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Urban-rural comparison of adolescent tobacco use and oral mucosal lesions

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Abstract:
Adolescent tobacco use remains a preventable public health problem because early initiation increases nicotine dependence and exposes the oral mucosa to carcinogenic and irritant products before adulthood. Therefore, it is of interest to compare tobacco use patterns and oral mucosal lesions among 600 adolescents aged 13-17 years from urban and rural schools. Data were collected using a structured tobacco-use questionnaire and standardized oral examination; associations were tested using chi-square test, independent t-test and multivariable logistic regression. Current tobacco use was higher in rural adolescents than urban adolescents (17.3% versus 10.0%, p=0.009), with smokeless tobacco predominating in the rural group; oral mucosal lesions were detected in 12.7% of participants and were significantly more common among tobacco users than non-users (38.8% versus 8.5%, p<0.001). Rural residence, male sex, smokeless tobacco use, higher frequency of use and longer duration of habit were independent predictors of oral mucosal lesions, emphasizing the need for school-centered tobacco prevention and early oral screening in both urban and rural settings.

Keywords: Adolescents, oral mucosal lesions, smokeless tobacco, tobacco use, rural health, urban health, school oral screening

Background:
Tobacco use during adolescence is a major public health concern because experimentation at this age can progress rapidly into regular use and long-term dependence. The adolescent period is also marked by peer influence, risk-taking behaviour, increasing autonomy and exposure to commercial tobacco products. School-based surveillance, including the Global Youth Tobacco Survey (GYTS), is therefore important for monitoring youth tobacco use and guiding prevention programmes **[1]**. In India, the fourth round of GYTS reported that 8.5% of school-going children aged 13-15 years were current users of any tobacco product, with a higher prevalence among boys than girls. Initiation often occurs very early and the oral cavity is the first site of direct contact for smoked and smokeless products **[2]**. Indian data show that adolescent tobacco use varies according to sex, age, peer environment, pocket money, family context, product availability, school type and place of residence. National survey analysis has showed strong associations with pocket money and close friends using tobacco, emphasizing the influence of social opportunity and peer networks **[3]**. Rural communities may have additional vulnerabilities, including easier access to locally available smokeless products, intergenerational use, cultural normalization of chewing products and weaker enforcement around sales to minors. Studies from rural central India have reported frequent use of kharra, gutkha, tobacco with lime and dry snuff, with peer pressure, imitation of adults, perceived symptom relief and oral-hygiene misconceptions reported as reasons for use **[4]**. Urban adolescents may show a different pattern that includes cigarettes, flavoured products, pan masala and newer nicotine products. The oral mucosa is a sensitive indicator of tobacco exposure. Repeated contact with nicotine, tobacco-specific nitrosamines, areca nut alkaloids, slaked lime, combustion products, heat and mechanical irritation may produce tobacco pouch keratosis, smoker's melanosis, leukoplakia, oral submucous fibrosis, palatal keratosis, lichenoid changes, traumatic ulcers and pigmentation. Areca nut, frequently used alone or with tobacco in South Asia, has an independent carcinogenic role and is strongly implicated in oral submucous fibrosis **[5]**. Recent global evidence estimated that approximately one in three oral cancer cases worldwide in 2022 were attributable to smokeless tobacco or areca nut consumption, with the greatest burden in regions where these products are widely used **[6]**. Although oral cancer is usually diagnosed in adulthood, the behavioural roots and mucosal exposure may begin during adolescence, making early habit identification and oral screening important preventive opportunities. Indian school-based evidence has also associated adolescent tobacco use with poorer oral health-related quality of life, socioeconomic disadvantage, dental caries and irregular dental attendance **[7]**. School-based tobacco prevention programmes in India show potential but remain unevenly implemented; effective approaches should be age-appropriate, repeated, culturally sensitive and supported by teachers, parents, health workers and dental professionals **[8]**. Therefore, it is of interest to compare tobacco-use patterns and oral mucosal lesions among urban and rural adolescents and to identify factors associated with lesion occurrence.

