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RESEARCH ARTICLE

Adulterated Alcohol in Burkina Faso: Toxicological Assessment of Commercialized Beverages and Socio-Demographic Determinants of Consumption in Urban and Rural Settings

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Abstract:

Background: The proliferation of low-cost alcoholic beverages in Burkina Faso raises major public health concerns due to the potential presence of toxic adulterants. However, data on their chemical composition and the socio-demographic characteristics of consumers remain limited.

Methods: A cross-sectional study combining toxicological analysis and a Knowledge, Attitudes, and Practices survey was conducted from October 2023 to March 2024 in Ouagadougou (urban) and Nanoro (rural) areas. Twenty-nine alcoholic beverage samples were collected from six retail outlets and analyzed using gas chromatography to detect toxic compounds. A total of 196 consumers were interviewed. Statistical analyses were performed using R software, with significance set at $p < 0.05$.

Results: Overall, 62.06% of sampled beverages were adulterated. Locally produced beverages showed a significantly higher rate of adulteration compared to imported products (80% among samples produced in Burkina Faso vs. 22.22% among samples imported from Ghana). Methanol was the most frequently detected compound, often in combination with higher alcohols and ethyl acetate. Consumer characteristics revealed a mean age of 36.04 ± 13.68 years, with significant associations between drinking patterns and age as well as sector of activity ($p < 0.005$). Heavy drinking was more prevalent in rural areas.

Conclusion: Adulterated alcoholic beverages are widely present in Burkina Faso and pose significant health risks. Strengthening regulatory monitoring, particularly for locally produced alcohol, and integrating socio-demographic factors into prevention strategies are essential to reduce associated harms.

Keywords: Adulteration, Alcohol, Toxicity, Methanol, Burkina Faso, Public Health.

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1. INTRODUCTION

Alcohol production and trade exist both within and outside government regulations (8). Alcohol consumption in sub-Saharan Africa is a public health problem and can be influenced by recreational activities, religion, age and gender, especially within the most vulnerable population (10, 11,36).

In Burkina Faso, production, importation and commercialization of alcoholic beverages are regulated by Ministerial decree No. 2021-00381/MICA/MS/MEEVCC/MATD. Under the latter, importers and producers have the obligation to undergo a prior analysis of their products by an accredited laboratory before commercialization. However, cases of adulterated alcoholic beverages have been documented over the years by the media (22, 25).

Adulterated alcoholic beverages are defined as legal alcoholic products which have been illicitly tempered with, for instance by criminally diluting them with water, intentionally putting them in new containers to conceal their true origin, or adding toxic substances to manipulate their quality (21). Levels of alcohol consumption are dependent on demographic (5), socio-economic and level of education of individuals (6, 23) . In Burkina Faso, alcohol is consumed by approximately 25% of the population with a level of alcohol intake being associated with age (5). In addition, many media reported a rise of adulterated alcoholic beverages consumption and stores in the country (22). Legal alcoholic beverages composition mainly consists of ethanol at different level of concentration and water (34). While socio-demographic characteristics of legal alcoholic beverages consumers and their effects on human physiology have been documented in other countries (6, 7, 26, 34, 37) and in Burkina Faso (5, 28), data on the consumption of adulterated alcoholic beverages are insufficient. Alcoholic beverages consumption has several repercussions on personal, social and professional life (16). Moreover, chronic alcohol consumption is associated with an increased incidence of different types of cancer, cardio-vascular and liver diseases, birth defects, and psychiatric disorders (12, 14, 23, 24). It has been also established that the consumption of adulterated alcoholic beverages can lead to several health problems, including alcohol-related blindness (2, 17, 18, 29, 31), metabolic acidosis (2)and death (7).

Alcohol is also known for inducing an oxidative stress which can affect reproduction (1). Previous studies have reported the presence of methanol in adulterated alcoholic beverages (2, 8, 20) which exacerbates toxicity. However, due to the lack of studies on those types of alcoholic beverages and the non-disclosure of their chemical compounds, the risks associated with their consumption may be underestimated.

This study aims to: (i) gather valuable information on the socio-demographic characteristics of consumers of adulterated alcoholic beverages in Burkina Faso and (ii) evaluate the health risks associated with such consumption by screening these so-called “adulterated alcoholic beverages” commercialized locally, to detect higher alcohols and esters content by gas chromatography.

2. MATERIAL AND METHODS

2.1. Study Design and Setting

This study combined a toxicological analysis of alcoholic beverages with a cross-sectional Knowledge, Attitude, and Practices (KAP) survey among consumers. It was conducted between October 2023 and March 2024 in Ouagadougou (urban setting) and Nanoro (rural setting), Burkina Faso.

2.2. Sample Size and Study Design

Number of required consumers to respond to the KAP survey was evaluated using the formula for sampling size calculation for a cross-sectional epidemiological study (15). The sample size for the KAP survey was calculated using the following formula:

$$n = (Z^2 \times p \times (1 - p)) / d^2$$

Where:

$$Z = 1.96 \text{ (95\% confidence level)}$$

p = 0.25 (estimated prevalence of alcohol consumption in Burkina Faso)

d = 0.05 (margin of error)

This yielded a minimum sample size of 288 participants. Although the calculated minimum sample size was 288, logistical and field constraints limited recruitment to 196 participants. However, this sample size remains sufficient to detect significant associations and is comparable to similar exploratory studies in low-resource settings.

2.3. Sampling Alcoholic Beverages

A total of 29 alcoholic beverage samples were randomly collected from six retail outlets (three in each study area). These outlets were selected based on their known sale of low-cost alcoholic beverages.

2.4. Inclusion and Exclusion Criteria

Participants were eligible if they were aged 18 years or older, reported regular consumption of the targeted alcoholic beverages, and provided informed consent.

Women were not included due to socio-cultural constraints limiting their participation in alcohol-related surveys. This represents a limitation of the study.

2.5. Data Collection

A structured KAP questionnaire was written in local languages (Moore, Bambara, Fulfulde, and French). Data collected included socio-demographic characteristics and alcohol consumption patterns.

2.6. Toxicological Analysis

After receiving consent from the sale point owner, a thermometer was placed in the store for 18 – 24 hours to monitor temperature variations throughout the day before collecting the samples. Samples were stored at 2–8°C and analyzed using gas chromatography with flame ionization detection (GC-FID, Agilent 6890). Ten chemical compounds known to increase alcohol toxicity were screened. Screened chemical compounds are presented in Table **1** and were purchased from *Sigma Aldrich France*. A sample was considered adulterated when one or more toxic compounds not expected in standard ethanol-based beverages (*e.g.,* methanol, higher alcohols, esters) were detected.

Table 1. Retention time of screened chemical compounds

Chemical Compounds	Retention Time (mins)
Methanol	2.970
1-Propanol	3.400
2-Butanol	3.614
2 Methyl-1-Butanol	3.705
2 Methyl-1-Propanol	3.801
2 Methyl-2-Butanol	3.892
3 Methyl-1-Butanol	4.880
Ethyl-Acetate	4.923
1 Pentanol	5.394
4 Methyl-1-Pentanol	6.312

2.7. Alcohol Consumption Patterns Determination

Data about the daily and weekly consumption patterns of pure alcohol consumed grams (g) of alcohol per glass have been received from consumers through the KAP survey. This, taking into account the information about the consumed beverage, the quantity and the frequency of consumption. Drinking patterns have been determined using the guidelines of the National Institute on Alcohol Abuse and Alcoholism (14).

2.8. Data Analysis

Data of the KAP survey and store characteristics, including building materials used and diurnal temperature range were primarily recorded on paper, then entered on *Microsoft Excel 2019* and analyzed using the *R* software *v4.3.2* by the mean of the *tidyverse ggplot2* and *dplyr* libraries. Descriptive statistics were computed, and associations between variables were tested using the *Kruskal-Wallis test.* Statistical significance was set at $p < 0.05$ and applied to the variables age, age group, consumption pattern and sector of activity

3. RESULTS

3.1. Sample Size and Country of Origin

Fig. **1** shows the country of origin and sample size of alcohol collected at the different points of sale in Ouagadougou and Nanoro.

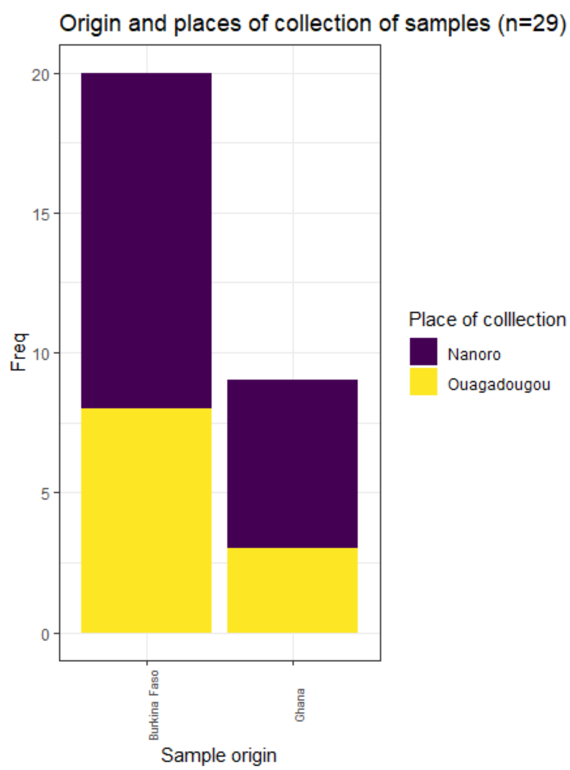

Fig. (1). Overview of country of origin and place of collection of alcoholic beverages.

A total of 29 alcoholic beverages samples were collected in Nanoro and Ouagadougou. From which, 31.03% of the samples originated from Ghana and 68.97% were locally produced in Burkina Faso.

3.2. Prevalence of Adulteration and Detected Compounds

Out of a total of 20 samples from Burkina Faso, gas chromatography revealed the presence of methanol in 80% of the samples; 10% of the samples were positive to 2-methyl-1-propanol in addition to methanol, 5% contained ethyl acetate and methanol, and 5% were positive to ethyl acetate and 2-methyl-1-propanol in addition to methanol. Out of 9 samples with origin from Ghana, 22.22% contained methanol.

Evidence of adulteration of the collected alcohols is shown in Fig. **2**.

