Association between dental and periodontal conditions with chronic kidney disease: A cross-sectional analysis of urban South Africans

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ABSTRACT

Introduction

Oral diseases are preventable causes of poor health outcomes in people with chronic kidney disease (CKD).

Aims and objectives

Investigate the association between dental and periodontal conditions with kidney function and determine whether inflammation mediate the association between periodontitis and CKD.

Design

Cross-sectional analysis of 1551 South African adults of mixed ancestry.

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Methods

CKD was classified as estimated glomerular filtration rate (eGFR) <60mL/min/1.73m^2. Oral profile was captured by decayed, missing, filled teeth index (DMFTi), bleeding on probing (BOP), pocket depth (PD), clinical attachment loss (CAL), and periodontitis classified as PD ≥4 mm.

Results

Overall, 6% had CKD, with 93% and 66% of participants with and without CKD, respectively having a high DMFTi (p<0.0001). Further, 84% (CKD) and 43% (without CKD) were edentulous (p<0.0001). A great proportion of the dentate sub-sample (n=846) had periodontitis, however, BOP, PD ≥4mm and CAL ≥4mm were similar between the groups. DMFTi was associated with eGFR and prevalent CKD (p<0.023), with this association driven by the Missing component. Periodontitis was not associated with eGFR nor CKD (p>0.282).

Conclusion

In routine care of people with CKD, attention should be given to oral health.

Key words: chronic kidney disease; oral disease; periodontitis; dental; tooth loss; Africa

INTRODUCTION AND BACKGROUND

Chronic kidney disease (CKD) is a major public health problem,[1] estimated to affect at least 10% of the global adult population.[2] Given that African populations are at even higher risk of developing CKD,[3] it is essential to identify and manage the modifiable risk factors for CKD and progression to end-stage renal disease (ESRD), to reduce the significant burden on an already ailing health system.

Oral diseases are estimated to affect nearly half the global population.[4,5] Of these oral diseases, periodontitis and dental caries have been implicated as a potential and preventable cause of poor health outcomes in people with CKD.[6-9] Periodontitis, which affects the tissue surrounding the teeth, is thought to contribute to renal deficiency via inflammatory pathways.[10-13] Indeed, several cross-sectional studies have reported that adults with periodontitis generally have elevated acute-phase systemic markers, like serum C-reactive protein (CRP) and oxidative stress responses,[14, 15] and are up to twice as likely to have CKD as their counterparts without periodontitis.[9, 16, 17] On the contrary, dental caries, characterized by the localized destruction of the teeth due to the accumulation of acidic by-products,[10] is much less

explored in the context of CKD. In fact, there is no consensus in the literature on dental caries prevalence and the association with CKD. Certainly, some studies have shown that patients with CKD presents with lower dental caries,[18,19] where others show that CKD is associated with a worse dental status[20] compared to those without CKD, with a few studies showing no association between dental complications and CKD.[21, 22]

Despite the advances made in the aetiology governing the development and progression of CKD, including the potential link with the oral cavity, population-based data on the overall oral status of people with CKD, particularly in Africa are lacking. We therefore aimed to, 1) characterise the dental and periodontal profile of those with and without CKD, 2) investigate the association between dental and periodontal conditions with kidney function and prevalent CKD, and further 3) evaluate whether systemic inflammation, as measured by hsCRP, mediates the association between periodontitis and kidney function and prevalent CKD in a community-based sample of urban South Africans of mixed-ancestry.

MATERIALS AND METHODS
Study setting and population
The data utilized in this analysis is from adult South Africans of mixed-ancestry (in South Africa referred to as the Coloured population).[23] The study was approved by the Research Ethics Committees of the Cape Peninsula University of Technology and Stellenbosch University (NHREC: REC—230 408–014 and N14/01/003) respectively and conducted in accordance with the Declaration of Helsinki. As such, voluntarily signed written informed consent was received from all participants after the explanation of all procedures.

