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ORIGINAL ARTICLE

Dental calculus formation in children and adolescents undergoing hemodialysis

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Abstract
Background This study aimed to determine whether dental calculus formation is really higher among patients with chronic kidney disease undergoing hemodialysis than among controls. Furthermore, the study evaluated correlations between dental calculus formation and dental plaque, variables that are related to renal disease and/or saliva composition.
Methods The Renal Group was composed of 30 patients undergoing hemodialysis, whereas the Healthy Group had 30 clinically healthy patients. Stimulated whole saliva and parotid saliva were collected. Salivary flow rate and calcium and phosphate concentrations were determined. In the Renal Group the saliva collection was carried out before and after a hemodialysis session. Patients from both groups received intraoral exams, oral hygiene instructions, and dental scaling. Three months later, the dental calculus was measured by the Volpe–Manhold method to determine the rate of dental calculus formation.
Results The Renal Group presented a higher rate of dental calculus formation ($p<0.01$). Correlation was observed between rate of dental calculus formation and whole saliva flow rate in the Renal Group after a hemodialysis session ($r=0.44$, $p<0.05$). The presence of dental calculus was associated with phosphate concentration in whole saliva from the Renal Group ($p<0.05$).
Conclusion In conclusion, patients undergoing hemodialysis presented accelerated dental calculus formation, probably due to salivary variables.

Keywords Chronic kidney disease · Dental calculus · Oral manifestations · Child · Adolescents

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Introduction

Chronic kidney disease (CKD) is related to many oral manifestations, such as low prevalence of dental caries, enamel hypoplasia, delayed tooth eruption, dental staining due to iron supplementation, dry mouth, low salivary flow rate, and altered salivary composition. In addition, the presence of dental calculus (mineralized dental plaque) is considered one of the most common oral manifestations in patients with CKD [1–6]. However, the studies that suggest an increased tendency for dental calculus formation as an oral manifestation of CKD are generally based on a single dental calculus measurement. This procedure is not sufficient to classify a patient as having a heavy dental calculus deposition because the dental calculus may have been building up over a long period. Thus, to observe the true dental calculus formation rate, the patient must be without any dental calculus at the baseline and, later, the measurement is made to determine whether this patient has a tendency for dental calculus formation.

As dental plaque (biofilm composed of a community of micro-organisms embedded in an extracellular matrix of

polymers of host and microbial origin) precedes dental calculus formation [5, 6], the presence of dental calculus may be associated with personal characteristics of oral hygiene [7]. Nevertheless, some authors have suggested a relationship between dental calculus and systemic variables of CKD [3, 8]. So, it remains unclear whether the presence of dental calculus in patients with CKD is related to personal characteristics of oral hygiene or to systemic variables due the renal disease [9]. Thus, additional studies are necessary to identify factors that could influence dental calculus formation in patients with CKD in order to help establish a preventive program to improve the oral health of these patients.

Therefore, this study aimed to determine the rate of dental calculus formation in children and adolescents with CKD undergoing hemodialysis and compared them with clinically healthy patients to certify whether dental calculus formation is really higher among patients with CKD. Furthermore the study evaluated the correlation between dental calculus formation and dental plaque, variables that are related to renal disease and/or saliva composition.

Material and methods

The study comprised a group of 38 children and adolescents with CKD from both genders, with ages ranging from 7 to 19 years old, who were undergoing hemodialysis at eight different nephrology centers (Rio de Janeiro, Brazil) to make up the Renal Group. The Healthy Group was paired in age and gender to the Renal Group and comprised 38 clinically healthy patients with no history of chronic illnesses, especially renal disease, who came for dental treatment at the dental school of a public university in Rio de Janeiro, Brazil. The medical history of the Renal Group concerning CKD, such as when it was diagnosed, how long the patient had been undergoing hemodialysis, and the medications prescribed, was obtained from their medical records. Exclusion criteria for the Renal Group included any patient who had been submitted to kidney transplantation and for the Healthy Group any patient who had used any continuous medication during the 6 months prior to this study. Also, for both groups, any participant receiving orthodontic treatment was excluded from the study.

