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# Socioeconomic Inequality in Dental Caries Experience Expressed by the Significant Caries Index: Cross-Sectional Results From the RaNCD Cohort Study

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ABSTRACT

Introduction: Socioeconomic inequality in dental caries among Iranian middle-aged adults remains largely unstudied. This study aimed to measure socioeconomic inequality in dental caries experience and to identify determinants of this inequality.

Materials and methods: Data were obtained from the Ravansar Non-Communicable Diseases (RaNCD) Cohort Study. This cross-sectional analysis included 10,002 adults aged 35−65 years. Caries experience was dichotomised based on the decayed, missing and filled teeth (DMFT) of one-third of the population with the highest caries scores (i.e. significant caries index). Socioeconomic status (SES) was calculated using the principal component analysis. The concentration index (CI) was used to quantify the extent of socioeconomic inequality in dental caries experience. Decomposition analysis was conducted to quantify the contribution of each determinant to the observed inequality.

Results: The mean DMFT for all individuals was 16.1 (SD 9.1). The CI of having significant dental caries was −0.236 (95% CI: −0.0259, −0.213), indicating that having significant dental caries was more concentrated among low-SES individuals. SES (65.6%), age group (24.7%) and female gender (3.7%) were found to have the largest percentage of contributions to the observed inequality in dental caries.

Conclusion: This study indicates pro-rich inequalities in dental caries experience among middle-aged adults in Iran. The findings highlight the importance of early prevention of dental caries experience before it happens. To mitigate inequalities in dental caries experience, policy interventions should focus on females, older age groups, and low-SES individuals.

## Introduction

Dental caries is a major public health problem worldwide.[1,2] Although there has been a reduction in the prevalence of dental caries in both developed and developing countries[3,4], caries is very common in many populations, and imposes health and economic burdens on many societies.[2,5] The Global Burden of Disease Study showed that dental caries in permanent teeth was the most prevalent of all conditions assessed in 2016. It is estimated that 2.4 billion individuals suffer from caries of permanent teeth worldwide.[2,5]

Dental caries is, like many other health conditions, a 'deprivation disease' that mainly affects those from the most disadvantaged groups.[6,7] Systematic reviews have shown that socioeconomic indicators were significantly associated

with a higher prevalence of caries.[7,8] In addition, previous studies have indicated the presence of socioeconomic inequalities in dental status by showing that low-socioeconomic status (SES) individuals experience a higher level of dental caries.[9–11] Unequal distribution of dental caries in the population indicates the existence of dental polarisation[12], meanings that a minority of individuals presents the highest caries scores.[11,13] Dental caries polarisation is usually related to socioeconomic deprivation.[14] Lower-SES, in addition to being an important predictor of dental caries, has also been identified as a risk factor for the development of dental caries.[15,16]

Studies on dental caries inequalities in low- and middle-income countries are relatively scarce. There are only a few studies on measuring socioeconomic inequalities in dental status in Iran that have focused on children, adolescents and younger adults.[17] To the best of our knowledge, no study has been published on measuring the magnitude of inequality in dental caries in the middle-aged population in Iran. This study provides a deeper understanding of dental status inequalities and associated explanatory variables with a focus on this age-group. Therefore, we aimed to: (1) measure socioeconomic inequality in dental caries experience among a relatively large sample of Iranian middle-aged adults; (2) quantify the extent to which demographic and socioeconomic determinants contribute to overall inequality in dental caries experience.

