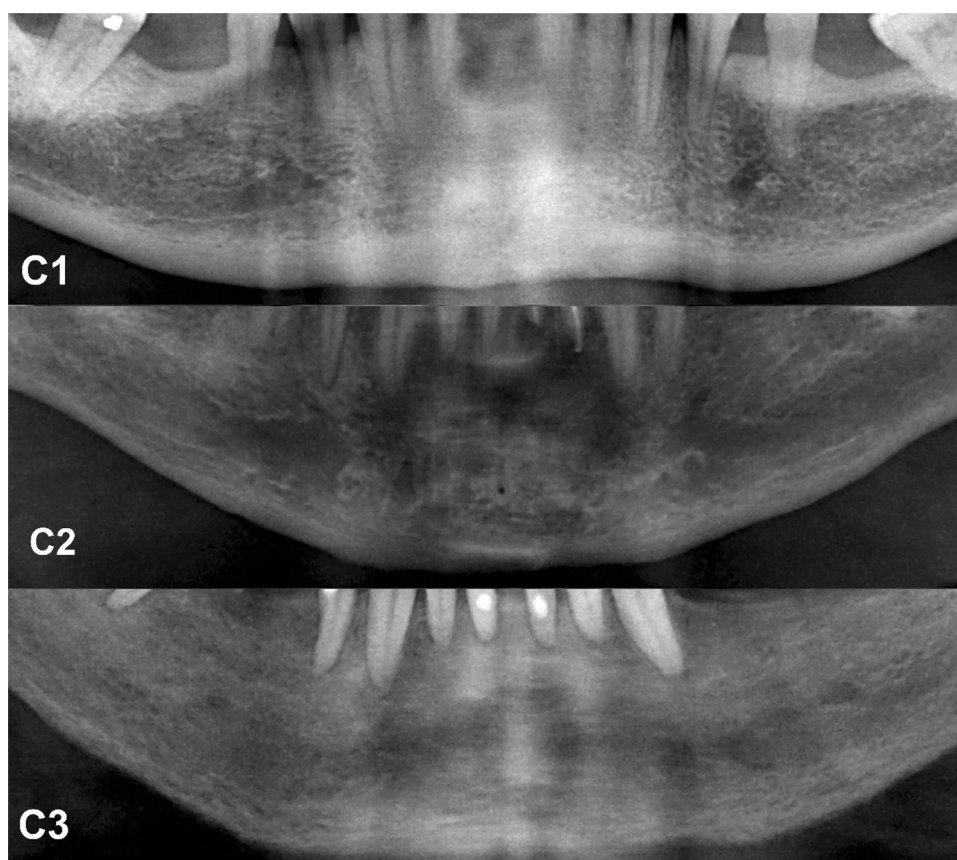
Fig. 2 A subject presenting with grade C3 Mandibular Cortical Index (MCI) and a Trabecular Bone Pattern Index (TBP) qualitatively classified as "sparse with ground glass appearance". Complete loss of the lamina dura is also evident

The results also showed a statistically significant correlation ($p < 0.01$) among the indices (Table 5).

In eight subjects (33%), additional calcified structures were found on the panoramic radiographs. Panoramic radiographic analysis revealed five subjects with carotid atheromas (20%); six with tonsil calcifications (25%); three with calcified lymph nodes (12.5%), and one with a Monckeberg calcification (4%). Brown tumors were found in two subjects (8%). All these abnormalities occurred in patients with PTH values ≥500 pg/ml. Only one carotid atheroma was found in the group with PTH values <500 pg/ml. Only four patients (16%) with PTH values ≥500 pg/ml had complete loss of the lamina dura, visualized on the panoramic radiographs.