Questionnaires and physical examination
All anthropometric measurements were taken three time and the average presented in this paper. An Omron body fat meter HBF-511 digital bathroom scale was used to determine body weight, with the individual in light clothing and without shoes. Waist circumference (WC) was measured with a non-elastic tape measure by standard procedure, thus at the level of the narrowest part of the torso, as seen from the anterior view. Body mass index (BMI) was calculated by means of the conventional calculation as weight divided by the square of height (kg/m^2). Systolic and diastolic blood pressure (SBP and DBP, respectively), taken in a seated position after 10 minutes of seated rest, were recorded three times on the right arm using a semi-automated digital blood pressure monitor (Omron M6 Comfort (Omron Healthcare Co., Ltd.). With the first measurement discarded, the average of the last two measures were used as the blood pressure measurement. A standardized oral examination, based on the World Health Organization (WHO) guidelines,[24] was performed on all participants by a trained dental practitioner and has been published earlier.[25] Briefly, bleeding on probing (BOP) was classified if bleeding was observed after a gentle periodontal probing around the tooth circumference. Each tooth was also examined for the presence of dental pockets by probing around the whole circumference and recording the highest score. Pocket depth (PD) categories included 0-3mm and ≥4mm. Finally, clinical attachment loss (CAL) was recorded with a periodontal probe as the highest score obtained for each sextant. Periodontitis was classified as the presence of PD ≥4 mm of one site. Decayed, missing and filled teeth (DMFT) index, which is a key measure of caries experience in dental epidemiology, was recorded for every participant, according to WHO guidelines.[24] In short, the DMFT index

is applied to all permanent dentition and is expressed as the total number of teeth or surfaces that are decayed (D), missing (M), or filled (F). Based on the DMFT score, DMFT severity was categorized based on the WHO criteria,[24] as very low (<5.0), low (5.0-8.9), moderate (9.0-13.9) and high (>14). All participants were also asked about their perceived health of their mouth and to rate it as excellent, good, fair, poor or bad.

Biochemical analysis and classifications
The biochemical analyses were all conducted at an ISO 15189 accredited pathology practice (Path-Care, Reference Laboratory, Cape Town, South Africa) according to set protocols. Serum samples were processed for the measurement of creatinine, hsCRP and cotinine by the modified Jaffe-Kinetic method (Beckman AU, Beckman Coulter, South Africa), and chemiluminescent assays (Immun Diagnostik AG, Bensheim, Germany and Immulite 1000, Siemens) respectively.

Kidney function was estimated by means of the serum creatinine-based 4-variable Modification of Diet in Renal Disease (MDRD) equation,[26] without the ethnicity correction factor. Findings were mostly similar in secondary analyses based on CKD Epidemiology Collaboration (CKD-EPI) equation[27] estimated GFR (data not shown). As per the National Kidney Foundation Disease Outcomes Quality Initiative (NKF-KDOQI) guidelines,[28] CKD was classified as an estimated glomerular filtration rate (eGFR) <60 ml/min/1.73 m^2. Smoking and non-smoking were categorized as cotinine levels ≥15 ng/ml and <15 ng/ml, respectively. Hypertension was classified as SBP ≥140 mmHg and/or DBP ≥90 mmHg,[29] or a previous diagnoses of hypertension. Diabetes was classified as a history of previously diagnosed type 2 diabetes (T2D) or fasting glucose ≥7.0 mmol/l and/or 2-h glucose ≥11.1 mmol/l. Additional glucose tolerance categories were also classified based on the oral glucose tolerance test (OGTT)[30] as: (1) normal glucose tolerance [FG <6.1 mmol/l and 2-h glucose <7.8 mmol/l], (2) impaired fasting glucose (IFG, 6.1≤FG< 7.0 mmol/l), and (3) impaired glucose tolerance (IGT, 7.8<2-h glucose<11.1 mmol/l). A BMI≥25kg/m^2 and BMI≥30kg/m^2 were classified as overweight and obese, respectively.