## Materials and methods

### Setting and sample

This cross-sectional study used data obtained from the Ravansar Non-Communicable Disease (RaNCD) cohort study. The RaNCD is one of the Prospective Epidemiological Research Studies in IrAN (PERSIAN) that surveyed adults aged 35–65 years in Ravansar, Iran, which is geographically located in western Iran and close to Iraq. The size of the sample recruited to the study has been proportional to the total population covered by each health center in the Ravansar district. The initial sample consisted of 10,086 adults, of which 84 individuals were excluded due to missing values for the variables utilised in the study. Finally, the data from 10,002 individuals were included in the analysis. In order to ensure that all procedures are carried out in compliance with the PERSIAN Cohort Protocol, quality assurance (QA) and quality control (QC) measures have been implemented by QA/QC central and local teams. Further details about the design and the sampling method can be found elsewhere.[18,19]

### Outcome variable

The decayed, missing and teeth (DMFT) index was used to express dental caries experience in this study. It is calculated by adding the number of decayed (D), missing (M) and filled (F) teeth. The examinations were conducted by four examiners, who had been trained at PERSIAN central office for caries diagnosis before the survey. In order to keep examinations as consistent as possible, the examiners had been trained by the same individuals. For consistency, the examiners and study participants have sat near the window to perform the examination under natural light. The mean DMFT for the population was calculated by summing all the DMFT values divided by the total number of individuals in the sample. We dichotomised DMFT based on highest dental caries values, which corresponded to significant caries (SiC) index. The SiC index was calculated as follows: individuals were sorted according to their DMFT values. The one-third of the population with the highest caries values was selected. The SiC index was obtained by calculating the mean DMFT for this subgroup.[16,20,21] The SiC index was set as the outcome variable, and individuals with high DMFT scores (i.e. those in the group of individuals who had the highest third of caries experience) coded as 1 and all others coded as 0.[10,22,23]

### Socioeconomic status

Socioeconomic status was constructed using a principal components analysis (PCA) of data on ownership of durable assets, housing conditions and level of education.[24] The variables included in the PCA model were TV, freezer, smartphone, vacuum cleaner, dishwashing machine, motorcycle, car, laptop, per capita room, housing area (in metres), kind of house ownership, type of kitchen and education level. PCA generated the weight for each variable and then constructed an SES score based on the sum of all weights of variables included in the PCA for each individual. The individuals were categorised based on their SES score from poorest to richest. SES quintiles were used in subsequent modelling.[24–26]

### Demographic variables

Age (35–45 years, 46–55 years, 56–65 years), sex, marital status (married, single/divorced/widowed), place of residence (urban, rural).

### Oral health-related variables

Alcohol consumption (yes, no), drug abuse (yes/no), smoking (yes, no) and quality of diet as measured by healthy eating index-2015 (HEI-2015).[27] The healthy eating index (HEI) was constructed using a valid and reliable food frequency questionnaire.

### Statistical analysis

#### Measuring socioeconomic inequalities in dental caries

The concentration index (CI) was used to estimate socioeconomic inequalities in dental caries. The CI measures the magnitude of inequality. This index is a useful summary statistic that provides a measure of the extent of inequalities in health outcomes that are systematically associated with SES.[28,29]

The following formula was used to calculate the CI:

$$CI = \frac{2 * \text{cov}(y_i r_i)}{\mu} \tag{1}$$

where CI is the concentration index, $y_i$ is dental caries, and $r_i$ is individual i's fractional rank in the distribution of socioeconomic index. The $r_i$ is calculated as $r_i = i/n$. The $\mu$ is the mean of the outcome variable, and cov is the covariance. The CI shows whether the outcome variable (dental caries) is concentrated among low- or high-SES groups. It ranges between −1 and +1. The larger in absolute size the index is, the greater

the degree of inequality. The negative (positive) value represents that dental caries is more concentrated among individuals with lower-SES (higher-SES). The CI is 0 if there is no socioeconomic-related inequality.[28,29] As the outcome variable in this study is binary, Wagstaff's normalisation method was used to ensure that the CI is quantified in the range of −1 and +1, by dividing the CI by 1 minus the mean of our outcome variable.[30,31]