Fig. 3 The Phalangeal Cortical Index (PCI): the left phalanx is classified as P1 (normal cortex), the central phalanx as P2 (moderately eroded cortex) and the right phalanx as P3 (severely eroded cortex)
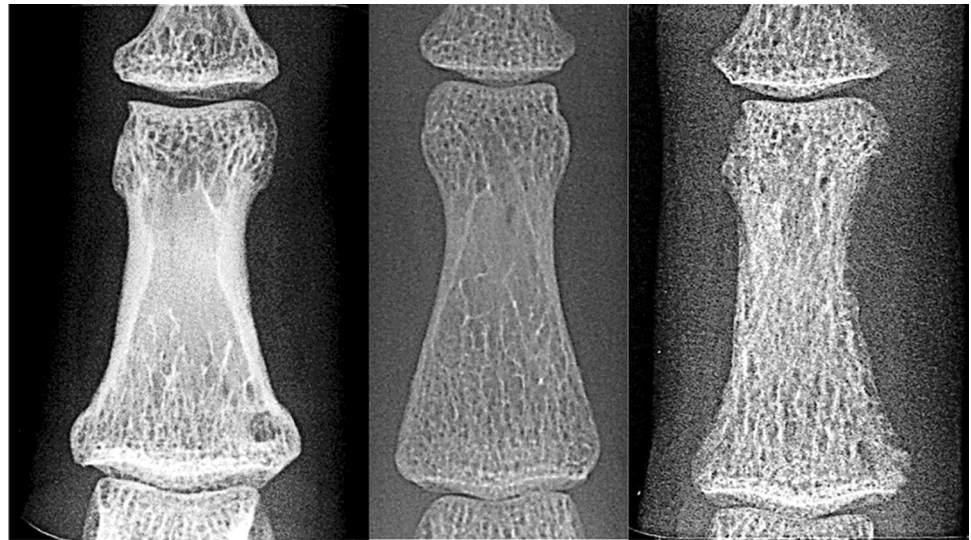

Fig. 4 The size 2 intraoral phosphor storage plate covering the middle phalanx of the index finger (*left*). The same storage plate on the middle finger (*right*)

Discussion

Subperiosteal bone resorption of the middle phalanges of the fingers has been recognized as the first radiographic finding of bone loss resulting from hyperparathyroidism and the marked increase in PTH levels [5, 8, 9, 18–21]. The PCI uses hand and wrist radiographs to evaluate the cortical morphology of the middle phalanges of patients with chronic kidney disease and secondary hyperparathyroidism, and consists of three levels of severity (P1, P2, P3) which correlate directly with increases in hormone levels [7].

The present study is the first to substitute conventional radiographs of the hand and wrist with size 2 digital

Table 1 Spearman's correlation between PTH and MCI, PCI and TBP variables

Variable	Correlation	*p* value
MCI	0.462	0.023
PCI	0.424	0.039
TBC	0.439	0.032

PTH parathyroid hormone, *MCI* Mandibular Cortical Index, *PCI* Phalangeal Cortical Index, *TBP* Trabecular Bone Pattern Index

Table 2 Frequency distribution of MCI in the two groups

Group	C1	C2	C3
PTH < 500 pg/ml	10	2	0
PTH ≥ 500 pg/ml	7	1	4

MCI Mandibular Cortical Index

Table 3 Frequency distribution of PCI in the two groups

Group	F1	F2	F3
PTH < 500 pg/ml	5	7	0
PTH ≥ 500 pg/ml	5	3	4

PCI Phalangeal Cortical Index

Table 4 Frequency distribution of TBC in the two groups

Group	Dense	Heterogeneous	Sparse	Sparse with ground glass appearance
PTH < 500 pg/ml	4	8	0	0
PTH ≥ 500 pg/ml	5	1	2	4

TBP Trabecular Bone Pattern Index

Table 5 Spearman's correlation between MCI, PCI, and TBC

	Correlation	*p* value
MCI vs PCI	0.624	0.001
MCI vs TBP	0.570	0.004
PCI vs TBP	0.524	0.009

MCI Mandibular Cortical Index, *PCI* Phalangeal Cortical Index, *TBP* Trabecular Bone Pattern Index

intraoral-computed radiographs of the finger phalanges, resulting in better quality visualization of the details of bone resorption resulting from the disease. In addition to the improved quality of the digital intraoral films compared with conventional radiographs of the hands and wrists, dental health professionals have this radiographic equipment readily available in the dental office environment. Thus, this method is convenient and easy to perform in the clinic. Additionally, when available, occlusal digital intraoral film may be used with the advantage of requiring a single exposure for irradiating the middle phalanges of the index, middle, and ring fingers, reducing the need for a second exposure (Fig. 5).

Our findings corroborate those of a previous study [7, 8] that showed a high correlation of the PTH level with the indices evaluated (MCI, PCI, and TBP), and good correlation among these indices, showing how important are these parameters to collaborate in the diagnosis process. The group with PTH ≥ 500 pg/ml displayed greater severity of resorption, highlighting the extent to which the increased level of PTH acts on bone resorption of the phalanges and maxillary bones in patients with chronic kidney disease.

We also observed a significant number of calcifications in the panoramic radiographs, resulting from disturbances in the calcium levels of patients as the disease progresses, and associated with calcium supplement treatment to replace the lost calcium [22–25]. Most of the calcifications, apart from the complete loss of lamina dura and brown tumor lesions, were found in the group with PTH levels ≥500 pg/ml. This is consistent with the finding that higher hormone levels are associated with more severe symptoms of the disease.