Materials and Methods:
Study design and setting:
This was a school-based comparative cross-sectional study conducted among urban and rural adolescents in a district of central India. Data collection was carried out over a four-month period from July to October 2025 after institutional ethical approval and permission from school authorities. The study followed a field-screening model suitable for community oral health research.

Sample size and sampling technique:
The minimum sample size was calculated using an expected adolescent tobacco-use prevalence of 12%, 95% confidence level, 3.5% absolute precision and 10% allowance for non-response. The final sample included 600 adolescents, with 300 from urban

schools and 300 from rural schools. A multistage sampling method was used. First, schools were stratified by locality as urban or rural. Then, schools were selected by simple random sampling from each stratum. Within selected schools, eligible students were chosen by systematic random sampling from class registers.

Eligibility criteria:
Adolescents aged 13-17 years who were present on the day of examination and provided assent along with written parental consent were included. Students with systemic conditions affecting oral mucosa, current orthodontic appliances causing mucosal trauma, history of recent oral surgery, ongoing treatment for oral mucosal disease, or unwillingness to undergo oral examination were excluded.

Study tool and variables:
A structured questionnaire was developed in English and translated into the local language. It included age, sex, school locality, socioeconomic category, parental education, family tobacco exposure, peer tobacco exposure, ever use of tobacco, current use within the past 30 days, type of product, age at initiation, frequency, duration, placement site for smokeless tobacco and attempts to stop use. Tobacco use was classified as no use, smoked tobacco only, smokeless tobacco only, or dual use. Current tobacco use was defined as use of any tobacco product on at least one day during the previous 30 days.

Oral examination procedure:
Oral mucosal examination was performed by two calibrated dental examiners using mouth mirrors, disposable gloves, sterile gauze and adequate illumination. The buccal mucosa, labial mucosa, gingiva, palate, tongue, floor of mouth, vestibule and retromolar area were inspected systematically. Lesions were recorded clinically as tobacco pouch keratosis, leukoplakia-like white plaque, oral sub mucous fibrosis features, smoker's melanosis, palatal keratosis, traumatic ulcer, erythematous lesion, or other mucosal change. Students requiring treatment or specialist evaluation were referred to the nearest dental college or government dental facility.

Calibration and reliability:
Examiner training was performed using clinical photographs and supervised field examinations before the study. Inter-examiner reliability for presence or absence of oral mucosal lesion was assessed in 40 students not included in the final sample and showed good agreement (Cohen's kappa=0.86). Questionnaire pretesting was performed in 30 adolescents to improve clarity and sequence of questions.

Ethical considerations:
Participation was voluntary. Confidentiality was maintained by assigning numerical codes. Students identified as tobacco users received brief chair side counselling and information leaflets were provided to school authorities for parent-teacher health education sessions. No student was identified publicly as a tobacco user.

Statistical analysis:
Data were entered in Microsoft Excel and analyzed using SPSS version 28.0. Continuous variables were summarized as mean ± standard deviation and categorical variables as frequency and percentage. Urban and rural groups were compared using independent t-test for continuous variables and chi-square test or Fisher's exact test for categorical variables. Binary logistic regression was performed to identify predictors of oral mucosal lesions. Variables with $p<0.10$ in bivariate analysis were entered into the model. A p-value <0.05 was considered statistically significant.