Statistical analysis
Due to the skewed distribution of most variables, participant characteristics were summarised as median (25th-75th percentiles) or count and percentages. However, the DMFT index and total number of teeth were also presented as mean and standard deviation (SD), to comply with the standard presentation of data obtained from the WHO and mean comparisons with other studies. Group comparisons were done with chi-square tests (categorical variables) and Student-t test or Wilcoxon rank-sum test (continuous variables). Multivariable robust linear regression models were used to assess the independent association between eGFR and the DMFT index. Whereas multivariable logistic regression models were used to determine whether the DMFT index predicted prevalent CKD, independent of confounding variables (listed in the models below). Since individuals with edentulism are unable to experience periodontitis, a sub-analysis on dentate participants (n=846) were conducted. Thus, multivariable linear regression and logistic regression models were employed to assess the independent association of eGFR and prevalent CKD with periodontitis. The models used were as follows: Model 1: DMFT or periodontitis; Model 2: Model 1 + Age ≥60years; Model 3: Model 2 + smoking status + obesity; Model 4: Model 3 + hypertension; Model 5: Model 4 + diabetes; Model 6 (DMFT): Model 5 + edentulism; Model 6 (periodontitis):

Model 5 + hsCRP. All statistical analyses were performed using STATA version 15 (Statcorp, College Station, TX) and statistical significance was based on a p-value <0.05.

RESULTS

General characteristics of study population

The general characteristics of the study population are summarised in Table I. The original study sample comprised 1,979 participants. Of those, 428 participants were excluded from this analysis due to missing data on serum creatinine or variables required to estimate kidney function, including age and gender, as well as those participants who did not receive an oral examination. The final sample included 1,551 participants, of which 25.2% were male, with ages ranging from 20 to 91 years (median age of 51 years), and 6% having an eGFR <60 ml/min/1.73m^2. Of those with CKD, 79.2%, 15.6% and 5.2% where in stages 3, 4 and 5 CKD, respectively. Compared to the participants with normal kidney function, those with CKD were on average older (68 vs. 49 years; p<0.0001), had a greater weight (75.0 vs. 71.7 kg; p=0.049), with a higher WC (100.2 vs. 91.0 cm; p<0.0001) and BMI (30.8 vs. 28.2 kg/m^2; p=0.001). Further, 81.8% had a BMI in the overweight/obese range, compared to 65.0% in the group with normal kidney function. Of the participants with CKD, 11.8% and 44.7% had IFG/IGT and T2D, respectively, compared to 14.7% and 17.5%, respectively, in the group with normal kidney function. Also, those with CKD had a higher prevalence of hypertension compared to those without CKD (54.6% vs 35.1%, p<0.0001). Compared to those with normal kidney function, those with CKD also had higher hsCRP levels (4.7 vs. 3.9 µg/ml; p=0.044), with similar prevalence of smokers (p=0.765).

Dental and periodontal profile of study population

The dental profile of the study population is summarised in Table II and Figure 1. In the total sample, edentulism was found in 84.1% of those with CKD, compared to 43.1% of individuals with normal kidney function. On average those with reduced kidney function had significantly less teeth compared to those participants with normal kidney function (3.2 vs. 13 teeth; p<0.0001). Furthermore, CKD was characterized by a higher mean DMFT index compared to those without CKD (29.2 vs. 20.6; p<0.0001). Despite 93.2% and 66.0% of people with CKD and without CKD, respectively having a DMFT index greater than 14, 50% and 38.5% of those with and without CKD, respectively rated their overall oral health as either good or excellent. Based on the components of the DMFT index, for both groups the "missing" component had the highest contribution to the score with a greater contribution in those with CKD compared to those without CKD (87% vs. 69%; p<0.0001). On the contrary, compared to those without CKD, participants with CKD had a lower prevalence of decayed (8% vs. 25%; p<0.0001) and similar prevalence of filled teeth (5% vs. 6%; p=0.053) (Figure 1). Of the participants with CKD,