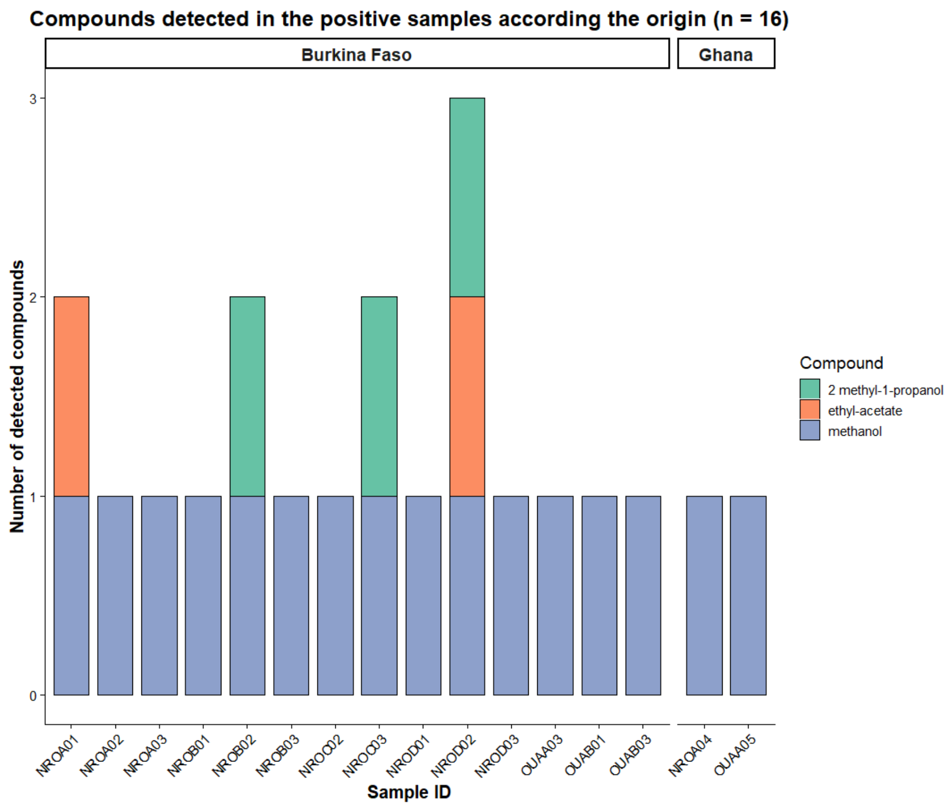

Fig. (2). Distribution of chemical compounds among collected alcoholic beverages.

3.3. Socio-demographic Characteristics of Consumers

Consumer's professional activities were classified by sector of activity. The primary sector involves the extraction or harvesting of natural resource. The secondary sector focuses on transforming raw materials into finished products. The tertiary sector is the services sector. The public sector encompasses organizations that are owned and operated by the government, providing essential services to citizens. Daily alcohol intake consists of the volume of liquor and other spirits usually drank by the consumer within the day. Consumers provided answers on how many drinks served in a measurement glass of 50 milliliters (mL) they drink daily and the number of days of consumption within the week. The characteristics of the study population are presented in Table **2**.

A total of 196 consumers were included in the study, with 124 from Ouagadougou and 72 from Nanoro. The overall mean age was 36.04 ± 13.68 years. Consumers in rural areas were older on average than those in urban settings (47.2 vs. 30.75 years). Age of consumers by study site is represented in Fig. **3**.

3.4. Alcoholic Beverage Consumption Patterns by Age

Consumers were interviewed about their drinking habit. The latter differs depending on the age and the study site. As presented in Table **3**, the number of heavy drinking consumers was higher in Nanoro than in Ouagadougou (51.38% versus 17.74%) and was represented in majority by the age group of 35 – 55+ years (45.83%) in Nanoro and the 25 -55+ age group in Ouagadougou (17.4%). In Ouagadougou, the majority of consumers had low-risk drinking (LRD) habits (69.35%) and were represented by the age group of under 25 to 34 years (61.29%). Binge drinking consumers in Ouagadougou (8.06%) were represented mainly by those aged 25 to 34 (4.83%) while in Nanoro (16.66%) those aged 45 to 54 represented the majority (6.94%). The distribution of extreme binge drinking consumers according to age in Nanoro is equitable for the age groups 25 to 34 years, 25 to 54 years, and over 55 years (1.38% for each age group). In Ouagadougou, extreme binge drinking consumers (4.83%) are mostly equally represented between those under 25 and those aged 35 to 54 (1.61% for each age group). The drinking patterns of consumers by age group and study site are presented in Table **3**.

Table 2. Characteristics of consumers by age, sector of activity and alcohol intake.

-	N	%	X^2	P value
Subjects			1013.6	<0.005
Age(years)	196	100		
Mean	36.04			
Sd	13.68			
Sector of activity			56.796	<0.005
Primary sector	49	25		
Secondary sector	40	20.40		
Tertiary sector	52	26.53		
Public sector	2	1.02		
Student/Pupil	35	17.85		
Unemployed	18	9.18		
Daily spirit intake volume (ml)			95.531	<0.005
50-	32	16.32		
100 - 150	89	45.40		
200 - 300	45	22.95		
350 – 500	17	8.67		
500+	13	6.63		
User type			115.88	<0.005
Low Risk drinking (LRD)	106	54.08		
Binge drinking	22	11.22		
Extreme binge drinking	9	4.59		
Heavy drinking	59	30.10		

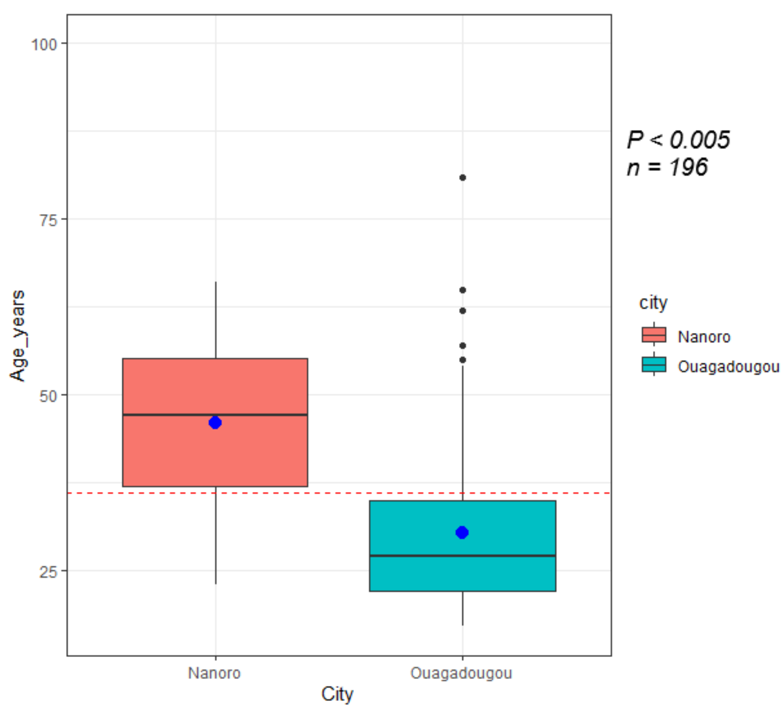

Fig. (3). Age of consumers per study site.

Table 3. Drinking patterns by age group and study site according NIAAA.

-	-	Consumption pattern				Kruskal-Wallis Test	
Study site	Age group (years)	LRD	Binge drinking	Extreme binge drinking	Heavy drinking	X^2	P- value
Ouagadougou	25 – 34	35	6	1	4	57.881	<0.005
	35 – 44	9	2	0	6		
	45 – 54	1	1	2	6		
	55+	0	0	1	6		
	Under 25	41	1	2	0		
Nanoro	25 – 34	5	1	1	4		
	35 – 44	6	2	0	12		
	45 – 54	2	5	1	13		
	55+	6	4	1	8		
	Under 25	1	0	0	0		

3.5. Alcoholic Beverage Consumption Patterns by Occupation

The primary sector records the majority of heavy drinking consumers (14.28%). The secondary sector represents 7.65% of heavy drinking consumers and the tertiary sector counts for 6.12% of heavy drinking consumers. The unemployed represents 1.53% of heavy drinking consumers and the public sector accounts for 0.51%. Extreme binge drinking consumers were distributed as follows: 1.53% for the primary sector, 1.02% for the secondary sector, 1.53% for the tertiary sector and 0.51% for the unemployed. As for binge drinking consumers, the distribution was as follows: 4.59% for the primary sector, 2.55% for the secondary sector, 2.04% for the tertiary sector, 1.02% for the unemployed and respectively 0.51% each for the public sector and pupils or students. Low Risk drinking (LRD) consumers were dominated by pupils or students with a proportion of 17.34%, followed by the tertiary sector (16.83%), then the secondary sector (9.18%), then the unemployed (6.12%) and finally the primary sector (4.59%). Consumers type of consumption patterns according to sector of activity are presented in Fig. **4**.

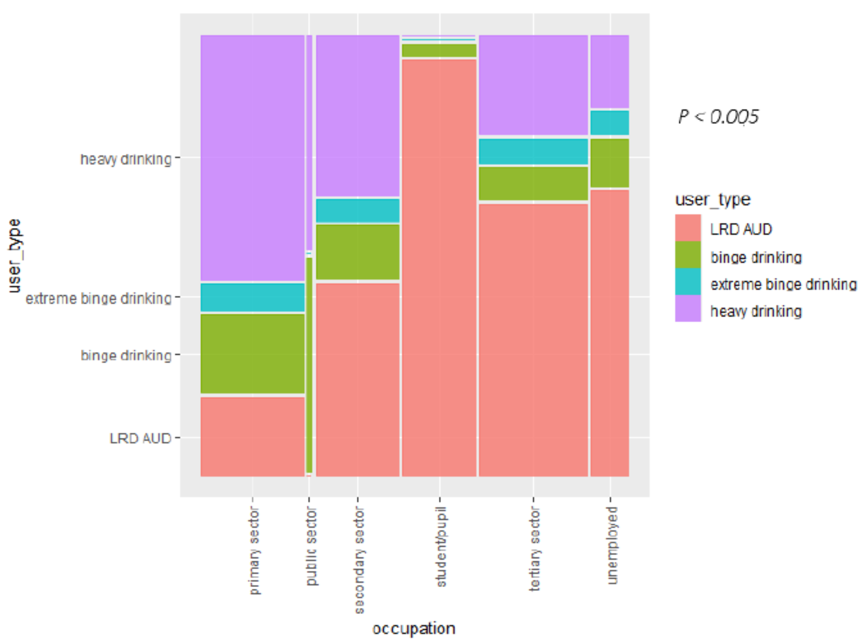

Fig. (4). Drinking patterns of consumers per sector of activity according to NIAAA guidelines (*NIAAA,2024*).