After personal data collection, stimulated whole saliva and parotid saliva were collected from all participants to determine the salivary flow rate and the calcium and phosphate concentrations. For the Renal Group, saliva was collected at two different times: just prior to the first hemodialysis session of the week, and subsequent to completion of the same hemodialysis session. All participants were instructed not to eat for at least 1 h before saliva collection. Whole saliva was stimulated by chewing on a piece of Parafilm (10× 10 cm, weighing 1.40 g) and parotid saliva by applying a 2 % citric acid solution onto the lateral border of the tongue for 30 s. Parotid saliva was collected by a Lashley cup placed at the orifice of the Stenon duct. Both salivary collections were carried out over a 5-min period. The saliva secreted in the first 30 s was discarded. The salivary flow rate (ml/min) was calculated soon after collection. For laboratorial analysis, samples were prepared by mixing equal quantities of saliva and 10 % nitric acid solution. Calcium and phosphate concentrations were analyzed by inductively coupled argon plasma with atomic emission spectrometry [10].

Following saliva collection, an intraoral exam was performed to verify the presence of dental plaque and dental calculus based on the Plaque Index System [11] and the Volpe–Manhold method [12]. Oral hygiene instructions were given individually to each participant. They also received a toothbrush, dental floss, and dentifrice. Twice a week, the main researcher helped patients individually to perform the proper toothbrushing techniques. This procedure was repeated until the participants achieved satisfactory dental plaque control. Participants with dental calculus underwent scaling. Thus, at this first stage of data collection—considered the baseline—no participant had dental calculus accumulation and all had satisfactory dental plaque control.

The second stage of data collection took place 3 months later, when another intraoral exam was performed and the Plaque Index System [11], the Gingival Index System [13], and Volpe–Manhold method [12] were once more employed. The Volpe–Manhold method measured the height of the dental calculus deposited at three lingual surface sites (one vertical and two diagonal) of anterior lower teeth by using a periodontal probe (Hu-friedy, PCP 15, North Caroline University, NC, USA). As the Volpe–Manhold method is expressed in millimeters of dental calculus per tooth, the rate of dental calculus formation was established by dividing the result of the Volpe–Manhold method by three (number of months between baseline and the moment when the Volpe–Manhold method was carried out). Thus, results were expressed in millimeters per tooth per month. Based on the height of dental calculus formed per tooth per month, participants were classified as having light (0–0.5 mm), moderate (0.6–1.5 mm), or heavy (>1.6 mm) dental calculus formation, as suggested by Epstein et al. [14].

All stages of data collection were performed by the same examiner who was previously trained in the

Volpe–Manhold method (ICC=0.99). This study was approved by the Local Ethical Committee, and written informed consent was obtained from all guardians and verbal assent from children and adolescents. Furthermore, all participants and their parents were informed whether any dental treatment was necessary and subsequently were referred to the dental school clinic.

Statistical analyses were conducted using SPSS 11.0 (SPSS, Chicago, IL, USA). Statistical significance of the differences between the Renal Group and the Healthy Group was analyzed using Mann–Whitney and Kruskal–Wallis tests for quantitative variables (mean, minimum, maximum), and the chi-square test was applied to the qualitative variables. In addition, the Wilcoxon test was used to analyze differences between the salivary variables at the different collection times (before and after the hemodialysis session of the Renal Group). The Pearson correlation test was used to analyze differences between salivary variables and the rate of dental calculus formation. The confidence interval (CI) for analyses was set at 95 %.