Dental health professionals should be aware of the serious consequences to patients of secondary hyperparathyroidism, and should add the rapid and simple procedure of using intraoral radiographs of the phalanges to evaluate the PCI in the environment of the dental office. This will contribute to the prompt diagnosis of renal osteodystrophy triggered by the increase in hormone levels present in this disease.

Within the limitations of the sample, we conclude that the digital dental radiographs taken with the occlusal and size 2 intraoral phosphor storage plates are well suited for the correct evaluation of the PCI from the index, middle, and ring fingers of patients with chronic kidney disease affected by severe secondary hyperthyroidism.

The MCI, PCI, and TBC correlated with each other and with the plasma PTH levels that, in turn, were shown to increase as the level of these parameters increased.

Fig. 5 Occlusal intraoral phosphor storage plate, allowing visualization of the middle phalanges of the index, middle and ring fingers of a patient with chronic kidney disease with a single exposure
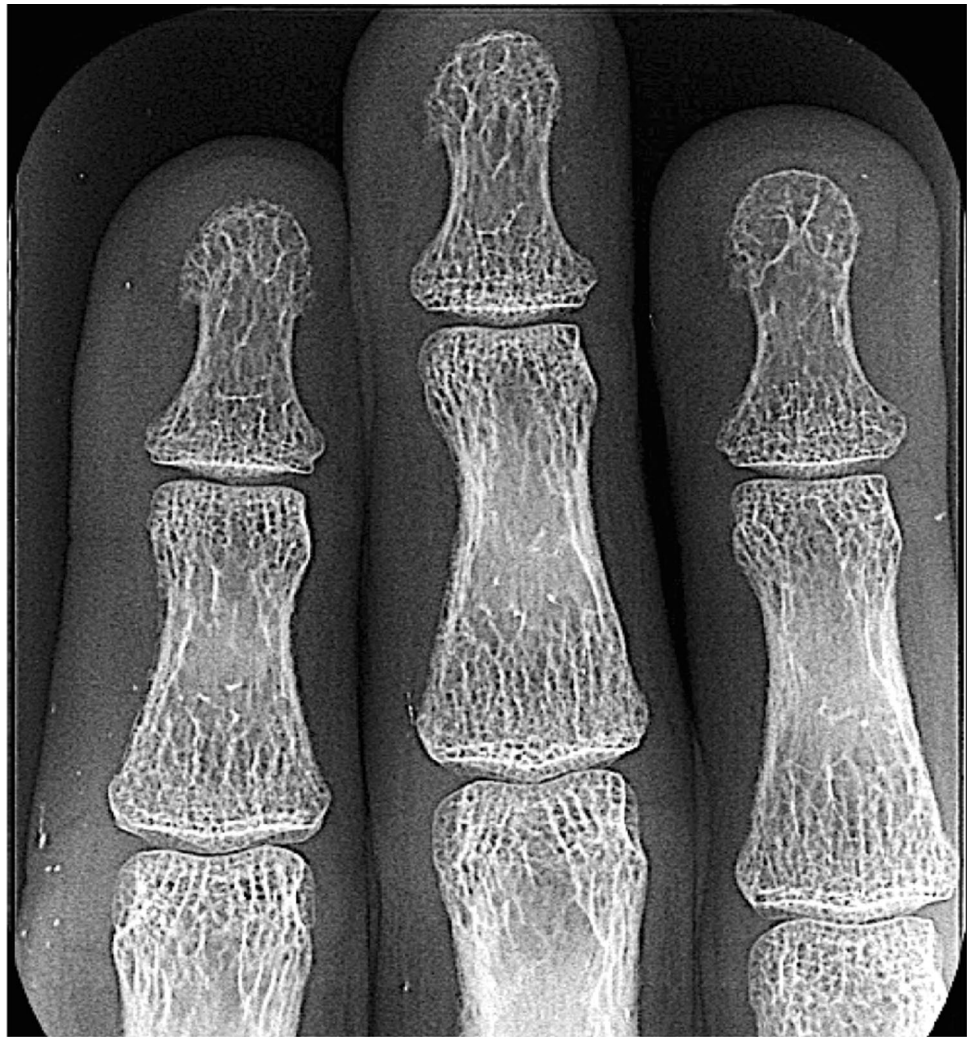
Compliance with ethical standards

Conflict of interest Authors Bruna Corrêa Massahud, João César Guimarães Henriques, Reinhilde Jacobs, Rafaela Rangel Rosa and Caio Vinícius Bardi Matai declare that they have no conflict of interest.

Human rights statements All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Informed consent Informed consent was obtained from all patients for being included in the study.

Animal rights statement This article does not contain any studies with animal subjects performed by any of the authors.

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