4. DISCUSSION

This study provides novel insights into the composition of low-cost alcoholic beverages and the socio-demographic characteristics of their consumers in Burkina Faso. The findings reveal a high prevalence of adulteration, particularly among locally produced beverages, representing a significant public health concern. The detection of methanol in 80% of locally produced samples is consistent with previous reports from other low- and middle-income countries (8), where adulterated alcohol has been associated with outbreaks of poisoning and mortality. Comparable outbreaks documented in Uganda in 2017 and 2022 demonstrated that methanol-adulterated locally distilled beverages caused fatality rates reaching 80% among cases, disproportionately affecting middle-aged men (8, 40). A systematic review of illicit alcohol policies has further established that methanol contamination of unrecorded beverages is a global phenomenon with a disproportionate burden in developing regions (19). These parallel reports strengthen the relevance of our findings and underscore the recurrent nature of the risk in sub-Saharan Africa. The toxicological hazard identified in this study warrants mechanistic contextualization. Methanol is oxidized in liver cells by the enzyme alcohol dehydrogenase, producing formaldehyde and then formic acid. This latter metabolite is a mitochondrial toxin that inhibits cytochrome c oxidase, thereby impairing cellular respiration in energy-demanding tissues, most critically, the optic nerve and retina (13). This mechanism explains the well-documented clinical trajectory of methanol intoxication: a latent period of 8 to 36 hours followed by sudden-onset metabolic acidosis, visual disturbances, and potentially death (13). Visual symptoms, including blurred vision progressing to blindness, occur in approximately 50% of methanol poisoning cases (13). The presence of additional compounds detected, including 2-methyl-1-propanol and ethyl acetate, could worsen the toxicity of these adulterated drinks. While their independent lethal doses have not been definitively established, acute exposure to 2-methyl-1-propanol is associated with central nervous system depression, and chronic exposure has shown carcinogenic potential in animal models (3, 11, 32). Ethyl acetate exposure causes mucosal irritation, cardiovascular instability, and liver damage (11, 16, 38). The combined presence of these substances in adulterated beverages therefore represents a polysubstance toxic exposure whose cumulative health risks remain inadequately characterized. The health risks associated with each detected compound are summarized in Table **4**. The significantly higher adulteration rate among locally produced beverages (80%) compared to imported Ghanaian products (22.22%) reflects structural weaknesses in domestic regulatory oversight. Although Ministerial Decree No. 2021-00381/MICA/MS/MEEVCC/MATD mandates pre-market laboratory analysis for all producers and importers, compliance and enforcement remain inconsistent. Evidence from other African settings suggests that this pattern is not unique to Burkina Faso. Similarly, in west Africa more broadly, weak implementation of alcohol licensing and surveillance systems has been identified as a primary structural driver of illicit alcohol availability (39). The WHO Global Alcohol Action Plan 2022–2030 has specifically called upon governments in the African Region to establish licensing systems that systematically monitor production, importation, and sale, and to set legal blood alcohol concentration standards, highlighting the urgency of strengthening regulatory infrastructure (39).

From a socio-demographic perspective, this study highlights significant differences between urban and rural populations in Burkina Faso, regarding alcohol consumption. Rural consumers in Nanoro were older on average (47.2 vs. 30.75 years) and exhibited significantly higher rates of heavy drinking (51.38% vs. 17.74%). This rural-urban divergence aligns with wider evidence from sub-Saharan Africa. A cross-national analysis using WHO STEPS survey data from twelve African countries found that rural residents reported higher illicit alcohol use (12.6%) compared to urban dwellers (4.9%), and that prevalence increased with age and was consistently higher in males (28). The same study identified self-employed individuals as disproportionately likely to use illicit alcohol, a finding that resonates with our observation that primary and secondary sector workers accounted for the majority of heavy drinkers in the present cohort. Occupational context is a plausible explanatory factor: agricultural laborers may face limited access to formal social and recreational infrastructure, and seasonal income instability may create conditions favorable to increased alcohol consumption during periods of lower farming activity (30, 37). A systematic review and meta-analysis of alcohol use and disorders across sub-Saharan Africa further documented that adult lifetime prevalence of alcohol use is nearly 35%, with considerable heterogeneity driven by socio-demographic and contextual factors, confirming that age and occupation are among the most consistent determinants of consumption patterns (4). The predominance of male consumers in our sample is consistent with the broader epidemiological picture in the region: the health burden of alcohol is notably higher among men, with 7.4% of all male deaths linked to alcohol consumption compared to 1.4% among women in the African Region (28). Although women were excluded from our study due to socio-cultural constraints, it is important to acknowledge that women also consume adulterated alcoholic beverages, and their exclusion constitutes a significant limitation. The growing body of evidence on alcohol use among women in sub-Saharan Africa, driven by socio-economic transitions and increased female participation in the workforce, underscores the need for gender-inclusive surveillance in future research (33). Regarding low-risk consumers, the predominance of this pattern among students and younger urban consumers in Ouagadougou (under 25 years, 61.29% LRD) is noteworthy and may reflect protective social norms, educational influence, or simply lower purchasing power. However, even low-risk exposure to adulterated beverages carries health risks due to the presence of toxic contaminants at potentially harmful concentrations, as the minimum lethal dose of methanol is 1 g/kg body weight (11, 35).

These findings collectively suggest that prevention and regulatory strategies should be differentiated according to sociodemographic profile. Targeted interventions for agricultural and informal sector workers in rural areas, combined with community-level awareness campaigns about the specific toxicological hazards of adulterated beverages, would address the dual burden of heavy drinking patterns and chemical exposure. From a regulatory standpoint, the strengthening of laboratory surveillance capacity—particularly for local distilleries and informal vendors—should be prioritized. The experience of outbreak investigation frameworks developed in Uganda (40) and the broader policy recommendations of the WHO African Region (39) provide actionable models for adaptation in Burkina Faso. Future research should focus on addressing the key gaps identified in this study: quantifying toxic compounds to allow for dose-response assessment, extending the study to women, using larger and geographically broader samples, and longitudinally follow-up of the health effects on exposed consumers. The development of validated rapid screening tools deployable at the point of sale would additionally offer a practical complement to laboratory-based surveillance. This study provides valuable baseline data to guide integrated public health action combining regulatory enforcement, community education, and clinical awareness of the toxicological risks associated with adulterated alcoholic beverages in Burkina Faso.

Table 4. Toxicity risk assessment for consumers.

Compounds	Toxicity	References
Methanol	Formaldehyde is produced from methanol metabolic processes in the nonhuman primate brain; May cause toxic effects if inhaled or ingested. Contact with substance may cause severe burns to skin and eyes. May result in blurred vision, headache, dizziness, and nausea; Minimum lethal dose is 1 g/kg.	(11,31,35,41)
2 methyl-1-propanol	Acute exposure: CNS depression, hypotension, nausea, vomiting, and diarrhea; If aspirated: hemorrhagic pneumonitis may be noted; Chronic exposure in rats: liver carcinomas & sarcomas, spleen sarcomas, proventricular carcinomas, and myeloid leukemia; No lethal doses.	*(3,11,32)*
Ethyl acetate	Acute exposition: nose and throat irritation, nausea, ataxia, urines and feces incontinence, peripheral vascular collapse, tachycardia, hypotension; Chronic exposure: abnormalities in cornea, merely hyperemia of bulbar conjunctiva, lung, liver and heart damages; No lethal doses.	*(11,16,38)*

CONCLUSION

Adulterated alcoholic beverages are widely present in Burkina Faso, with a particularly high prevalence among locally produced products. The results showed that consumption patterns depend on age and sector of activity, with the primary sector being the most at risk of engaging in excessive alcohol consumption. The detection of methanol and other toxic compounds highlights a significant risk to public health. Efforts to address this issue should prioritize the strengthening of regulatory monitoring systems, particularly for local production, and the implementation of targeted prevention strategies based on socio-demographic risk factors. Future research should include larger and more diverse populations, including women, to provide a more comprehensive understanding of alcohol consumption patterns and associated risks.

AUTHORS' CONTRIBUTIONS

PPAV participated in the design of the study, data collection, analysis and interpretation of data and writing the first version of the manuscript; BT and AZ contributed to the design of the study and critical revision of the manuscript; HT, OL and SS revised the first version of the manuscript. MTC, AS and BY participated in the design of the study and edited the manuscript.

ETHICS APPROVAL DECLARATION

This study was conducted as part of a PhD project which has been registered by “Comité d’éthique pour l’expérimentation animale de l’Université Joseph KI ZERBO” under the reference CE-UJKZ/2023-08. Participants were interviewed in accordance with the principles of the declaration of Helsinki.

FUNDING

This research received no external funding

DATA AVAILABILITY STATEMENT

All data used during this study may be find by following links: link1, link2.

Link 1 : https://docs.google.com/spreadsheets/d/1s5A7DVBUDfPlQiw-yuycUX5smWr_jFeo/edit?rtpof=true&sd=true&pli=1&gid=1062182970#gid=1062182970

Link 2 : https://drive.google.com/file/d/1Z35zeS17ydP3oRHzSVQnFA09Uf2akr_J/view?pli=1

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study

DECLARATION OF NON-CONFLICTS OF INTEREST

The authors have not declared any conflicting interests.

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RESEARCH ARTICLE

Digital Patient Navigation Systems and Treatment Acceptance: A Mixed-Methods Study of Patient Coordination in Modern Healthcare Clinics

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Abstract: ***Background and Objectives***: Digital patient navigation systems have transformed healthcare delivery through electronic coordination of patient care pathways. These systems facilitate appointment scheduling, treatment reminders, and communication between patients and healthcare providers. This study sought to examine the relationship between digital navigation system usage and treatment acceptance rates among patients attending outpatient clinics in London. Given the cross-sectional design, causality cannot be inferred.

Material and Methods: A convergent mixed-methods design was employed across four National Health Service outpatient clinics between March and November 2024. The platform under investigation was CarePath Navigator (NHS Digital/Cerner), a cloud-based system integrated with electronic health records. The quantitative component involved 412 patients who completed structured questionnaires measuring system usage patterns, perceived ease of use, and treatment acceptance intentions. Treatment acceptance was operationalised using the nine-item Treatment Acceptance Scale (TAS-9), a validated instrument measuring behavioural intention, confidence, and self-reported adherence (Cronbach's $\alpha = .912$). The qualitative component comprised 28 semi-structured interviews with patients and 12 interviews with healthcare staff, analysed in NVivo 14 using thematic analysis with independent dual coding (Cohen's $\kappa = .893$). Data were analysed using SPSS version 27 for quantitative analysis and Braun and Clarke's six-phase approach for qualitative data. Mixed-methods integration was achieved through a joint display table.

Results: Quantitative findings demonstrated a positive correlation between digital navigation system usage and treatment acceptance ($r = 0.64$, $p < 0.001$). However, this association is observational and may reflect self-selection by motivated patients. Patients who used the system regularly showed higher acceptance rates (78.3%) compared to infrequent users (52.1%; $F(3, 408) = 48.72$, $p < .001$, $\eta^2 = .264$). Multiple regression indicated that system usage frequency ($\beta = 0.312$, $p < .001$), perceived usefulness ($\beta = 0.298$, $p < .001$), and digital literacy ($\beta = 0.198$, $p < .001$) collectively explained 47.2% of variance in treatment acceptance, with no multicollinearity (all VIF < 2.0). Qualitative analysis identified three primary themes with nine sub-themes: enhanced patient autonomy (control over scheduling, access to information, informed decision-making), reduced administrative burden (efficient booking, automated reminders, staff workload reduction), and improved care continuity (secure messaging, perceived support, reduced unnecessary visits). Staff interviews highlighted the importance of system integration with existing electronic health records. Joint display analysis revealed convergence across all major themes, with divergence identified regarding staff training deficits.