| Table I. General characteristics of the study population by CKD status			
Variables	**Without CKD (n=1463)**	**CKD (n=88)**	**p-value**
Age (years)	49 (36-59)	68 (62-74)	<0.0001
Age categories (n,%)			<0.0001
<24 years	103 (7.0)	0 (00	
25-34 years	230 (15.7)	1 (1.1)	
35-44 years	231 (15.8)	2 (2.3)	
45-54 years	376 (25.7)	4 (4.6)	
55-64 years	319 (21.8)	27 (30.7)	
65-74 years	161 (11.0)	33 (37.5)	
>75 years	43 (2.9)	21 (23.9)	
Gender (n,% male)	373 (25.5)	18 (20.5)	0.290
Weight (kg)	71.7 (59.1-85.4)	75.0 (65.5-87.6)	0.0491
Waist circumference (cm)	91.0 (77.8-103.0)	100.2 (89.5-106.5)	<0.0001
Body mass index (kg/m^2)	28.2 (22.7-34.1)	30.8 (26.4-36.3)	0.0013
Creatinine (µmol/l)	59.0 (51.0-67.0)	105.5 (89.0-141.5)	<0.0001
eGFR (ml/min/1.73m^2)	104.5 (88.6-121.5)	48.4 (33.8-56.2)	<0.0001
hsCRP (µg/ml)	3.9 (1.6-8.8)	4.7 (2.5-9.7)	0.0438
Smoking status (n, %)			0.765
Non-smoker	695 (49.5)	44 (51.2)	
Smoker	709 (50.5)	42 (48.8)	
BMI categories (n, %)			0.004
Normal weight	512 (35.0)	16 (18.2)	
Overweight	329 (22.5)	22 (25.0)	
Obese	622 (42.5)	50 (56.8)	
Hypertension (n, %)	513 (35.1)	48 (54.6)	<0.0001
Glucose tolerance categories (n, %)			<0.0001
Normal glucose tolerance	976 (67.9)	37 (43.5)	
IFG/IGT	211 (14.7)	10 (11.8)	
Type 2 diabetes	251 (17.5)	38 (44.7)	

Data is presented as median (25th-75th percentiles), count and percentages. CKD, chronic kidney disease; BMI, body mass index; eGFR, estimated glomerular filtration rate; hsCRP, high-sensitivity C-reactive protein; IFG/IGT, impaired fasting glucose and impaired glucose tolerance.

Table II. Dental profile of total study population dichotomised by CKD status			
Variables	Without CKD (n=1463)	CKD (n=88)	p-value
Edentulous (n, %)	631 (43.1)	74 (84.1)	<0.0001
No of teeth (median; 25th – 75th percentile)	13 (0-26)	0 (0-0)	<0.0001
No of teeth (mean±SD)	13.3 ± 2.7	3.2 ± 7.8	<0.0001
DMFT (score) (median; 25th – 75th percentile)	21 (10-32)	32 (32-32)	<0.0001
DMFT (score) (mean±SD)	20.6 ±11.4	29.2 ± 6.8	<0.0001
DMFT categories (n, %)			<0.0001
Very low (<5.0)	159 (10.9)	1 (1.1)	
Low (5.0-8.9)	143 (9.8)	0 (0)	
Moderate (9.0-13.9)	195 (13.3)	5 (5.7)	
High (>14.0)	966 (66.0)	82 (93.2)	
Dentures (n, %)	669 (45.7)	67 (76.1)	<0.0001
Perceived health of teeth (n, %)			0.032
Excellent	69 (4.7)	8 (9.1)	
Good	495 (33.8)	36 (40.9)	
Fair	610 (41.7)	37 (42.0)	
Poor	186 (12.7)	2 (2.3)	
Bad	45 (3.1)	3 (3.4)	
Unanswered	59 (4.0)	1 (1.1)	

Data is presented as median (25th-75th percentile), mean ± standard deviation, count and percentages. Due to the severe level of tooth extracted in the whole population skewing the data, the total number of teeth and the DMFT score is presented as both median (25th-75th percentiles) and mean ± SD. CKD, chronic kidney disease; DMFT, decay-missing-filled teeth. The DMFT index is categorized according to WHO criteria 24 as very low (<5.0); low (5.0-8.9); moderate (9.0-13.9); and high (>14.0). Category termed dentures includes top and bottom fixtures, as well as partial top, partial bottom and top only fixtures.