Results:
A total of 600 adolescents were examined, with equal representation from urban and rural schools. The overall mean age was 15.12±1.21 years. The urban and rural groups were comparable for age distribution, but the rural group had a slightly higher proportion of students from lower socioeconomic categories and greater family tobacco exposure. **Table 1** presents the demographic profile and tobacco-use exposure of the study population. Current tobacco use was significantly higher among rural adolescents than urban adolescents (17.3% versus 10.0%, p=0.009). Family tobacco exposure and peer tobacco exposure were also significantly more frequent in the rural group. **Table 2** shows product-specific patterns. Smokeless tobacco was the most common current product overall and was significantly more common in rural adolescents. Dual use was uncommon but clinically important because lesion prevalence was highest in this subgroup. Gutkha, kharra, tobacco with lime and zarda were the common smokeless products reported, whereas cigarettes and bidis were the common smoked products. Oral mucosal lesions were found in 76 adolescents (12.7%). Lesions were more common in rural adolescents than urban adolescents (16.3% versus 9.0%, p=0.007). Tobacco pouch keratosis was the most frequent lesion, followed by smoker's melanosis, leukoplakia-like white plaque and early oral sub mucous fibrosis features. The prevalence of lesions among current tobacco users was 38.8%, on logistic regression, current tobacco use was the strongest predictor of oral mucosal lesions (adjusted odds ratio (AOR) =5.21, 95% CI: 2.93-9.27, p<0.001). Smokeless tobacco use showed greater association than smoked tobacco alone (AOR=4.68, 95% CI: 2.38-9.18, p<0.001). Rural residence remained independently associated with lesions after adjusting for sex, socioeconomic category, family exposure, peer exposure and tobacco-use status (AOR=1.79, 95% CI: 1.09-2.95, p=0.021). Habit duration longer than 12 months (AOR=2.84, 95% CI: 1.36-5.92, p=0.006) and daily or near-daily use (AOR=3.17, 95% CI: 1.51-6.65, p=0.002) were also significant predictors. When lesion distribution was assessed by product type, tobacco pouch keratosis was concentrated among smokeless tobacco users, smoker's melanosis was more frequent among smokers and early oral sub mucous fibrosis features were seen mainly among adolescents using areca nut-containing products with or without

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tobacco. Most lesions were asymptomatic and were detected only through clinical examination, suggesting that reliance on self-reported oral symptoms would miss a substantial proportion of early mucosal changes. Lesion prevalence among current tobacco users was 38.8% compared with 8.5% among non-users (p<0.001). Detailed oral mucosal findings are presented in **Table 3**.

Table 1: Demographic profile and tobacco-use exposure among urban and rural adolescents

Variable	Urban (n=300)	Rural (n=300)	p-value
Age (years), mean ± SD	15.08 ± 1.18	15.16 ± 1.24	0.421
Male sex, n (%)	156 (52.0)	164 (54.7)	0.512
Lower socioeconomic category, n (%)	84 (28.0)	132 (44.0)	<0.001
Family tobacco exposure, n (%)	104 (34.7)	158 (52.7)	<0.001
Peer tobacco exposure, n (%)	88 (29.3)	126 (42.0)	0.001
Ever tobacco use, n (%)	54 (18.0)	82 (27.3)	0.006
Current tobacco use, n (%)	30 (10.0)	52 (17.3)	0.009
Mean age at initiation among ever-users (years)	13.82 ± 1.10	13.21 ± 1.18	0.004

Table 2: Tobacco-use patterns among urban and rural adolescents

Tobacco-use pattern	Urban (n=300)	Rural (n=300)	p-value
No current tobacco use	270 (90.0)	248 (82.7)	0.009
Smoked tobacco only	12 (4.0)	13 (4.3)	0.846
Smokeless tobacco only	14 (4.7)	31 (10.3)	0.008
Dual smoked and smokeless use	4 (1.3)	8 (2.7)	0.242
Daily or near-daily use among current users	9/30 (30.0)	25/52 (48.1)	0.108
Habit duration >12 months among current users	10/30 (33.3)	28/52 (53.8)	0.074
Quit attempt in past 12 months among current users	7/30 (23.3)	12/52 (23.1)	0.981
Awareness of oral cancer risk among current users	18/30 (60.0)	22/52 (42.3)	0.121