Results

Eight patients from the Renal Group received kidney transplants before the end of data collection and consequently were excluded from the study. To keep the groups paired, eight participants from the Healthy Group were also excluded. Thus, the final total sample was 30 individuals in each group. The mean age in the Renal Group was 12.93±3.54 years and in the Healthy Group 12.18±3.37 years. In both groups, the sample was composed of ten girls and 20 boys. The different etiological causes attributed to CKD in the Renal Group were nephrotic syndrome, peritonitis, chronic pyelonephritis, rapidly progressive glomerulonephritis, neurogenic bladder, lupus nephritis, congenital malformation, and Alport syndrome. The mean length of time since CKD was first diagnosed was 6.55±5.15 (range 0.5–16.66) years, and mean age at the time of diagnosis was 8.33±5.22 (range 0–17) years. Participants had undergone hemodialysis for a mean of 2.72 (range 0.08–10) years. In terms of medication, all participants in the Renal Group were receiving antihypertensives, diuretics, and/or calcium carbonate.

Dental plaque, gingival inflammation, and dental calculus were considered present when the result of the applied indices was different from zero. The frequency of participants who presented dental plaque, gingival inflammation, and dental calculus in each group; mean, minimum, and maximum of dental calculus index; and rate of dental calculus formation in both groups are shown in Table 1. Table 2 shows participant classification based on the rate of dental calculus formation. In both groups, dental plaque was not associated with gingival inflammation or dental calculus. Dental calculus was not associated with gingival inflammation ($p>0.05$). The presence of dental calculus and its rate of formation in the Renal Group did not reveal any statistically significant association with medication that had been administered, mean length of time since CKD was first diagnosed, or mean time of treatment ($p>0.05$).

Data for salivary flow rate and calcium and phosphate concentrations in stimulated whole and parotid saliva are shown in Tables 3 and 4, respectively. When the salivary variables were compared with the presence of dental calculus and its rate of formation, statistically significant results were observed only between stimulated whole saliva flow rate in the Renal Group after the hemodialysis session and the rate of calculus formation ($r=0.44$, $p<0.05$) and phosphate concentration in stimulated whole saliva and the presence of calculus also in the Renal Group ($p<0.05$).

Discussion

Studies about the tendency of patients with CKD to form dental calculus must be based on the rate of dental calculus formation with a proper baseline (i.e., starting without the presence of dental calculus) in order to assess dental calculus formation [8]. If dental calculus formation is observed just at one particular time, it cannot reveal a formation rate, as the calculus would have been building up over an unknown period of time.

Table 1 Oral variables: frequencies (%) and values (mean, minimum, maximum) from the Healthy Group and the Renal Group

Oral variables	Healthy Group ($n=30$)	Renal Group ($n=30$)
Presence of dental plaque	30.6 %	38.6 %
Presence of gingival inflammation	11.1 %	20.5 %
Presence of dental calculus[a]	36.1 %	75 %
Calculus index (mm/tooth)[a]	0.37 (0–3.66)	2.09 (0–18.5)
Rate of calculus formation (mm/tooth/month)[a]	0.13 (0–1.22)	0.60 (0–6.16)

[a]Significant statistical differences within groups

Table 2 Classification of Healthy Group and Renal Group based on the rate of dental calculus formation

Dental calculus classification	Healthy Group (n=30)	Renal Group (n=30)
Light	91.70 %	61.11 %
Moderate	8.3 %	33.3 %
Heavy	0	5.6 %

Chi-square; $p<0.01$

As this study aimed to determine the rate of dental calculus formation associated with CKD, a baseline time was established at which no dental calculus was present in order to observe accumulation at the end of a 3-month period. This study is important because, to the best of our knowledge, there has been no research thus far addressing dental calculus formation rate in children and adolescents with CKD.

The results show that our study participants with CKD presented a higher dental calculus formation when compared with healthy children and adolescents, which was expressed by the calculus index applied and the rate of dental calculus formation determined. However, it must be emphasized that the rate of dental calculus formation in the Renal Group was more than four times higher than that observed in the Healthy Group. An indication of the importance of measuring dental calculus formation rate (and not just the presence of dental calculus itself) is that, when these results are compared with our previous study [4], in which dental calculus was measured without a prestudy scaling, even with similar results (higher dental calculus accumulation in the Renal Group), the values observed were different. Our previous study found that 26.6 % of participants from the Healthy Group were considered as having heavy dental calculus formation. In the study reported here, however, no participant with heavy dental calculus formation was observed in the Healthy Group.