Figure 1. Average contribution of each component (decay, missing and filled) to the DMFT score for the total sample according to CKD status. Data is presented as percentages. CKD, chronic kidney disease
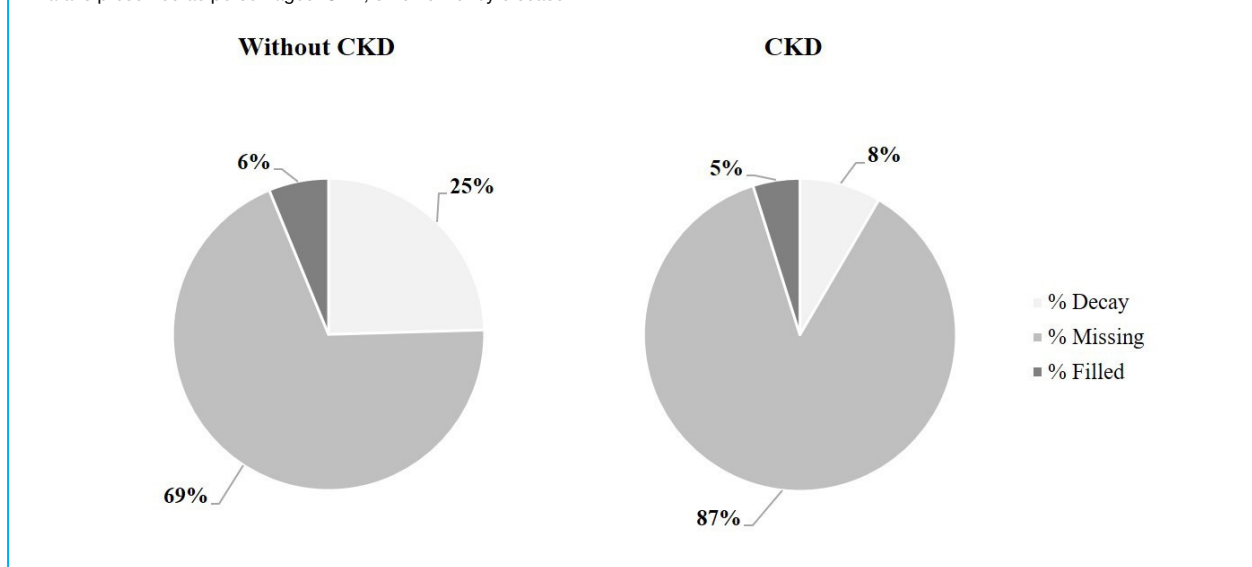
76.1% were fitted with dentures, compared to 45.8% of individuals with normal kidney function.

The periodontal profile of the dentate sub-sample (n=846) is presented in Table III and Figure 2. Compared to the participants with edentulism, those in the dentate sub-sample were on average younger (40.4 vs. 59.5 years; p<0.0001), had a higher eGFR (112.7 vs. 91.7 ml/min/1.73m²; p<0.0001) and lower prevalence of CKD (2% vs. 11%; p<0.0001). The periodontal profile of those with CKD were not different to those with normal kidney function. On average, people with CKD had similar total number of teeth compared to those without CKD (19.9 vs. 23.3 teeth; p=0.075). Despite the high prevalence of periodontitis, no differences were observed between those with and without CKD (67.1% vs. 57.1%; p=0.301) (Figure 2). Likewise, similar prevalence of BOP, PD ≥4mm and CAL

≥4mm was observed for participants with and without CKD (p>0.276 for all). Furthermore, the average number of teeth with BOP and PD ≥4mm was similar for individuals with CKD and those without CKD (p>0.391 for all). Also, similar prevalence levels of bleeding teeth and teeth with dental pockets greater than 4mm were observed between the two groups (12.2% vs. 10.9%; p=0.656 and 14.9% vs. 7.7%; p=0.246, respectively).

Relationship between dental caries and periodontitis with kidney function and prevalent chronic kidney disease

The unadjusted and adjusted associations for eGFR and prevalent CKD by DMFT index and periodontitis are presented in Tables IV and V, respectively. In robust linear regression analysis, higher DMFT scores were associated with lower eGFR (p<0.0001 for all), independent of older

Table III. Periodontal profile of the dentulous sub-sample dichotomised by CKD status			
Variables	Without CKD (n=832)	CKD (n=14)	p-value
Total number of teeth	23.3 ± 7.1	19.9 ± 6.7	0.075
Bleeding on probing			
Number of teeth bleeding on probing	2.8 ± 3.5	2.1 ± 3.2	0.391
% bleeding on probing (of total teeth)	12.2 ± 15.2	10.9 ± 13.8	0.656
Dental pockets			
Teeth with pockets <4mm	15.7 ± 7.3	15.4 ± 5.4	0.634
Teeth with pockets ≥4mm	2.1 ± 3.2	1.6 ± 2.3	0.535
% teeth with pockets <4mm	85.1 ± 23.2	92.3 ± 10.7	0.345
% teeth with pockets ≥4mm	14.9 ± 23.2	7.7 ± 10.7	0.246
Sextant with pockets <4mm	4.3 ± 1.9	4.3 ± 1.8	0.946
Sextant with pockets ≥4mm	0.7 ± 1.1	0.6 ± 1.2	0.477
Data is presented mean ± standard deviation. CKD, chronic kidney disease.			