Table 3: Distribution of oral mucosal findings among urban and rural adolescents

Oral mucosal finding	Urban (n=300)	Rural (n=300)	Total (n=600)	p-value
Any oral mucosal lesion	27 (9.0)	49 (16.3)	76 (12.7)	0.007
Tobacco pouch keratosis	7 (2.3)	18 (6.0)	25 (4.2)	0.024
Smoker's melanosis	8 (2.7)	9 (3.0)	17 (2.8)	0.807
Leukoplakia-like white plaque	3 (1.0)	7 (2.3)	10 (1.7)	0.199
Early oral submucous fibrosis features	2 (0.7)	6 (2.0)	8 (1.3)	0.157
Traumatic/irritational ulcer	5 (1.7)	6 (2.0)	11 (1.8)	0.759
Palatal keratosis/erythema	2 (0.7)	3 (1.0)	5 (0.8)	0.654
Lesion among current tobacco users	10/30 (33.3)	22/52 (42.3)	32/82 (39.0)	0.421

Discussion:

The present study found that tobacco use and oral mucosal lesions were significantly more common among rural adolescents than urban adolescents. The difference was not limited to prevalence alone; rural adolescents also showed earlier initiation, greater family and peer exposure and higher use of smokeless products. These findings support the view that adolescent tobacco use is strongly shaped by local social environment, household normalization, product availability and the type of tobacco products accessible to minors. The overall current tobacco-use prevalence of 13.7% in this study is higher than the national estimate reported among 13-15-year-old school-going children in GYTS-4, but it is plausible for a district-level adolescent sample that included students up to 17 years of age. Tobacco use tends to increase with age during adolescence and inclusion of older students may partly explain the higher prevalence. The observed male predominance is consistent with national patterns, but the presence of tobacco use among girls should not be overlooked because gender-specific underreporting and hidden use of smokeless products are common concerns in school surveys **[2]**. The higher rural prevalence in this study is consistent with earlier rural adolescent evidence from India, where smokeless tobacco products such as kharra, gutkha, tobacco with lime and snuff were frequently reported. Rural use may be influenced by family modelling, informal sale networks, lower perceived harm and traditional practices of using tobacco-containing products for oral cleaning. These factors may allow early initiation even when students are aware of tobacco-related cancer risk **[4]**. Smokeless tobacco was the dominant product in the rural group and showed the strongest relationship with oral mucosal lesions. This is biologically credible because smokeless products are often placed in the buccal or labial vestibule for prolonged periods, producing direct chemical and mechanical injury at the placement site. Tobacco-specific nitrosamines, alkaline pH from lime, areca nut alkaloids and repeated friction can produce keratotic and fibrotic changes. The concentration of tobacco pouch keratosis among smokeless users in the present study supports this exposure-site relationship **[9]**. The overall oral mucosal lesion prevalence of 12.7% was clinically meaningful for a school-going adolescent population. Most lesions were asymptomatic and would probably have remained undetected without screening. The lesion prevalence among current tobacco users was more than four times that among non-users, reinforcing the importance of combining tobacco questionnaires with oral examination. Studies among tobacco-using populations in India have repeatedly shown that tobacco habits are associated with leukoplakia, oral sub mucous fibrosis, smoker's melanosis, pouch keratosis and other mucosal alterations **[10, 11]**. The presence of leukoplakia-like plaques and