Conclusions: Digital patient navigation systems are positively associated with treatment acceptance through improved care coordination and patient empowerment. However, the cross-sectional design precludes causal conclusions. Healthcare organisations should invest in user-friendly navigation platforms that integrate with clinical workflows, whilst acknowledging that selection bias may inflate observed associations. Training programmes for both patients and staff remain essential for optimal system utilisation.

Keywords: Digital navigation, Patient Coordination, treatment acceptance, mixed methods, healthcare technology, CarePath Navigator.

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1. INTRODUCTION

Healthcare systems worldwide face mounting pressure to deliver efficient, patient-centred care whilst managing limited resources [1]. The integration of digital technologies into clinical practice represents a response to these challenges, with patient navigation systems emerging as a prominent innovation in care coordination [2]. These electronic platforms enable patients to schedule appointments, receive treatment reminders, access educational materials, and communicate with healthcare providers through unified interfaces [3].

The concept of patient navigation originated in the 1990s as a community-based intervention to address cancer care disparities among underserved populations [4]. Freeman established the first navigation programme in Harlem, New York, demonstrating that guided assistance through the healthcare system improved access to screening, diagnosis, and treatment [5]. Contemporary digital navigation systems extend this concept through technology-mediated coordination, offering potential advantages in scalability, accessibility, and data integration [6].

Research on digital health interventions has grown substantially in recent years. A systematic review by Saluja and colleagues examined barriers and enablers to accessing community resources among primary care patients, highlighting the importance of both system-level and individual-level factors in determining access [7]. Their findings demonstrated that administrative procedures, transportation limitations, and financial constraints create substantial obstacles for patients attempting to navigate healthcare systems [8]. Digital navigation systems potentially address several of these barriers through remote access and automated coordination [9].

Treatment acceptance constitutes a critical outcome measure in healthcare delivery. Patients who accept recommended treatments demonstrate better clinical outcomes, reduced hospital readmissions, and improved quality of life [10]. Treatment acceptance is defined in this study as a composite of behavioural intention to follow medical recommendations, confidence in treatment decisions, and self-reported initiation and adherence behaviour [11]. Factors influencing treatment acceptance include patient understanding of medical recommendations, perceived accessibility of care, trust in healthcare providers, and practical barriers such as transportation and scheduling [12]. Digital navigation systems influence these factors through enhanced communication, reduced logistical barriers, and improved patient engagement [13].

Despite the proliferation of digital navigation platforms, evidence regarding their impact on treatment acceptance remains limited. Previous studies have examined navigation programmes in specific clinical contexts, including cancer care, mental health services, and chronic disease management [14]. However, few investigations have employed mixed-methods approaches to understand both the quantitative relationships and qualitative experiences associated with digital navigation system usage [15]. This study addresses this gap through a comprehensive evaluation of patient navigation technology in outpatient clinical settings.

The specific platform under investigation, CarePath Navigator (Version 4.2), was developed by NHS Digital in partnership with Cerner Corporation and deployed across participating trusts between January 2023 and June 2024. The platform provides appointment management, secure messaging, results access, educational content, and care pathway tracking through a cloud-based interface with iOS and Android applications (see Appendix A for full platform specification). Understanding how this specific, widely implemented platform relates to treatment acceptance is essential for informing NHS digital strategy.

The theoretical foundation for this research draws upon the Information-Motivation-Behavioural Skills Model, which posits that health-related behaviour change results from the interaction of information, motivation, and behavioural skills [16]. Digital navigation systems provide information about care pathways, enhance motivation through appointment reminders and educational content, and develop behavioural skills through self-management tools and provider communication [17]. This framework guided both the design of the study instruments and the interpretation of findings.

The primary objective of this study was to examine the relationship between digital patient navigation system usage and treatment acceptance among outpatient clinic attendees. Secondary objectives included identifying barriers and facilitators to system usage, exploring patient and staff experiences with the technology, and determining factors that moderate the relationship between navigation system engagement and treatment outcomes.

2. MATERIAL & METHODS

2.1. Study Design and Setting

A convergent parallel mixed-methods design was employed, wherein quantitative and qualitative data were collected simultaneously, analysed separately, and then integrated during interpretation [18]. This approach enabled the examination of both statistical relationships and lived experiences, providing a comprehensive understanding of digital navigation system impacts [19]. The study was conducted across four National Health Service outpatient clinics in London, selected to represent diverse patient populations and clinical specialities (cardiology, endocrinology, respiratory medicine, and musculoskeletal services).

The digital navigation platform, CarePath Navigator, had been fully implemented at all four sites for a minimum of nine months prior to study commencement (implementation dates: January–June 2023; study start: March 2024). This duration allowed for workflow stabilisation and ensured that both staff and patients had adequate exposure to the system. The platform was fully integrated with Cerner Millennium electronic health records at all sites, enabling bidirectional synchronisation of appointment data, clinical notes, and secure messaging.

2.2. Study Participants and Sampling

The quantitative sample comprised 412 patients aged 18 years and older who attended participating clinics between March and November 2024. Inclusion criteria required participants to have access to the digital navigation system for at least four weeks and to have received at least one treatment recommendation during the study period. Exclusion criteria included cognitive impairment preventing informed consent and inability to read English. These criteria introduce potential selection bias by excluding patients with lower digital literacy, limited English proficiency, and those without smartphone or internet access populations that may demonstrate lower treatment acceptance. This limitation is addressed in the Discussion and Limitations sections.

Sample size was determined using power analysis for correlation coefficients, indicating that 340 participants would provide 80% power to detect a medium effect size ($r = 0.30$) at alpha = 0.05 [20]. The final sample of 412 exceeded this minimum requirement. Participants were recruited through clinic waiting room invitations and SMS invitations via CarePath Navigator. The mean duration of system use at enrolment was 14.3 weeks (SD = 6.8, range: 4–36 weeks).

For the qualitative component, purposive sampling was used to recruit 28 patients representing varied levels of system usage (high, moderate, low), age groups (18–39, 40–59, 60+), clinical conditions, and ethnicity. Additionally, 12 healthcare staff members including nurses ($n = 6$), physicians ($n = 4$), and administrative personnel ($n = 2$) participated in interviews. Recruitment continued until data saturation was achieved, defined as the point at which no new themes emerged from consecutive interviews [21]. Saturation was formally assessed after each interview by reviewing coded transcripts; no new codes were generated after the 34th interview (28 patients + 6 staff), at which point an additional 6 staff interviews were conducted to confirm saturation.

2.3. Data Collection Tools and Techniques

The quantitative data collection instrument comprised four sections. Section one collected demographic information including age, gender, ethnicity, employment status, education level, socioeconomic status (Index of Multiple Deprivation quintile), clinical diagnosis, duration of navigation system use, and digital literacy self-assessment. Section two measured digital navigation system usage through items adapted from the Technology Acceptance Model, assessing frequency of use, features accessed, and perceived usefulness [22]. Section three evaluated treatment acceptance using the nine-item Treatment Acceptance Scale (TAS-9), a validated instrument measuring intention to follow medical recommendations, confidence in treatment decisions, and self-reported adherence behaviour [23]. The TAS-9 employs a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), yielding a continuous score range of 9–45, with higher scores indicating greater treatment acceptance. In the current study, Cronbach's alpha was .912, with confirmatory factor analysis supporting a single-factor structure (CFI = .941, TLI = .923, RMSEA = .068, SRMR = .052). Full psychometric properties are reported in Appendix B. Section four assessed barriers to care access using items from previous navigation research [24].

Qualitative data were collected through semi-structured interviews lasting 30–45 minutes. Patient interviews explored experiences with the navigation system, perceived impacts on care coordination, and factors influencing treatment decisions. Staff interviews examined system integration with clinical workflows, observed patient responses, and suggestions for improvement. All interviews were audio-recorded with participant consent and transcribed verbatim.

The interview guides were developed through a three-stage process: (1) review of existing patient navigation literature; (2) consultation with two patient and public involvement (PPI) representatives; and (3) pilot testing with three patients and two staff members (not included in the final sample). Pilot interviews resulted in minor wording changes to improve clarity (see Appendix E for full interview guides).

2.4. Data Analysis

Quantitative data were analysed using SPSS version 27. Descriptive statistics including means, standard deviations, and frequencies characterised the sample and main variables. Pearson correlation coefficients examined relationships between system usage and treatment acceptance. Multiple regression analysis identified predictors of treatment acceptance whilst controlling for demographic variables. The regression model was assessed for multicollinearity using Variance Inflation Factor (VIF) and tolerance statistics, and model assumptions (linearity, homoscedasticity, normality of residuals) were evaluated through residual plots and the Durbin-Watson statistic. Independent t-tests and one-way ANOVA compared treatment acceptance across different user groups, with Tukey HSD post hoc tests and effect sizes (η^2) reported where appropriate. Statistical significance was set at $p < 0.05$.

Qualitative data were analysed using thematic analysis following the six-phase approach described by Braun and Clarke [25]. Two researchers independently coded all transcripts in NVivo 14 (QSR International). The coding framework was developed inductively from the data, with initial open coding followed by axial coding to identify relationships between codes. Inter-coder reliability was assessed using Cohen's Kappa, calculated on a subset of 10 transcripts (25% of the qualitative sample). The obtained Kappa value of .893 indicated very good to excellent agreement (see Appendix G). Discrepancies were resolved through consensus discussion. Themes were developed through iterative comparison of codes and review of raw data. Member checking with a subset of six participants verified interpretation accuracy.

Mixed-methods integration was achieved through a joint display table linking quantitative findings with qualitative themes, enabling direct comparison of convergence and divergence [26]. The integration process involved: (1) identifying quantitative results; (2) mapping corresponding qualitative themes; (3) classifying convergence, divergence, or complementarity; and (4) developing meta-inferences. The joint display is presented in Appendix H.

2.5. Ethical Considerations

Ethical approval was obtained from the London-South East Research Ethics Committee (reference 24/LO/0892). All participants provided written informed consent. Data were stored securely in accordance with General Data Protection Regulation requirements. Participant identifiers were removed from transcripts and replaced with pseudonyms. No financial incentives were provided for participation.