Figure 2. Prevalence of periodontitis, bleeding on probing, pocket depth ≥4mm and clinical attachment loss ≥4mm depth, categorized by CKD status. Data is presented as %.
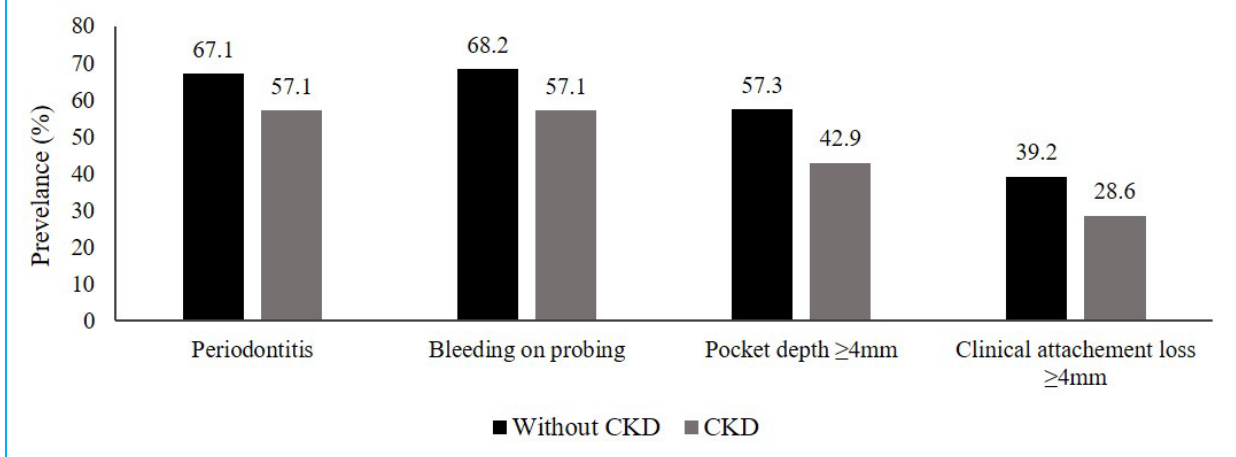
age (≥60 years), smoking status, obesity, hypertension, and diabetes status (Table IV, Models 1-5). However, this association was not independent of edentulism (p=0.261) (Table IV, Model 6). Similarly, higher DMFT scores predicted prevalent CKD (p<0.023 for all) (Table V, Models 1-5), however not independent of edentulism (p=0.645) (Table V, Model 6). Periodontitis on the other hand was not associated with eGFR (p>0.558 for all) nor prevalent CKD (p>0.258 for all) (Tables IV and V, respectively; Model 1-5), before and after adjustment for relevant confounding variables.

Effect modification by hsCRP on the relationship between periodontitis and kidney function and prevalent CKD
There was no evidence of effect modification by hsCRP on the relationship between periodontitis and eGFR (p=0.792) (Table IV, Model 6), nor did hsCRP mediate the association between periodontitis and prevalent CKD (p=0.390) (Table V, Model 6), as the addition of hsCRP to the models had no effect on the association.

DISCUSSION
To the best of our knowledge, this is the first study to evaluate the periodontal and dental status of people of mixed ancestry with CKD. This study shows that adults of mixed ancestry, with and without CKD, have a severely impaired periodontal and dental status, with the clear majority experiencing periodontitis, dental caries and/or edentulism. Yet, despite the high prevalence of periodontitis in this population, this inflammatory condition seemingly had no effect on renal

function nor could it predict CKD in this sample. However, given the small sub-sample of dentate individuals with CKD, this result should be viewed cautiously. We further showed that even though CKD is associated with a higher level of dental caries experienced, given the high DMFT index, this association is driven by the "missing" component and particularly the high level of edentulism in this group. Indeed, evaluating the components of the DMFT score, we found that CKD is associated with less decayed and filled teeth, but more missing teeth.