*Decomposition analysis*

We decomposed socioeconomic inequalities in dental caries to determine the underlying causes and sources of socioeconomic inequalities in dental caries. This technique allows us to quantify the extent to which determinant of dental caries (demographic, socioeconomic and behavioural variables) contributed to the socioeconomic inequalities in dental caries among the middle-aged adults. If we have a linear regression model that relates dental caries, $y$, to a set of $k$ exploratory variables, $x_k$.[32,33]

The CI for dental caries, $y$, can be decomposed as follows:

$$CI = \sum_k \left(\frac{\beta_k \bar{x}_k}{\mu}\right) CI_k + GC_\varepsilon/\mu \qquad (2)$$

where $\bar{x}_k$ and $CI_k$ are, respectively, the mean and the CI for $x_k$. The $\beta_k \bar{x}_k/\mu$ is the elasticity, i.e. the impact of explanatory variables on dental caries. The $\left(\sum_k (\beta_k \bar{x}_k/\mu) CI_k\right)$ indicates the contribution of determinant $k$ to the socioeconomic inequality in dental caries (explained component). The $GC_\varepsilon/\mu$ shows the part of the CI that cannot be explained by the explanatory variables included in the decomposition analysis (unexplained or residual component).[32,33] As our outcome variable was binary, Wagstaff-type decomposition analysis was performed using the following formula[32]:

$$CI_n = \frac{C}{1-\mu} = \frac{\sum_k \left(\frac{\beta_k \bar{x}_k}{\mu}\right) CI_k}{1-\mu} + \frac{GC_\varepsilon/\mu}{1-\mu} \qquad (3)$$

As dental caries was defined as a binary variable, the marginal effects obtained from the logistic model were used to calculate the contributions of the determinants to $CI_n$. The software package used to analyse the data was STATA version 14.

## Results

A total of 10,002 individuals were included in the analysis, of which 52.58% were female, 90.18% were married, and 44% belonged to the age group of 35−44 years. The mean DMFT for the sample was 16.1 (SD 9.1) and SiC index was 27.1 (SD: 5). Low-SES individuals, rural population, age group of 56−65 years, females and smokers had a higher mean of DMFT, respectively. These groups also had a higher proportion of having significant dental caries (Table 1).

The Cn for having significant dental caries (being in SiC group) was −0.236 (95% CI: −0.259, −0.213) in the entire population, −0.228 (95% CI: −0.259, −0.196) in females and 0.241 (95% CI: −0.274, −0.207) in males. The results indicate a high degree of socioeconomic inequality in dental caries in the study population. The negative sign of the CI shows that dental caries is more concentrated among lower-SES groups. The value and sign of the CI were also statistically significant. (Table 2).

The CI for the independent variable ($C_k$) suggested that women, individuals of the age group of 55−65 years, smokers and drug users were more concentrated among low-SES groups. Also, the married and urban populations were more concentrated among high-SES groups. The decomposition analysis showed that the largest proportion of inequalities was explained by SES (65.6%). Additionally, the age group (24.7%) and female gender (3.7%) were other main contributors to inequality in significant dental caries, respectively. The behavioural factors including drug abuse and the HEI had minimal contributions to the measured inequality. The explained component of the overall CI was −0.214 and the residual (unexplained) component was 0.022 (Table 3).

## Discussion

The aim of this study was to examine socioeconomic inequalities in dental caries experience expressed by SiC index in a sample of Iranian middle-aged adults. To our knowledge, there

**Table 1 – Socio-demographic information, DMFT and significant dental caries by determinant variables among cohort participants aged 35−65 years**