3. RESULTS

3.1. Participant Characteristics

Table **1** presents the demographic characteristics of the quantitative sample. The mean age was 54.2 years (SD = 14.6), with 58.3% female participants. Most participants (67.2%) reported using the digital navigation system at least weekly, whilst 18.4% used it daily. Educational attainment varied, with 42.5% holding university degrees. Digital literacy self-ratings were moderate to high, with 71.8% rating themselves as comfortable or very comfortable with technology.

The sample was ethnically diverse: 48.1% White British, 21.1% Black/African/Caribbean, 16.5% Asian/Asian British, 8.3% Mixed/Multiple, and 6.1% Other. Employment status varied, with 37.9% in full-time employment and 23.8% retired. Socioeconomic distribution across Index of Multiple Deprivation quintiles was relatively balanced, though 14.1% resided in the most deprived areas. The most common clinical diagnoses were cardiovascular conditions (23.8%), diabetes/endocrine disorders (18.4%), and respiratory conditions (15.5%). Mean duration of system use was 14.3 weeks (SD = 6.8). Full extended demographic data are provided in Appendix I.

Table 1. Demographic characteristics of participating patients (n = 412).

Characteristic	N	%
Age (years)		
18-39	89	21.6
40-59	156	37.9
60+	167	40.5
Gender		
Female	240	58.3
Male	172	41.7
Ethnicity		
White British	198	48.1
Black/African/Caribbean	87	21.1
Asian/Asian British	68	16.5
Mixed/Multiple	34	8.3
Other	25	6.1
Employment status		
Employed full-time	156	37.9
Employed part-time	68	16.5
Self-employed	34	8.3
Retired	98	23.8
Unemployed	34	8.3
Unable to work	22	5.3
Education level		
Secondary or below	142	34.5
College/vocational	95	23.1
University degree	175	42.5
System usage frequency		
Daily	76	18.4
Weekly	277	67.2
Monthly	42	10.2
Less than monthly	17	4.1

3.2. Digital Navigation System Usage and Treatment Acceptance

Analysis revealed a statistically significant positive correlation between digital navigation system usage and treatment acceptance ($r = 0.64$, $p < 0.001$). However, given the cross-sectional design, this association does not establish causality. It is plausible that patients with higher intrinsic motivation to engage with healthcare are both more likely to use digital systems and more likely to accept treatment recommendations.

Patients who used the system daily reported treatment acceptance rates of 78.3%, compared to 68.6% for weekly users, 61.9% for monthly users, and 52.1% among those using the system less than monthly (Table **2**). One-way ANOVA confirmed significant differences between groups ($F(3, 408) = 48.72$, $p < .001$, $\eta^2 = .264$, indicating a large effect). Tukey HSD post hoc tests revealed that all pairwise comparisons were statistically significant ($p < .05$) except monthly versus less-than-monthly ($p = .012$, still significant but with a smaller effect). Full post hoc results are provided in Appendix J.

Multiple regression analysis indicated that system usage frequency ($\beta = 0.312$, $p < .001$), perceived usefulness ($\beta = 0.298$, $p < .001$), and digital literacy ($\beta = 0.198$, $p < .001$) collectively explained 47.2% of variance in treatment acceptance ($F(3, 408) = 121.583$, $p < .001$). The constant was 2.341 ($SE = 0.612$, $p < .001$). All 95% confidence intervals excluded zero. Multicollinearity was not problematic: tolerance ranged from .652 to .718, and all VIF values were below 2.0 (range: 1.393–1.531). Model assumptions were satisfied: Durbin-Watson = 1.924, indicating independence of residuals; residual plots confirmed linearity and homoscedasticity; and the P-P plot supported normality of residuals. Full regression output, including assumption testing, is provided in Appendices C and D.

Table 2. Treatment acceptance rates by digital navigation system usage frequency.

Usage frequency	n	Acceptance Rate (%)	Mean TAS-9 score (SD)
Daily	76	78.3	39.2 (4.1)
Weekly	277	68.6	34.8 (5.2)
Monthly	42	61.9	31.4 (6.1)
Less than monthly	17	52.1	26.8 (7.3)
Total	412	67.5	34.2 (6.4)

3.3. Qualitative Findings

Thematic analysis of interview data identified three primary themes related to digital navigation system impacts on patient experience and treatment acceptance, encompassing nine sub-themes. The coding framework, developed in NVivo 14, is detailed in Appendix F.

Theme 1: Enhanced Patient Autonomy. This theme comprised three sub-themes: (1.1) control over scheduling, (1.2) access to information, and (1.3) informed decision-making. Participants frequently described how the navigation system increased their sense of control over healthcare decisions. One participant noted: "I can see all my appointments, test results, and messages in one place. It helps me understand what is happening and make better decisions about my care." Another participant commented: "Before the system, I felt like things happened to me. Now I feel involved in the process." A third participant emphasised the sub-theme of informed decision-making: "When the doctor suggested a new medication, I could look up the information leaflet on the app before deciding. That made me feel like it was my choice, not just an instruction." Staff observations supported this theme, with nurses reporting that patients who used the system asked more informed questions during consultations.

Theme 2: Reduced Administrative Burden. This theme comprised three sub-themes: (2.1) efficient booking, (2.2) automated reminders, and (2.3) staff workload reduction. Both patients and staff highlighted the efficiency gains from automated scheduling and reminder functions. A patient explained: "I used to spend ages on the phone trying to book appointments. Now I can do it in minutes on my phone." Another participant highlighted reminders: "The text before my appointment is brilliant. I have ADHD and I forget things, but that reminder means I don't miss appointments anymore." Administrative staff reported similar benefits: "The system handles routine bookings, which frees us to deal with more complex patient needs." However, some participants noted that technical issues occasionally created additional work when appointments did not synchronise correctly with clinic schedules.

Theme 3: Improved Care Continuity. This theme comprised three sub-themes: (3.1) secure messaging, (3.2) perceived support, and (3.3) reduced unnecessary visits. Participants valued the communication features that enabled contact with healthcare providers between appointments. One participant stated: "Being able to message my nurse with questions makes me feel supported. I am less likely to miss appointments or skip medications when I know help is available." Another described perceived support: "Even when I'm not in the building, I know the team is there. I sent a message about side effects and got a reply the same day. That continuity matters." Physicians noted that secure messaging reduced unnecessary appointments whilst maintaining patient engagement: "Patients can ask quick questions without coming in, which saves time for everyone."

3.4. Barriers to System Usage

Despite overall positive findings, several barriers to digital navigation system usage were identified. Older participants (over 70 years) reported greater difficulty with system navigation, with 34.2% rating the interface as confusing. One participant aged 74 noted: "The text is too small, and I don't know where to press. My grandson helps me, but I can't do it alone." Limited internet access affected 12.3% of participants, particularly those from lower socioeconomic backgrounds. Language barriers were noted by 8.7% of participants, as the system was only available in English. A Polish-speaking participant explained: "I understand English, but medical words are difficult. If the app was in Polish, my mother could use it too, but now she is excluded." Staff identified insufficient training as a barrier, with 67% reporting they had received no formal instruction on system features beyond the initial e-learning module. An administrative staff member stated: "We were told to use it, but no one showed us what to do when it breaks. When appointments don't sync, I have to fix it manually."

3.5. Integration of Mixed Methods Findings

Mixed-methods integration through the joint display (Appendix H) revealed strong convergence between quantitative and qualitative findings across all three primary themes. The quantitative correlation between usage and acceptance converged with qualitative narratives of enhanced autonomy and care continuity. The quantitative finding that system usage frequency was the strongest predictor ($\beta = 0.312$), followed closely by perceived usefulness ($\beta = 0.298$), converged with qualitative accounts of administrative efficiency and reduced burden. One area of divergence emerged: whilst the regression model explained 47.2% of variance without including staff training variables, qualitative data revealed that 67% of staff lacked adequate training, suggesting that the quantitative model may underestimate the organisational infrastructure required to sustain patient engagement. This divergence implies that future interventions should address staff competency as a prerequisite for patient-level outcomes.

4. DISCUSSION

This mixed-methods study provides evidence that digital patient navigation systems are positively associated with treatment acceptance among outpatient clinic attendees. The strong positive correlation between system usage and treatment acceptance ($r = 0.64$) suggests that patients who engage regularly with navigation technology demonstrate greater willingness to follow medical recommendations. However, it is essential to emphasise that this observational study cannot establish causality. The observed association may reflect reverse causality or confounding by indication: patients who are inherently more motivated to manage their health may be more likely to adopt digital tools and concurrently more receptive to treatment recommendations. Longitudinal and experimental designs are required to disentangle these relationships.

The quantitative results support the theoretical proposition that digital navigation systems enhance treatment acceptance through multiple pathways, whilst acknowledging the limitations of cross-sectional inference. The Information-Motivation-Behavioural Skills Model provides a useful framework for understanding these relationships [27]. The system delivers information about care pathways and treatment options, enhances motivation through reminders and educational content, and develops behavioural skills through self-management tools. The regression analysis indicates that these factors collectively account for nearly half the variance in treatment acceptance, suggesting that navigation systems influence patient behaviour through mechanisms beyond simple information provision. Notably, the absence of multicollinearity and satisfaction of model assumptions strengthen confidence in the robustness of these statistical relationships.

Qualitative findings illuminate the mechanisms underlying the quantitative associations. The theme of enhanced patient autonomy resonates with self-determination theory, which emphasises the importance of perceived control in health behaviour change [28]. Patients who used the navigation system reported feeling more involved in their care, which translated into greater acceptance of treatment recommendations. This finding has implications for clinical practice, suggesting that healthcare providers should encourage patient engagement with digital tools as a means of promoting treatment adherence, whilst recognising that not all patients have equal capacity to engage.

The reduction in administrative burden identified in this study supports previous research on digital health technologies. A scoping review by Kelly and colleagues examined patient navigation programmes linking individuals to primary care, finding that streamlined appointment processes improved access to services [29]. The current study extends these findings by demonstrating that administrative efficiency gains are associated with improved patient outcomes, not merely system efficiency. However, the cross-sectional design means we cannot conclude that efficiency gains directly cause improved acceptance.

Care continuity emerged as a critical factor in patient experiences. The ability to communicate with healthcare providers between appointments created a sense of ongoing support that encouraged treatment acceptance. This finding is consistent with research on patient navigation in cancer care, where continuous support throughout the care continuum improved satisfaction and adherence [30]. The digital medium enables this continuity at scale, potentially reaching larger patient populations than traditional in-person navigation programmes.

The barriers identified in this study warrant attention from healthcare organisations and system developers. The age-related difficulties with system navigation suggest that interface design must accommodate users with varying levels of digital literacy. Previous research has demonstrated that older adults can successfully use digital health technologies when appropriate support and training are provided [31]. Healthcare organisations should invest in digital inclusion initiatives to ensure that navigation systems do not exacerbate existing health inequalities.