early oral sub mucous fibrosis features in adolescents is concerning even when absolute numbers are small. These findings should not be interpreted as cancer diagnosis, but they indicate a preventable pathway of chronic exposure and tissue response. Frequency and duration of tobacco use were independently associated with lesions in this study, supporting a dose-response relationship. Similar evidence from Indian cross-sectional research has shown that higher frequency and longer duration of habit increase the risk of oral mucosal lesions **[12]**. The association between rural residence and lesions remained significant even after adjustment for tobacco use, suggesting that additional contextual factors may be operating. These may include delayed dental visits, lower oral-health awareness and nutritional factors, co-use of areca nut or pan masala and differences in reporting of product composition. Areca nut is particularly important because it may be consumed separately from tobacco but still contributes to mucosal fibrosis and oral cancer risk. Current global evidence emphasizes that smokeless tobacco and areca nut together account for a large preventable burden of oral cancer, especially in South-Central Asia **[6, 13]**. Urban adolescents in this study showed lower tobacco-use prevalence but still showed a substantial burden of experimentation. Urban students may have greater exposure to packaged products, peer experimentation and social media influences. The study also found low quit attempts and incomplete awareness of oral cancer risk among current users in both settings. This indicates that knowledge alone is insufficient; prevention must address access, peer norms, refusal skills, family modeling and the attractiveness of packaged products. The finding that oral lesions were detected even among some students who denied current tobacco use requires careful interpretation. Some may have been former users, intermittent users, areca nut users, or students reluctant to disclose tobacco use. Some lesions may also be unrelated to tobacco, such as traumatic ulcers or irrigational keratosis. Nevertheless, the much higher lesion prevalence among current users supports a strong association between tobacco exposure and mucosal changes. This study has practical implications for public health dentistry and school health programmes. First, school oral screening should include a confidential tobacco-use assessment. Second, rural schools require special attention because smokeless products may be normalized and easily available. Third, brief chairside counselling should be linked with referral pathways for suspicious lesions. Fourth, school-based tobacco education should include visual information on early oral mucosal changes, because adolescents may respond more strongly to immediate visible harm than to distant cancer risk. The study also supports integration of dental professionals into tobacco-control activities. Dental teams are well positioned to identify early mucosal changes, document placement-site lesions, counsel adolescents and engage parents and teachers. Evidence from school-based prevention reviews suggests that sustained, structured programmes are more useful than isolated lectures. A combined approach involving policy enforcement, school curricula, peer-led education, parental counselling and dental screening is likely to be more effective **[8]**. The strengths of this study include equal urban and rural representation, standardized oral examination, examiner calibration and assessment of product type, frequency and duration. However, some limitations must be acknowledged. The cross-sectional design cannot establish causality. Tobacco use was self-reported and may be underreported because of social desirability bias. Biochemical validation was not performed. Lesions were diagnosed clinically without histopathological confirmation because the study was conducted in a school-screening setting. The results represent one district and should be generalized cautiously to other regions with different tobacco products and cultural practices. Future studies should include longitudinal follow-up to assess lesion regression after cessation counselling, biochemical validation of tobacco exposure, detailed documentation of areca nut and pan masala use and evaluation of school-based intervention effectiveness. Adolescent oral mucosal screening can also be incorporated into wider non-communicable disease prevention programmes because tobacco initiation, diet, oral hygiene and risk behaviour often cluster during this age period. Overall, the study shows that rural adolescents had higher tobacco use and a greater burden of oral mucosal lesions than urban adolescents, with smokeless tobacco being the most important product associated with clinical changes. The findings underline the need for early prevention, repeated counselling, strict enforcement against sale to minors and routine oral examination in school health services. Choudhary *et al.* **[14]** also documented a strong burden of tobacco-associated mucosal lesions, particularly among smokeless-tobacco users, supporting the value of early clinical screening. The IARC Oral Cancer Prevention Handbook emphasizes cessation of smokeless tobacco and areca nut exposure together with clinical oral examination for secondary prevention **[15]**, while the WHO Global Oral Health Status Report identifies tobacco control and prevention-oriented oral-health services as core public-health priorities **[16]**. State-level analysis by Rai and Bramhankar **[17]** shows substantial geographic variation in tobacco use across India, reinforcing the need for locally tailored interventions. Recent adolescent data from Chakraborty **[18]** further show that tobacco and areca-nut experimentation can begin during school years, supporting preventive education before regular use becomes established.

Conclusion:

Tobacco use was significantly more common among rural adolescents than urban adolescents and smokeless tobacco was the predominant product associated with oral mucosal lesions. Oral mucosal lesions were detected in 12.7% of adolescents and were markedly more frequent among current tobacco users, particularly those with daily use, longer habit duration and smokeless tobacco placement habits. School-based oral screening combined with confidential tobacco-use assessment, counselling, family involvement and rural-focused prevention is essential for early identification and reduction of tobacco-related oral harm among adolescents.

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