Regarding dental calculus formation classification, most participants from the Healthy Group (91.70 %) were classified as having light and none (0 %) as having heavy dental calculus formation. On the other hand, although most participants in the Renal Group (61.11 %) were considered as having light dental calculus formation, 33.3 % and 5.6 % were classified as having, respectively, moderate and heavy dental calculus formation based on the amount of calculus formed per month. A statistically significant difference could be observed between groups.

As it is not known whether the frequency of dental calculus in patients with CKD is related to a lack of oral hygiene or to systemic variables due to the renal disease [9], we instructed all study participants on proper toothbrushing techniques and motivated them to take good oral care before we recorded baseline data. Even though the Renal Group had more dental plaque than the Healthy Group, there was no significant statistical difference between groups, corroborating with an earlier study [2]. Besides, no association between the presence of dental plaque and dental calculus was observed. Considering that dental plaque deposition precedes dental calculus formation [7], this last result reinforces the hypothesis that systemic variables of CKD could be related to dental calculus formation [15].

Another finding that corroborates with the cited hypothesis is a case described by Davidovich et al. [16]: In a 2-year-old with excessive dental calculus deposits undergoing hemodialysis, dental calculus was mechanically removed and oral hygiene instructions were emphasized, but dental calculus reappeared to the same extent 4 months later, even when the infant had fair oral hygiene during that time. Surprisingly, 4 and 8 months after renal transplantation, no signs of dental calculus were observed, although massive plaque accumulation could be observed. This finding emphasizes the need for further studies examining the influence of complex pathogenic mechanisms arising from CKD on processes in the oral cavity, including examination of saliva composition.

The presence of dental plaque in patients with CKD was strongly associated with gingival inflammation by other authors [8], but this finding was not observed in our study. Our data are in agreement with Lucas and Roberts [17], who

Table 3 Whole saliva flow rate and calcium and phosphate concentrations (mean, minimum, maximum) in the Healthy Group and Renal Group (before and after hemodialysis)

Variables in whole saliva	Healthy Group	Renal Group before hemodialysis	Renal Group after hemodialysis
Flow rate (ml/min)	0.91 (0.20–2.08)	0.65 (0.20–2.00)[a]	0.83 (0.20–2.24)
Calcium (mEq/l)	1.17 (0.35–3.18)	1.21 (0.39–4.75)	0.90 (0.18–1.61)
Phosphate (mEq/l)	3.31 (0.22–5.48)	3.10 (0.43–5.96)	3.32 (0.01–7.38)

Mann–Whitney, Wilcoxon ($p<0.05$)

[a] Significant statistical differences within groups

Table 4 Parotid saliva flow rate and calcium and phosphate concentrations (mean, minimum, maximum) in the Healthy Group and Renal Group (before and after hemodialysis)

Variables in parotid saliva	Healthy Group	Renal Group before hemodialysis	Renal Group after hemodialysis
Flow rate (ml/min)	0.84 (0.10–1.84)	0.47 (0.10–1.10)[a]	0.85 (0.10–1.78)
Calcium (mEq/l)	0.67 (0.33–1.07)	1.45 (0.19–4.99)[a]	1.15 (0.37–1.89)
Phosphate (mEq/l)	2.24 (0.06–3.33)	2.17 (0.35–3.83)	2.08 (0.37–3.65)

Mann–Whitney, Wilcoxon ($p<0.05$)

[a] Significant statistical differences within groups

affirmed that gingival inflammation is not a common oral manifestation in children with CKD. Nevertheless, a previous study [18] suggested that the paleness of gingival tissue caused by anemia can hide gingival inflammation. Also, a tendency for all periodontal parameters to increase with the duration of hemodialysis was observed in another study with children [15]. However, in our study, when considering the influence hemodialysis treatment duration on dental calculus formation, it was not possible to establish any correlation, which is in accordance with Bot et al. [2]. In addition, no correlation was observed related to any other renal disease variables.