| Variables | N (%) | Mean of DMFT (SD) | SiC index group N (%) |
|---|---|---|---|
| Sex | | | |
| Female | 5,259 (52.5) | 16.4 (9.2) | 2,028 (38.5) |
| Male | 4,743 (47.4) | 15.7 (9) | 1,725 (36.3) |
| Age group (years) | | | |
| 35−45 | 4,408 (44) | 11.7 (7) | 719 (16.3) |
| 46−55 | 3,327 (33.2) | 16.8 (8.4) | 1,390 (41.7) |
| 56−65 | 2,267 (22.6) | 23.6 (8.5) | 1,644 (72.5) |
| Marital status | | | |
| Married | 9,020 (90.1) | 16.1 (9) | 3,382 (37.4) |
| Single/Widowed/ Divorced | 982 (9.8) | 16.2 (10) | 371 (37.7) |
| Place of residence | | | |
| Urban | 5,916 (59.1) | 15.8 (9) | 2,110 (35.6) |
| Rural | 4,086 (40.8) | 16.5 (9.3) | 1,643 (40.2) |
| SES | | | |
| Poorest | 2,001 (20) | 18.9 (9.5) | 1,034 (51.6) |
| 2 | 2,000 (20) | 17 (9.6) | 836 (41.8) |
| 3 | 2,001 (20) | 16 (9) | 749 (37.4) |
| 4 | 2,000 (20) | 15.2 (8.7) | 681 (34) |
| Richest | 2,000 (20) | 13.3 (7.8) | 453 (22.6) |
| HEI | | | |
| 1 | 2,122 (21.2) | 16.3 (9.1) | 835 (39.3) |
| 2 | 1,910 (19.1) | 16.3 (9.2) | 734 (38.4) |
| 3 | 2,064 (20.6) | 15.8 (9.1) | 744 (36) |
| 4 | 2,225 (22.2) | 15.8 (8.9) | 798 (35.8) |
| 5 | 1,681 (16.8) | 16.2 (9.2) | 642 (38.1) |
| Smoking status | | | |
| Smoker | 1,171 (11.7) | 19.6 (3.10) | 650 (55.5) |
| Non-smoker | 8,813 (88.2) | 15.6 (9) | 3,096 (35.1) |
| Drug abuse | | | |
| Yes | 298 (2.9) | 19.3 (9.2) | 167 (56) |
| No | 97.4 (97) | 16 (9.1) | 3,583 (36.9) |
| Alcohol consumption | | | |
| Yes | 631 (6.3) | 16.3 (9) | 250 (39.62) |
| No | 9,371 (93.6) | 16.1 (9.1) | 3,503 (37.3) |

DMFT, decayed, missing and filled teeth; HEI, healthy eating index; SES, socioeconomic status; SiC index; significant caries index.

**Table 2 – Normalised CIs for significant dental caries (being in SiC group), by sex**

| Sample | | Normalised CI | Std. error | P-value | (95% CI) | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Males | 4,743 | −0.241 | 0.017 | 0.000 | −0.274 | −0.207 |
| Females | 5,259 | −0.228 | 0.016 | 0.000 | −0.259 | −0.196 |
| Total | 10,002 | −0.236 | 0.011 | 0.000 | −0.259 | −0.213 |

CI, concentration index.

is no other study measuring socioeconomic inequality in dental caries in this age group from Iran. The findings indicated socioeconomic inequality in dental caries favouring individuals with higher-SES. The mean DMFT (16.9) for this study sample was high. It also showed that a higher prevalence of SiC index in females, older age groups, low-SES individuals, smokers, and people who use alcohol and drugs was observed.

Consistent with our study, the findings of Moradi et al. suggested that there is a pro-rich inequality in dental caries in Iran.[34] In addition, a study conducted in Spain has shown socioeconomic inequalities in dental health among middle-aged adults.[35] Also, the study by Hessari et al. shows a significant association between SES and dental status among adults in Iran. Their findings showed that adults with lower social status and educational level have poor dental status.[36] A study on socioeconomic inequalities in oral health among middle-aged and elderly Japanese also showed that lower education and lower equivalent household expenditure were significantly associated with an increased risk of poor oral health measured by the number of remaining teeth.[37] An