Though there is support for an association between periodontitis and CKD[6] and periodontitis has been identified as a potential source of inflammation in CKD patients,[31, 32] the current evidence is insufficient to link periodontitis with CKD, through an inflammatory pathway. Contrary to our study, previous studies evaluating the link between periodontitis and CKD are either in patients undergoing haemodialyis or peritoneal dialysis or in the instance where the studies are conducted in predialysis patients, these patients have severe CKD, thus close to initiating dialysis.[6,16,33] Also, the association between periodontitis and CKD is dependent on the severity of periodontitis. As such, the strength of the link between periodontitis and CKD increases with increasing severity of periodontitis.[6,34] Even though we found no association between periodontitis and reduced kidney function in this study, we cannot exclude the possibility of such an association. Thus, it is not possible to determine, based on the existing evidence, if the relationship is truly

Table IV. Multivariable robust linear regression models for eGFR by DMFT index and periodontitis						
Models	**DMFT**			**Periodontitis**		
	β	95% CI	p	β	95% CI	p
1	-0.87	-0.98 to -0.76	<0.0001	0.93	-2.83 to 4.69	0.628
2	-0.51	-0.63 to -0.39	<0.0001	1.07	-2.52 to 4.66	0.558
3	-0.45	-0.57 to -0.33	<0.0001	0.62	-2.93 to 4.17	0.732
4	-0.44	-0.56 to -0.32	<0.0001	0.50	-3.03 to 4.03	0.782
5	-0.44	-0.57 to -0.32	<0.0001	0.41	-3.14 to 3.96	0.820
6	-0.13	-0.36 to 0.10	0.261	0.48	-3.08 to 4.03	0.792

Data is presented as β-coefficient, 95% confidence interval and p-value. DMFT, Decayed, Filled and Missing Teeth; Model 1: DMFT/Periodontitis; Model 2: Model 1 + Age ≥ 60 years; Model 3: Model 2 + smoking status + obesity; Model 4: Model 3 + hypertension; Model 5: Model 4 + diabetes; Model 6 (DMFT): Model 5 + edentulism; Model 6 (Periodontitis): Model 5 + hsCRP

Table V. Multivariable logistic regression models for chronic kidney disease by DMFT index and periodontitis						
Models	**DMFT**			**Periodontitis**		
	β	95% CI	p	β	95% CI	p
1	1.10	1.07 to 1.14	<0.0001	0.57	0.20 to 1.67	0.307
2	1.04	1.01 to 1.08	0.023	0.55	0.19 to 1.63	0.282
3	1.05	1.01 to 1.09	0.012	0.52	0.17 to 1.61	0.258
4	1.05	1.01 to 1.09	0.013	0.58	0.18 to 1.80	0.343
5	1.05	1.01 to 1.09	0.016	0.59	0.19 to 1.86	0.370
6	1.02	0.94 to 1.10	0.645	0.60	0.19 to 1.92	0.390

Data is presented as odds ratio (OR), 95% confidence interval and p-value. DMFT, Decayed, Filled and Missing Teeth; Model 1: DMFT/Periodontitis; Model 2: Model 1 + Age ≥ 60 years; Model 3: Model 2 + smoking status + obesity; Model 4: Model 3 + hypertension; Model 5: Model 4 + diabetes; Model 6 (DMFT): Model 5 + edentulism; Model 6 (Periodontitis): Model 5 + hsCRP

absent in this group, or whether our study was not sufficiently powered to detect the difference, given the reduced sample of dentulous individuals. This hypothesis therefore needs further investigation.

With more than two thirds of the population presenting with a DMFT score greater than 14, the severity of caries experienced in this under-studied South African population is more comparable to higher income countries, such as the USA, Australia and Canada as opposed to other African countries,[35] or even other population groups in South Africa.[36] Furthermore, and perhaps of greater concern, is that CKD is associated with even higher DMFT scores. Indeed, in people with CKD nearly all teeth are somehow affected, with the M (missing) component making the largest contribution to the DMFT score. Given that untreated dental caries is one of the main causes of tooth loss,[37, 38] with the prevalence increasing with age,[39] it could be assumed that higher dental caries and thus higher tooth loss associates with CKD. However, because the DMFT index quantifies the life-long caries experience and do not account for teeth lost for reasons other than decay, it is difficult to say whether the prevalence of the missing component in this population is solely because of untreated caries. In fact, there is no consensus in the literature on caries prevalence in people with CKD.[19, 21] Thus, based on the cross-sectional design of this study it might be more appropriate to evaluate the contribution of each component making up the score, as opposed to the overall score.