The presence of large amounts of dental calculus in patients with CKD is also suggested to be due to the high calcium and phosphorus supplementation often used as part of the dietary control of CKD [17]. For this reason, the relationship between dental calculus formation and the administration of calcium carbonate, a phosphate binder that provides additional calcium intake [19], was investigated in this study. Calcium carbonate is known to cause deposition of calculus in soft-tissues and urinary tissues as a side-effect. It is taken orally, every day, by the majority of participants in our Renal Group (85.4 %). Hence, it was suspected that this medication could also influence dental calculus deposition. Nevertheless, this hypothesis was not confirmed by the results herein discussed.

Another hypothesis is that salivary changes might have contributed to a higher dental calculus deposition in participants with CKD [2]. Therefore, calcium and phosphate concentrations in saliva and their relationships to dental calculus formation were investigated, as they are the main components of dental calculus [7]. However, only phosphate concentration in stimulated whole saliva was associated with dental calculus in the Renal Group, corroborating with Epstein et al. [14], who affirmed that elevated levels of phosphate, and also protein, may contribute to dental calculus formation in these individuals. According to Davidovich et al. [20], who studied the association between renal dysfunction severity in young patients and the formation of dental calculus, more phosphate is secreted in saliva due to renal function deterioration, and precipitation with calcium occurs, leading to dental calculus formation.

Even so, it must be remembered that dental calculus formation consists of complex processes that involve numerous calcium phosphate phases, as well as interactions between these ions and organic molecules [19]. For example, authors of a study exploring calcium-oxalate (CaOx) as part of dental calculus specifically in CKD patients, observed an elevated concentration of Ox in saliva, probably due to the decrease in glomerular filtration rate and urinary excretion [20]. In addition, selective adsorption of salivary components is involved in this process [21], which may also be a result of increased pH in dental plaque and, consequently, more supersaturated saliva with respect to hydroxyapatite [22]. So, it must be noted that the degree of supersaturation of plaque fluid increases when its pH is high. Thus, calculus formation is most likely to occur when dental plaque pH remains above the critical level for long periods. Furthermore, the high salivary film velocity will bring more urea to that region, leading to an elevated dental plaque pH. The urea in saliva diffuses into plaque and can be converted by certain bacteria into ammonia and carbon dioxide (CO_2), causing a rise in dental plaque pH [23]. Therefore, dental calculus accumulation in patients with CKD must also be associated with increased pH of the oral cavity, as observed by Davidovich et al. [16]. Hence, it is difficult to relate a higher rate of dental calculus formation to specific changes in salivary composition, as it is unclear which specific factor or combination of salivary factors is involved [14]. Nevertheless, it is important that, in our study, statistically significant results could be observed only in the Renal Group, suggesting that the salivary variable in these patients may actually be associated with dental calculus formation.

Based on our results, it is possible to conclude that children and adolescents with CKD experience an accelerated rate of dental calculus formation, which seems to be influenced by salivary variables. Considering that dental calculus acts as a retentive factor to dental plaque, which can contain products toxic to soft tissue, it is suggested that scaling must be carried out at least every 3 months to prevent future oral infections. In addition, good oral hygiene must be emphasized and the patient motivated to carry it out to improve oral health.