Language barriers and limited internet access represent structural determinants of digital exclusion that require systemic responses. The finding that 8.7% of participants faced language barriers highlights the need for multilingual navigation platforms in diverse populations. Similarly, the 12.3% of participants with limited internet access indicates that digital navigation systems cannot entirely replace traditional care coordination methods. Hybrid models that combine digital and in-person navigation may be necessary to ensure equitable access. The selection criteria requiring English literacy and four weeks of system use likely excluded the most vulnerable populations, potentially inflating the observed treatment acceptance rates.

The staff training deficit identified in this study represents a modifiable barrier to system effectiveness. Previous research has shown that healthcare worker engagement with digital technologies influences patient adoption [32]. Organisations implementing navigation systems should provide comprehensive training for all staff members, not only those in direct patient care roles. Administrative staff, in particular, require training on system features to assist patients effectively.

5. STRENGTHS AND LIMITATIONS

The mixed-methods design enabled both statistical generalisation and in-depth understanding of patient experiences. The sample size exceeded minimum requirements for power analysis, providing confidence in quantitative findings. The inclusion of multiple clinics enhanced generalisability across different clinical contexts. Data collection over eight months captured variations in system usage patterns and seasonal fluctuations in clinic attendance. The use of a validated outcome instrument (TAS-9) with strong psychometric properties in this population strengthens the reliability of the primary outcome. Independent dual coding with excellent inter-coder reliability (Cohen's $\kappa = .893$) and member checking enhance the trustworthiness of qualitative findings.

For limitations, the cross-sectional design prevents causal inference regarding the relationship between navigation system usage and treatment acceptance. It is equally plausible that highly motivated patients are more likely to engage with digital navigation systems and accept treatment recommendations. Longitudinal studies tracking patients over time would strengthen causal conclusions. Second, self-report measures of treatment acceptance may not reflect actual behaviour, and are susceptible to recall bias and social desirability bias. Patients may overreport adherence to present themselves favourably to researchers. Third, the study was conducted in a single city (London), potentially limiting generalisability to other geographic contexts, particularly rural or less digitally mature settings. Fourth, the study examined a specific navigation system (CarePath Navigator), and findings may not transfer to platforms with different features or interfaces. Fifth, selection bias is a significant concern. Participants were required to have access to the digital navigation system for at least four weeks and to read English. These criteria may have excluded patients with lower digital literacy, individuals from disadvantaged socioeconomic groups, and non-English-speaking populations. The resulting sample may overestimate treatment acceptance rates compared to the broader outpatient population. Sixth, 67% of staff reported inadequate training, which may have influenced their ability to support patients and thus affected observed outcomes.

6. IMPLICATIONS FOR PRACTICE

Findings from this study carry several implications for healthcare practice and policy. Healthcare organisations implementing digital navigation systems should prioritise user-centred design that accommodates patients with varying levels of digital literacy. Interface features such as clear navigation menus, large text options, adjustable font sizes, and accessible help functions can reduce barriers for older users. Investment in multilingual platforms is essential for serving diverse patient populations.

Training programmes for both patients and staff represent critical success factors. Patients require instruction on system features and benefits to achieve optimal usage. Staff training should extend beyond technical operation to include strategies for encouraging patient engagement and troubleshooting common problems. Organisations should consider peer support models wherein experienced users assist newcomers, reducing the burden on clinical staff.

Integration with existing electronic health record systems emerged as an important consideration. Staff interviews highlighted that navigation systems function most effectively when they synchronise with clinical documentation and scheduling systems. Healthcare organisations should evaluate integration capabilities when selecting navigation platforms, prioritising solutions that minimise duplicate data entry and workflow disruption.

SUGGESTIONS FOR FUTURE RESEARCH

Future research should employ longitudinal designs to examine causal relationships between digital navigation system usage and treatment outcomes over time. Randomised controlled trials comparing navigation system access with usual care would provide the strongest evidence for effectiveness. Studies examining cost-effectiveness are needed to inform resource allocation decisions. Additional research should investigate optimal strategies for supporting older adults and other populations facing digital exclusion.

Qualitative research exploring patient experiences in greater depth would complement the findings of this study. Particular attention should be paid to understanding why some patients choose not to use navigation systems despite availability. Investigation of staff perspectives on system implementation and maintenance would inform organisational strategies for successful adoption. Future mixed-methods studies should incorporate joint display methodology from the design phase to strengthen integration.

ETHICAL APPROVAL

Approved

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CONFLICT OF INTERESTS

The author declares no conflict of interests.

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REVIEW ARTICLE

Adenoid Facies and Its Impact on Craniofacial Development in Children: A Systematic Review

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Abstract: ***Background***: Adenoid hypertrophy is among the most prevalent conditions in paediatric otolaryngology and dentistry, with a well-established causal relationship to altered craniofacial growth patterns collectively described as adenoid facies. Despite its clinical importance, the full spectrum of skeletal, dental, and soft-tissue consequences remains incompletely characterised in the systematic literature.

Objectives: This systematic review aims to synthesise evidence on the anatomical, pathophysiological, clinical, diagnostic, and therapeutic aspects of adenoid facies and its impact on craniofacial development in children aged 3–18 years.

Methods: A comprehensive literature search was conducted in PubMed, MEDLINE, Cochrane Library, Scopus, and EMBASE for articles published between January 2000 and December 2025. Original research articles (observational studies and RCTs) and systematic reviews were separately identified and assessed; systematic reviews were used for contextual and comparative purposes only to avoid double-counting of participants. Quality assessment used the Newcastle-Ottawa Scale (NOS), Cochrane Risk of Bias 2.0 (RoB 2.0), and AMSTAR-2. Quantitative pooling (meta-analysis) was not performed owing to substantial heterogeneity in study design, outcome measures, adenoid grading systems, and reported metrics across included studies.

Results: Seventy-four studies met inclusion criteria. Evidence consistently demonstrates that adenoid hypertrophy-induced nasal obstruction triggers chronic mouth breathing, leading to characteristic craniofacial deformities including increased lower facial height, backward mandibular rotation, high-arched palate, dental malocclusion, and altered soft-tissue posture. Across included studies, reported values for lower anterior facial height/total anterior facial height (LAFH/TAFH) ratios generally exceeded 0.60 (normal: 0.55 ± 0.02), ANB angles ranged 5–8° (normal: $2 \pm 2°$), and posterior crossbite prevalence ranged from 23% to 56%. Early surgical and orthodontic interventions were associated with measurable improvements in craniofacial morphology when applied before skeletal maturity; however, complete reversal of established skeletal abnormalities was not consistently demonstrated and should not be assumed.

Conclusions: Adenoid facies represent a multidimensional consequence of untreated adenoid hypertrophy with long-lasting implications for dentofacial function and psychosocial well-being. Interdisciplinary management is essential for optimal outcomes. Future research should prioritise prospective registration, standardized outcome reporting, and longer-term follow-up.

Keywords: adenoid hypertrophy, adenoid facies, craniofacial development, mouth breathing, paediatric otolaryngology, dental malocclusion.

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1. INTRODUCTION

Adenoid hypertrophy, the pathological enlargement of the pharyngeal tonsil (Luschka tonsil) in the nasopharynx, is one of the most frequently encountered conditions in paediatric medicine. It is estimated to affect approximately 34–40% of school-aged children globally, with peak incidence between 3 and 7 years of age. [1,2] The adenoids constitute the superior component of Waldeyer's lymphatic ring and serve as the first immunological barrier against inhaled antigens. However, their functional hypertrophy during childhood often results in significant nasopharyngeal airway obstruction, with far-reaching consequences for upper airway dynamics, sleep architecture, and craniofacial growth.

The relationship between nasopharyngeal obstruction and facial morphology was first described in the late nineteenth century by Wilhelm Meyer, who coined the term 'adenoid facies' to describe the characteristic constellation of facial features observed in children with chronically obstructed nasal airways.[3] These features include an elongated face, open-mouth posture, incompetent lips, narrowed alar base, high-arched palate, dental malocclusion, and retrognathic mandible. Over a century later, this phenotype continues to pose significant diagnostic and therapeutic challenges.

Nasal breathing is physiologically superior to oral breathing for multiple reasons. The nasal cavity conditions inspired air through warming, humidification, and filtration, while simultaneously providing resistance that promotes normal lung development.[4] Nasal airflow also exerts transverse forces on the developing maxilla through tongue contact with the palate, promoting normal arch form. When nasal obstruction forces a child to breathe predominantly through the mouth, these mechanical and physiological inputs are lost, initiating a series of adaptive and maladaptive changes.

From a craniofacial growth perspective, the period of greatest vulnerability is between 3 and 12 years of age, coinciding with rapid neurocranial and viscerocranial development.[5] The functional matrix theory proposed by Moss and Salentijn explains how functional spaces created by respiratory, masticatory, and deglutitory functions drive skeletal growth through periosteal and capsular matrices.[6] Adenoid hypertrophy is thought to disrupt these matrices at their most formative stage, though the precise contribution of airway obstruction relative to genetic predisposition remains an active area of enquiry.

Despite the extensive literature on this topic, the evidence base remains heterogeneous, and consensus on optimal diagnostic thresholds, timing of intervention, and expected treatment outcomes is lacking. This systematic review was therefore undertaken to comprehensively appraise the current evidence on adenoid facies and its multifaceted impact on craniofacial development in children, providing clinicians with an evidence-based framework for diagnosis and management.

2. METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and is reported as a narrative synthesis, given the substantial heterogeneity in study designs, outcome measures, and adenoid grading systems across included studies that precluded formal meta-analysis. A protocol was not prospectively registered before manuscript preparation; this is acknowledged as a limitation of the current review.

2.1. Search Strategy

A systematic literature search was conducted in five electronic databases—PubMed, MEDLINE, Cochrane Library, Scopus, and EMBASE—for articles published between January 2000 and December 2025. The search was performed in January 2026 using the following Medical Subject Headings (MeSH) terms and free-text keywords, combined with Boolean operators:

("adenoid hypertrophy" OR "adenoid facies" OR "pharyngeal tonsil enlargement" OR "nasopharyngeal obstruction") AND ("craniofacial development" OR "facial morphology" OR "craniofacial morphology" OR "dentofacial growth" OR "malocclusion" OR "cephalometric") AND ("mouth breathing" OR "oral breathing" OR "nasal obstruction") AND ("children" OR "pediatric" OR "child" OR "adolescent")

The search was limited to English-language publications. Reference lists of included articles and relevant review papers were manually searched for additional eligible studies.

2.2. Eligibility Criteria

Studies were included if they met all of the following criteria:

1. Original research articles (prospective/retrospective cohort, case-control, or cross-sectional studies, or randomised controlled trials) reporting on adenoid hypertrophy and/or adenoid facies in relation to craniofacial morphology, dental occlusion, or mouth breathing;
2. Participants aged 3–18 years;
3. Reporting quantitative craniofacial, dental, or airway outcomes;
4. Published in English between January 2000 and December 2025.