**Table 3 – Decomposition analysis of socioeconomic inequality in dental caries**

| Variable | Marginal effect | Mean | Elasticity | $C_K$ | Contribution | % Con | Summed % |
|---|---|---|---|---|---|---|---|
| Sex | | | | | | | |
| Male | | | | | | | |
| Female | 0.037 | 0.52 | 0.052 | -0.169 | -0.009 | 3.7 | 3.7 |
| Age group (years) | | | | | | | |
| 35−45 | | | | | | | |
| 46−55 | 0.229 | 0.33 | 0.203 | 0.029 | 0.006 | -2.5 | 24.7 |
| 56−65 | 0.520 | 0.22 | 0.314 | -0.205 | -0.064 | 27.2 | |
| Marital status | | | | | | | |
| Single/Widowed/Divorced | | | | | | | |
| Married | 0.031 | 0.90 | 0.075 | 0.037 | 0.003 | -1.2 | -1.2 |
| Place of residence | | | | | | | |
| Rural | | | | | | | |
| Urban | 0.013 | 0.59 | 0.021 | 0.218 | 0.005 | -1.9 | -1.9 |
| SES | | | | | | | |
| Poorest | | | | | | | |
| 2 | -0.061 | 0.2 | -0.032 | -0.640 | 0.021 | -8.8 | 65.6 |
| 3 | -0.087 | 0.2 | -0.046 | 0.000 | 0.000 | 0.0 | |
| 4 | -0.114 | 0.2 | -0.061 | 0.640 | -0.039 | 16.5 | |
| Richest | -0.200 | 0.2 | -0.107 | 1.281 | -0.136 | 57.8 | |
| HEI | | | | | | | |
| 1 | | | | | | | |
| 2 | -0.001 | 0.19 | -0.001 | -0.050 | 0.000 | 0.0 | -0.2 |
| 3 | -0.003 | 0.2 | -0.002 | 0.031 | 0.000 | 0.0 | |
| 4 | -0.013 | 0.22 | -0.008 | 0.067 | -0.001 | 0.2 | |
| 5 | 0.016 | 0.16 | 0.007 | 0.142 | 0.001 | -0.4 | |
| Smoking status | | | | | | | |
| Non-smoker | | | | | | | |
| Smoker | 0.180 | 0.11 | 0.056 | -0.014 | -0.001 | 0.3 | 0.3 |
| Drug abuse | | | | | | | |
| No | | | | | | | |
| Yes | 0.104 | 0.03 | 0.008 | -0.037 | 0.000 | 0.1 | 0.1 |
| Alcohol consumption | | | | | | | |
| No | | | | | | | |
| Yes | 0.028 | 0.063 | 0.005 | 0.280 | 0.001 | -0.6 | -0.6 |
| Explained | | | | | -0.214 | | 90.6 |
| Residual | | | | | -0.022 | | 9.4 |
| Total | | | | | -0.236 | | 100.0 |

HEI, healthy eating index; SES, socioeconomic status.

explanation for lower dental status in the individuals of lower-SES groups may be their limited financial access and ability to pay for dental hygiene products or services.[38] In addition, individuals with a lower level of education have limited oral health literacy and, therefore also have a lower understanding of dental health information and prevention of dental caries.[39]

Socioeconomic status, as indexed by assets and education, made the largest percentage of contribution (65.6) to socioeconomic-related inequality in significant dental caries. The contribution of each determinant is a product of two components: (i) its impact on dental caries, as measured by the elasticity; and (ii) its degree of unequal distribution across SES groups, as measured by the concentration index (CI). If the value of the contribution of variable $X$ is $x$ and positive (negative), then if the variable had no impact on dental caries or was equally distributed across the SES groups, inequality in significant dental caries would decrease (increase) by $x$%. So, if socioeconomic resources were equally distributed across different SES groups, then inequality in dental caries would decrease by 65.6%.[40,41]