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References

1. Bayraktar G, Kurtulus I, Kazancioglu R, Bayramgurler I, Cintan S, Bural C, Bozfakioglu S, Besler M, Trablus S, Issever H, Yildiz A (2008) Evaluation of periodontal parameters in patients undergoing peritoneal dialysis or hemodialysis. Oral Dis 14:185–189
2. Bots CP, Poorterman JHG, Brand HS, Kalsbeek H, Van Amerongen BM, Veerman ECI, Nieuw Amerongen AV (2006) The oral health status of dentate patients with chronic renal failure undergoing dialysis therapy. Oral Dis 12:176–180
3. Kho HS, Lee SW, Chung SC, Kim YK (1999) Oral manifestations and salivary flow rate, pH, and buffer capacity in patients with end-stage renal disease undergoing hemodialysis. Oral Sur Oral Med Oral Pathol Oral Radiol Endod 88:316–319
4. Martins C, Siqueira WL, Primo LG (2008) Oral and salivary flow characteristics of a group of Brazilian children and adolescents with chronic renal failure. Pediatr Nephrol 23:619–624
5. Marsh PD (2004) Dental plaque as a microbial biofilm. Caries Res 38:204–211
6. Ye J, Yip H (2002) Supragingival calculus: formation and control. Crit Rev Oral Biol Med 13:426–441
7. Lindhe J (2003) Textbook of clinical periodontology. 4th Munksgaard ed. Copenhagen
8. Pattanaporn K, Navia JM (1998) The relationship of dental calculus to caries, gingivitis, and selected salivary factors in 11- to 13-year-old children in Chiang Mai, Thailand. J Periodontol 69:955–961
9. Kitsou VK, Konstantinidis A, Siamopoulos KC (2000) Chronic renal failure and periodontal disease. Ren Fail 22:307–318
10. Korn MGA, Oliveira E (1995) Metal ion behavior in aqueous-organic medium in inductively coupled argon plasma with atomic emission spectrometry detection. ICP Inf Newslett 21:299–303
11. Silness J, Löe H (1964) Periodontal disease in pregnancy. II Correlation between oral hygiene and periodontal condition. Acta Odontol Scand 22:121–135
12. Volpe AR, Manhold JH, Hazen SP (1965) In vivo calculus assessment. I. A method and its examiner reproducibility. J Periodontol 36:292–298
13. Löe H, Silness J (1963) Periodontal disease in pregnancy. I. Prevalence and severity. Acta Odontol Scand 21:533–551
14. Epstein SR, Mandel I, Scopp IW (1980) Salivary composition and calculus formation in patients undergoing hemodialysis. J Periodontol 51:336–338
15. Davidovich E, Schwarz Z, Davidovitch M, Eidelman E, Bimstein E (2005) Oral findings and periodontal status in children, adolescents and young adults suffering from renal failure. J Clin Periodontol 32:1076–1082
16. Davidovich E, Frishberg Y, Aframian DJ, Peretz B (2006) Calculus in a toddler with end-stage renal disease due to prune-belly syndrome. Oral Dis 12:63–66
17. Lucas VS, Roberts GJ (2005) Oro-dental health in children with chronic renal failure and after renal transplantation: a clinical review. Pediatr Nephrol 20:1388–1394
18. Jaffe EC, Roberts GJ, Chantler C, Carter JE (1986) Dental findings in chronic renal failure. Br Dent J 160:18–20
19. Nancollas GH, Johnsson MA (1994) Calculus formation and inhibition. Adv Dent Res 8:307–311
20. Davidovich E, Davidovits M, Peretz B, Shapira J, Aframian DJ (2009) The correlation between dental calculus and disturbed mineral metabolism in paediatric patients with chronic kidney disease. Nephrol Dial Transplant 24:2439–2445
21. Slomiany A, Slomiany BL, Mandel ID (1981) Lipid composition of human parotid saliva from light and heavy dental calculus-formers. Arch Oral Biol 26:151–152
22. Fure S, Lingstrom P, Birkhed D (1998) Effect of three months' frequent use of sugar-free chewing gum with and without urea on calculus formation. J Dent Res 77:1630–1637
23. Dawes C (2007) Why does supragingival calculus form preferentially on the lingual surface of the 6 lower anterior teeth? J Can Dent Assoc 72:923–926