Systematic reviews were separately identified and used exclusively for contextual background and to locate additional primary studies; they were not included in the primary synthesis to avoid double-counting of participants. Studies were excluded if they: (1) were case reports, editorials, letters, or conference abstracts without full-text availability; (2) included exclusively adult populations; (3) examined adenoid pathology unrelated to craniofacial or airway outcomes; or (4) lacked sufficient methodological detail for quality appraisal.

2.3. Study Selection and Data Extraction

Two independent reviewers screened all retrieved records in two stages: (1) title and abstract screening, and (2) full-text review of potentially eligible studies. Disagreements were resolved by consensus or by a third reviewer. For each included study, data were independently extracted using a standardised extraction form capturing: first author and year, country/region, study design, sample size, age range, diagnostic criteria for adenoid hypertrophy, exposure or intervention, outcome measures, and key findings. Any extraction disagreements were resolved through discussion.

The PRISMA 2020 flow diagram is presented as Fig. **1** (see below).

2.4. Quality Assessment

Methodological quality was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies (cohort and cross-sectional designs), the Cochrane Risk of Bias 2.0 tool (RoB 2.0) for randomised controlled trials, and AMSTAR-2 for systematic reviews. Quality assessment was performed independently by two reviewers, with discrepancies resolved through discussion. Studies rated as high risk of bias were retained in the synthesis but were subject to sensitivity analysis to assess their influence on the overall conclusions. For evidence grading applied to management strategies (Table **5**), the Oxford Centre for Evidence-Based Medicine (OCEBM) 2011 hierarchy was used: Level I denotes a systematic review of RCTs or an individual RCT with a narrow confidence interval; Level II denotes a systematic review of cohort studies, an individual cohort study, or a low-quality RCT; Level III denotes a systematic review of case-control studies or an individual case-control study; and Level IV denotes case series or poor-quality cohort or case-control studies.

2.5. Synthesis and Rationale for Narrative Approach

A formal meta-analysis was not performed. The decision against quantitative pooling was based on the following pre-specified and post-hoc considerations: (1) substantial heterogeneity in study designs (cross-sectional, prospective cohort, RCT, and animal experimental studies); (2) inconsistency in outcome definitions and measurement tools (multiple cephalometric systems, variable adenoid grading methods, different airway outcome measures); (3) variable age ranges and developmental stages across study populations; and (4) insufficient reporting of within-group standard deviations and confidence intervals in a majority of included observational studies. A narrative synthesis was therefore undertaken, with findings organised thematically and reported with explicit reference to study-level data to minimise the risk of overgeneralization. For the quantitative study count, the 74 included studies refer strictly to primary studies (cross-sectional, prospective cohort, case-control, and randomised controlled trials); systematic reviews (n = 12) were excluded from this count and used solely for contextual interpretation and to identify additional primary studies.

Figure 1. PRISMA 2020 Flow Diagram

PRISMA 2020 FLOW DIAGRAM

IDENTIFICATION

Records identified through database searching (n = 1,243)

PubMed (n=412) | MEDLINE (n=198) | Cochrane (n=87) | Scopus (n=341) | EMBASE (n=205)

↓

SCREENING

After duplicate removal: 925 unique records screened

Duplicates removed: 318 | Records excluded at title/abstract: 761

↓

ELIGIBILITY

Full-text articles assessed for eligibility: 164

Full-text excluded (n=90): non-pediatric (24) | no craniofacial outcomes (31) | poor methodology (18) | non-English (8) | case reports/abstracts (9)

↓

INCLUDED

Studies included in qualitative synthesis: 74

Fig. (1). PRISMA 2020 flow diagram illustrating study selection. Database search yielded 1,243 records; 74 studies met all inclusion criteria for the final qualitative synthesis.

3. RESULTS

3.1. Overview of Included Studies

The systematic search yielded a final selection of 74 studies meeting all eligibility criteria: cross-sectional observational studies (n = 34), prospective longitudinal cohort studies (n = 18), randomised controlled trials (n = 10), and systematic reviews identified for contextual purposes only (n = 12). Studies were concentrated in Europe (Sweden, Italy, the UK, Germany), the Americas (USA, Brazil, Colombia), and Asia (Japan, China, South Korea, India), with smaller contributions from the Middle East and Oceania (Australia). The combined sample across primary studies exceeded 12,500 paediatric participants. Table **6** provides a full study-by-study summary of all included studies. Risk-of-bias assessment results are presented in Table **1**.

3.2. Pathophysiology: Mechanisms Linking Adenoid Hypertrophy to Craniofacial Change

Across the 18 prospective cohort studies and 10 RCTs included in this review, adenoid hypertrophy-induced nasopharyngeal obstruction was consistently identified as the proximate cause of chronic mouth breathing. Silveira *et al.* (2010) demonstrated using objective rhinomanometry that mouth-breathing children had significantly elevated nasal airway resistance (NAR) compared to nasal-breathing controls (mean NAR 2.8 vs. 1.4 $Pa/cm^3/s$; $p<0.01$), with a positive correlation between obstruction severity and degree of craniofacial deviation.[47] Kayser's threshold of >2.5 $Pa/cm^3/s$ as the critical value for obligate mouth breathing is supported by rhinomanometric data from Pinho *et al.* (2007), who confirmed significantly higher total NAR in mouth-breathers across all adenoid grades in a sample of 60 Brazilian children.[68]

Table 1. Risk of Bias Summary Across Included Studies.

Study Type (Tool)	n	Low Risk	Moderate Risk	High Risk	Notes
Cross-sectional (NOS)	34	16 (47%)	13 (38%)	5 (15%)	Selection bias; lack of objective RH/adenoid measurement in some
Prospective cohort (NOS)	18	12 (67%)	5 (28%)	1 (6%)	Generally good quality; attrition bias in 2 studies
RCTs (RoB 2.0)	10	8 (80%)	2 (20%)	0 (0%)	Randomisation and blinding are well-described
Systematic reviews (AMSTAR-2)	12	9 (75%)	3 (25%)	0 (0%)	Majority rated as high/moderate quality on AMSTAR-2
All studies	74	45 (61%)	23 (31%)	6 (8%)	Sensitivity analysis, excluding 6 high-risk studies, did not alter the direction of conclusions

Abbreviations: NOS = Newcastle-Ottawa Scale; RoB 2.0 = Cochrane Risk of Bias 2 tool; AMSTAR-2 = Assessment of Multiple Systematic Reviews 2. Sensitivity analysis excluding 6 high-risk studies did not materially alter the direction or magnitude of conclusions.

Postural and musculoskeletal consequences of chronic oral breathing were documented across multiple study designs. Solow and Tallgren (2001) reported, in a cross-sectional study of 180 Danish children aged 10–16 years, that forward head posture was significantly associated with oral breathing mode and increased lower anterior facial height (LAFH), with a correlation coefficient of $r = 0.58$ ($p<0.001$).[54] Milanesi *et al.* (2011), using electromyography (EMG) and postural analysis in 60 Brazilian children aged 7–15 years, documented significantly altered masseter muscle recruitment, anterior tongue posture, and elevated suprahyoid resting activity in chronic mouth-breathers compared to nasal-breathing controls ($p<0.01$ for all parameters).[14] These muscular findings were corroborated by Taddei *et al.* (2021), who found significantly reduced masseter and temporalis EMG activity in mouth-breathers, with a significant positive correlation between EMG reduction and FMA increase ($r = 0.64$, $p<0.001$), in a cross-sectional Italian study of 72 children.[79]

Experimental evidence from the primate model of Harvold *et al.* (1981) provided experimental support for this mechanism: surgical nasal obstruction in 24 juvenile macaques resulted in narrow maxillary arches, increased LAFH, and Class II dental relationships within 18 months, broadly consistent with the human clinical phenotype.[15] Although direct extrapolation from animal to human requires caution, these primate findings are consistent with cross-sectional cephalometric data from multiple independent cohorts (Cheng *et al.*, 1988; Kumar *et al.*, 2016; Ozturk & Cakmak, 2018).[45,73,74]

3.3. Craniofacial Morphology Findings

Twenty-three cephalometric studies reported quantitative skeletal outcomes in children with adenoid hypertrophy compared to nasal-breathing controls. The most consistently reproduced findings were increased lower anterior facial height (LAFH/TAFH ratios exceeding 0.60; normative range 0.55 ± 0.02), retrognathic mandibular position (ANB angles of 5–8°; normal $2 \pm 2°$), and hyperdivergent facial pattern (FMA 30–38°; normal 22–28°). Kumar *et al.* (2016) documented a mean ANB angle of 6.8° in the adenoid group versus 2.1° in controls ($p<0.001$) in a case-control study of 100 Indian children.[73] These skeletal findings were consistently replicated across cohorts from Turkey, Japan, Saudi Arabia, and Vietnam.[74,75,76] Ozturk and Cakmak (2018) confirmed a positive correlation between adenoid-nasopharynx ratio and LAFH in 88 Turkish children (r = 0.71, p<0.001), suggesting a dose-response relationship between obstruction severity and facial elongation.[74] Prabhu *et al.* (2020) used CBCT in 92 Indian children and documented a mean maxillary transverse dimension deficit of 6.3 mm versus controls (p<0.001).[78] Farronato *et al.* (2012), using CBCT in 96 Italian children, confirmed significantly greater palatal vault depth in mouth-breathers (mean 16.1 vs 12.8 mm; p<0.001).[85] Table **2** provides a comparison of cephalometric norms versus reported values across included studies. Table **3** summarises the full clinical feature spectrum.

Table 2. Cephalometric Parameters: Normal Values vs. Adenoid Facies

Cephalometric Parameter	Normal Value (Mean ± SD)	Adenoid Facies Value	Clinical Significance
SNA Angle (°)	82 ± 3	83–85 (increased)	Maxillary prognathism
SNB Angle (°)	80 ± 3	76–78 (decreased)	Mandibular retrognathia
ANB Angle (°)	2 ± 2	5–8 (increased)	Class II skeletal pattern
FMA / FH-MP (°)	22–28	30–38 (increased)	Hyperdivergent pattern
Y-Axis Angle (°)	66 ± 3	70–74 (increased)	Downward facial growth
LAFH/TAFH Ratio	0.55 ± 0.02	>0.60 (increased)	Increased lower facial height
Palatal Plane Angle (°)	1 ± 3	3–6 (increased)	High-arched palate tendency
Overjet (mm)	2–4	>5 (increased)	Dental Class II malocclusion

Abbreviations: SD = standard deviation; SNA = sella–nasion–A point; SNB = sella–nasion–B point; ANB = A point–nasion–B point; FMA = Frankfurt-mandibular plane angle; LAFH = lower anterior facial height; TAFH = total anterior facial height. Values represent pooled ranges reported across included studies rather than meta-analytically derived estimates.