In this study, compared to the F (filled) and M (missing) component, we found that the D (decayed) component contributed less to the DMFT index in those with CKD, compared to the contribution of this component to those with normal kidney function. This lower prevalence of decayed teeth in people with CKD has been reported in other studies,[19, 33] and this finding has previously been ascribed to the high salivary urea and phosphate levels in people with CKD.[18, 33, 40] Even though those end-points were not measured in the current study, the lower prevalence of decayed teeth in those with CKD could be explained by the higher pH environment originating from urea hydrolysis in the saliva, resulting in the neutralization of the end products of bacterial plaque and consequent reduced tooth decay.[18, 33, 40] People with CKD also presented with a significantly smaller proportion of filled teeth and higher proportion of missing teeth, reflecting the low utilization of curative dental care in the CKD population. Certainly, in resource-poor public healthcare settings, recommended regular preventive dental care may not be readily accessible.[35, 41, 42] Also, the perceived importance of oral health in this older population with CKD is of importance. Indeed, there is a perception that the loss of teeth, as the result of dental caries, are an inevitable consequence of ageing[43] and therefore preventative measures are not generally perceived as priority. Consequently, tooth extraction is often the socially acceptable solution to the pain or discomfort due to caries, in exchange for fitted dentures, rather than restoring the natural teeth.[35, 43] Also, there is a lack of awareness regarding the importance of oral health and disease.[44] Previous research indicates that a significant positive predictor of the utilisation of dental care is the "perceived need" for it.[45] This is indirectly shown through our findings, where despite the very high DMFT scores in 93% of people with CKD, all rated their overall oral health as either, fair, good or excellent. This perception of adequate oral health can be explained by the fact that people often rate their oral health status based on undesirable oral symptoms displayed[46] and since those with high DMFT had dentures the perception of good oral health are very likely.

Edentulism, which is the condition of being completely toothless, is also a major concern in this subpopulation with CKD, as 84% of the group had no teeth; an estimate substantially higher than most other countries.[47] Indeed, according to the latest systematic review, the global prevalence of edentulism in people with CKD is estimated at around 20% for adults aged 65 years and above.[37] This disparity from global estimates could be explained by the main factors associated with tooth loss and edentulism. According to the findings of a recent multi-country study, factors including older age, lower education, non-communicable diseases, obesity, tobacco use, and inadequate fruit and vegetable consumption are some of the risk factors predicting edentulism.[47] Indeed, more than half of the population with CKD in the current study were obese, 39% had diabetes and 64% had hypertension. Further, those with CKD were older, with 83% being older than 60 years, compared to those without CKD. Thus, the high exposure to risk factors and high prevalence of edentulism (because of age) are likely to explain the higher missing component and thus higher DMFT scores reported in the CKD population compared to the group with normal kidney function.

This study has some limitations, which includes the high female to male participation, however this is a common trend in South African population studies. The association across CKD categories could not be evaluated as there were very few participants in the advanced stages of CKD (stage ≥4). Our study also used a single serum creatinine measure to determine the grade of kidney function and did not include estimates of albuminuria. It is however a common practice in community-based studies to diagnose CKD using a single measurement of serum creatinine. Also, because such a large proportion of people with CKD were edentulous, removing those with no teeth rendered the group with CKD very small. Also, we never gained information centred around the reason for tooth loss, and we are therefore unable to confirm whether tooth loss was due to caries, periodontitis or due to any other reasons. However, despite these limitations, we are not aware of other studies that have assessed the association between oral disease and CKD and the potential mediatory effect of systemic inflammation on this association in this previously understudied South African population group.

CONCLUSION

It is crucial that decision makers implement health strategies that focus on promoting good oral health and preventing oral disease, such as periodontitis and dental caries, also shifting away from the current predominantly emergency service of dental extractions. Due to the complex nature of the determinants of oral disease, both for people with and without CKD, exploring CKD patient preferences and priorities for dental care could guide additional research and practice interventions.

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