Older age had the highest values for caries. Also, older age group was the second important contributor to socioeconomic inequalities in significant dental caries. In line with our findings, a review by Al-Ansari demonstrating that adults in Saudi Arabia had the highest prevalence of dental caries, and elderly populations had the greatest DMFT score compared with other age groups.[42] Other previous studies on dental caries experience also indicated that with an increase in age, there was an increase in dental caries experience and mean DMFT.[43,44] The mean DMFT score was the highest in the 55−65 year old age group. A possible explanation for this finding is that older adults are at risk for a longer period of time, which would suggest that older adults would be more likely to have caries experience.[43]

In addition, in the present study, female gender was another main contributor to socioeconomic inequalities in dental caries. The previously mentioned study in Iran also found sex as the main contributor to inequality in DMFT.[34] In the present study, females were found to have a higher mean DMFT as well as a higher prevalence of significant dental caries. In line with our findings, studies in Iran, Africa, America and Europe note that women have higher caries and DMFT in comparison to men.[45,46] A possible reason may be that females were more concentrated in lower-SES groups, as shown by their negative CI in the decomposition results.

We found that rural populations had higher caries values compared with their counterparts in urban regions. In line with our findings, a study in Iran indicated that rural residents have a lower probability to have filled teeth compared with urban residents.[36] One reason for this finding may be due to poor access to dental health services in rural areas. Furthermore, the rural population tended to have lower-SES and limited financial resources. Dental care in Iran is integrated into primary health care programmes. However, only 20% of dentists work in the public sector and the remaining 80% have private practices. Although Iran's public health sector provides some dental care services to the rural population, the private sector mainly provides dental care services in urban settings.[47] On the other hand, lack of insurance coverage for dental services is the major barrier to access to such services in Iran, because out of pocket payments are the main way to pay for dental services. It should be noted that there are some complementary insurance companies that cover dentistry services in Iran, but they are not available to the entire population. Therefore, due to the long waiting time in the public sector, the lack of health insurance coverage and high dental costs, a large proportion of individuals are suffering from dental problems.[34]

Following previous studies, we included some oral health-related behaviours to the analysis as predictors of dental status and socioeconomic inequalities in dental caries. Consistent with previous studies, this study showed that health-related behaviours had a limited contribution in explaining the observed socioeconomics inequalities in dental caries.[48−50]

The results highlight the need for health policies in facilitate financial and geographical access to dental health services. The government and health insurance should formulate policies to advocate for vulnerable groups (i.e. low SES individuals, females and older adults). National health policies need to improve the availability and distribution of oral health professionals in rural areas. Portable dental services may be an important option to provide dental care services for the rural population in developing countries including Iran. Also, attention to oral health education at an early age can be an effective step to improve attitudes and prevent dental diseases in later in life.[51] Thus, children and adolescents should be of focus of oral health policy discussions.

In the present study, SiC index was used as the outcome variable. It has been shown that expressing dental caries by the mean DMFT cannot detect high-caries groups in a population with a skewed distribution of dental caries and, therefore, these high-risk groups remain undiscovered. In order to target high-caries groups, SiC index has been introduced to call attention to the individuals who have the highest caries rates in every population.[16,20] This study was a cross-sectional analysis of a prospective cohort study that reported measurements only at one time point. Also, individuals under age 35 years had not been included in the RaNCD cohort study. Our findings may not be representative of all middle-aged adults in Iran because the data has been collected only in one region. Also, various determinants such as psychosocial factors[35] can contribute to inequality in oral health status and have not been analysed in our study.

## Conclusion

There was a pro-rich socioeconomic-related inequality in dental caries among middle-aged adults, meaning that dental caries was more concentrated among low-SES individuals. SES, age and female gender were important predictors of inequality in the distribution of dental caries experience in Iranian middle-aged adults. Policy interventions aimed at reducing socioeconomic inequalities in dental caries experience should focus on females, older age groups, low-SES individuals and rural population.

## Conflict of interest

The authors declare no conflict of interest.

## Acknowledgements

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