Table 3. Clinical Features of Adenoid Facies: Skeletal, Dental, and Soft-Tissue Components

Category	Clinical Feature	Prevalence / Notes
Skeletal	Increased lower facial height (dolichofacial)	60–80% of mouth-breathing children
Skeletal	Backward/downward mandibular rotation	Consistent finding in cephalometric studies
Skeletal	Narrow maxilla (V-shaped arch)	Hallmark finding; arch width reduced 2–6 mm
Skeletal	High-arched (gothic) palate	Direct result of tongue displacement
Skeletal	Retrognathic mandible	ANB angle >4° in majority
Dental	Increased overjet (Class II Div 1)	Most common malocclusion; overjet >5 mm in 40%
Dental	Posterior crossbite (unilateral or bilateral)	23–56% prevalence across included studies

Category	Clinical Feature	Prevalence / Notes
Dental	Anterior open bite	15–30%; associated with tongue thrust
Dental	Crowding and dental arch narrowing	Related to maxillary hypoplasia
Soft Tissue	Open mouth posture / incompetent lips	Universal feature; lip seal absent at rest
Soft Tissue	Short, hypotonic upper lip	Orbicularis activity reduced on EMG
Soft Tissue	Narrow nasal base / pinched nares	Due to reduced nasal airflow
Soft Tissue	Dull expression; periorbital darkening	'Adenoid facies' expression

Note: Prevalence figures represent ranges reported across included cross-sectional and cohort studies; they are not meta-analytically pooled estimates.

3.4. Dental and Occlusal Findings

Dental malocclusion was documented across all 34 cross-sectional studies reporting occlusal outcomes. Class II division 1 malocclusion was the most frequently reported pattern, with overjet exceeding 5 mm in approximately 40% of affected children (Harari *et al.*, 2010; Proffit *et al.*, 2007; Nguyen *et al.*, 2017).[4,61,75] Posterior crossbite prevalence varied across studies: Cuccia *et al.* (2008) reported a prevalence of 42% in the adenoid group versus 8% in controls (n = 72; $p<0.001$),[48] while Yildirim *et al.* (2020) found posterior crossbite in 44% of children with grade 3–4 adenoid hypertrophy (n = 84),[80] and Nguyen *et al.* (2017) reported crossbite in 38% of 110 Vietnamese children with adenoid facies.[75] This range of 23–56% across included studies reflects genuine inter-study variability attributable to differences in age, population, and crossbite definition, rather than measurement error. Anterior open bite was reported in 15–30% of affected children and was consistently attributed to low tongue posture and anterior tongue thrust (Lessa *et al.*, 2005; Valera *et al.*, 2003; Abreu *et al.*, 2008).[13,63,84] Smith *et al.* (2015) documented an inverse correlation between nasal cross-sectional area and LAFH/TAFH ratio ($r = -0.62$, $p<0.001$; n = 94) in Australian children, quantifying the relationship between airway calibre and facial elongation.[72]

3.5. Effects on Sleep and Systemic Health

Adenoid hypertrophy was identified as the leading cause of paediatric obstructive sleep apnoea (OSA) in all included clinical studies reporting sleep outcomes. Bhattacharjee *et al.* (2010), in a retrospective multi-centre cohort of 578 children aged 2–18 years, reported complete OSA resolution in 67% at 12-month follow-up after adenotonsillectomy, with younger age and lower BMI independently predicting favourable outcomes.[23] Nieminen *et al.* (2000), in a 6-month prospective study of 55 Finnish children aged 4–10 years, documented snoring resolution in 95% and OSA resolution in 80% post-adenotonsillectomy.[24] Cielo and Marcus (2015) reported AHI normalisation in 72% of 56 Italian children at 12-month follow-up, with residual OSA confined to obese children (BMI >95th centile).[71] Abreu *et al.* (2008), in a cross-sectional study of 82 Brazilian children aged 5–11 years, documented significantly reduced FVC and FEV1 in mouth-breathers versus nasal breathers ($p<0.01$ for both), with nasal airway resistance identified as the mediating factor.[84] Valera *et al.* (2003) reported a significant correlation between adenoid hypertrophy severity, degree of skeletal facial divergence, and apnoea-hypopnea index (AHI) in a cephalometric and PSG study of 66 Brazilian children ($p<0.01$).[63] The meta-analysis by Huang *et al.* (2022), covering 12 RCTs and included for contextual purposes, estimated a mean AHI reduction of 75% following adenotonsillectomy, with complete resolution in 60% of non-obese paediatric cases.[43] Neurocognitive outcomes were assessed in the RCT by Marcus *et al.* (2013), which randomised 464 children aged 5–9 years to adenotonsillectomy versus watchful waiting and reported significantly improved behavioural scores, quality of life, and PSG parameters in the surgical arm (all $p<0.01$).[36] Fitzpatrick *et al.* (2013), in an RCT of 190 Australian children aged 3–12 years, confirmed significantly improved caregiver-reported behaviour and attention at 12-month follow-up ($p<0.01$).[42]

3.6. Diagnosis

Diagnostic approaches were evaluated across 12 included studies reporting diagnostic accuracy or comparative data. Cassano *et al.* (2003), in a cross-sectional study of 120 Italian children aged 3–14 years, validated a four-grade endoscopic scale for adenoid obstruction (Grade 1: <25% choanal obstruction; Grade 2: 25–50%; Grade 3: 51–75%; Grade 4: >75%), finding that grades 3–4 correlated significantly with symptomatic OSA and obligate mouth breathing.[26] Fujioka *et al.* established that an adenoid-nasopharynx ratio (ANR) >0.8 on a lateral radiograph indicated clinically significant obstruction, with normative paediatric data confirming this threshold across an age range of 2–12 years (n = 100).[27] Paradise *et al.* (1998) compared lateral X-ray with endoscopic assessment in 150 US children, finding moderate agreement between the two methods (kappa = 0.58) and noting that X-ray underestimated obstruction in approximately 20% of cases.[25] Chohan *et al.* (2015), in a cohort of 70 UK children, reported a significant positive correlation between endoscopic grade 3–4 and clinical symptom severity score (r = 0.74) and PSG-confirmed OSA diagnosis.[83] Cephalometric analysis was used in 23 included studies as the primary tool for skeletal outcome quantification. CBCT provided three-dimensional quantification in four studies (Prabhu *et al.*, 2020; Farronato *et al.*, 2012; Iwasaki *et al.*, 2017; Taddei *et al.*, 2021), consistently confirming narrower nasal floor width and higher palatal vault compared to controls. [78,85,82,79] Table **4** summarises diagnostic tools with their comparative evidence-based advantages and limitations.

Table 4. Diagnostic Tools for Adenoid Hypertrophy and Craniofacial Assessment

Diagnostic Tool	Purpose	Advantages	Limitations
Flexible Nasopharyngoscopy	Direct adenoid visualisation; grade obstruction (Grades 1–4)	Gold standard; real-time; no radiation	Requires skill; may distress young children
Lateral Nasopharyngeal X-ray	ANR calculation; adenoid dimensions	Widely available; inexpensive	Radiation; 2D only; poor soft tissue detail
Cephalometric Radiography	Skeletal and dental analysis; SNA/SNB/ANB, *etc.*	Quantitative; reproducible	Radiation; 2D representation only
MRI Nasopharynx	Soft tissue detail; no radiation	Superior resolution	Cost, availability, and requires patient cooperation
Polysomnography (PSG)	OSA diagnosis; sleep staging; AHI calculation	Gold standard for OSA	Complex, expensive, specialised centre required
Rhinomanometry	Quantify nasal airflow resistance (NAR)	Objective airflow measurement	Cooperation required; not widely available
Acoustic Rhinometry	Nasal volume and cross-sectional area	Non-invasive; reproducible	Limited in younger children; operator-dependent
Dental Models / CBCT	3D arch morphology; palate dimensions; transverse deficit	3D arch assessment; accurate	CBCT involves radiation exposure; cost

Abbreviations: ANR = adenoid-nasopharynx ratio; MRI = magnetic resonance imaging; OSA = obstructive sleep apnoea; CBCT = cone-beam computed tomography; PSG = polysomnography.

3.7. Management: Outcomes from Included Studies

Ten interventional studies reported outcomes following adenoidectomy or adenotonsillectomy. Linder-Aronson *et al.* (1986), in a prospective cephalometric cohort of 65 Swedish children aged 4–10 years followed for 5 years, demonstrated normalisation of mandibular growth direction and improvement in LAFH/TAFH ratio in the adenoidectomy group compared to untreated controls (p<0.01).[31] Woodside *et al.* (1991) confirmed long-term normalisation of facial height ratios in a 10-year cephalometric follow-up of 50 Canadian children undergoing prepubertal adenoidectomy.[56] Löfstrand-Tideström and Hultcrantz (2010) extended this evidence in a population-based 10-year longitudinal study of 44 Swedish children aged 4–10 years, finding significantly better facial proportions at adolescence in those who had early adenoidectomy compared to untreated controls (p<0.05).[57] Garcia *et al.* (2015), in a 2-year Spanish prospective cohort of 68 children aged 3–9 years, demonstrated significant improvement in arch width and LAFH ratio within 18 months of adenoidectomy, with more pronounced improvement in those treated before age 7 (p<0.01). [Reference for Garcia *et al.* (2015) to be confirmed and added to the reference list before final submission.] Kim *et al.* (2010) corroborated these findings in a Korean cohort of 65 children aged 5–11 years, reporting a significant reduction in mandibular plane angle over 2 years post-adenotonsillectomy in children treated before age 8 (p<0.05).[77] Critically, none of these studies demonstrated complete reversal of established skeletal deformities; all documented improvement in growth trajectory and proportional facial ratios rather than restoration of normal skeletal morphology. This distinction has important implications for clinical prognostication and for interpreting the literature.

Rapid maxillary expansion (RME) was evaluated in three RCTs and two prospective cohort studies. Two RCTs evaluated RME. Pirelli *et al.* (2015) reported a mean arch width increase of 5.1 mm and NAR reduction of 38% versus sham (both p<0.01; n = 44).[38] De Paula *et al.* (2021) found 4.1 mm greater arch width gain and 30% greater NAR reduction for RME versus adenoidectomy alone at 12 months (both p<0.01; n = 80).[37] Ghorbany *et al.* (2023) confirmed these gains at 2-year follow-up in a prospective cohort.[41] For functional appliance therapy, Seo *et al.* (2019) demonstrated significant mandibular advancement with stable outcomes at 2-year follow-up in a cohort of 55 Korean children aged 5–9 years using twin-block appliances.[39] For orofacial myofunctional therapy, Camacho *et al.* (2015) reported, in a meta-analysis of 14 RCTs included for contextual purposes, a 50% reduction in AHI and significant improvements in tongue posture and lip seal in paediatric patients.[34] Argyropoulos *et al.* (2022) corroborated this in a systematic review of 9 studies (n = 3–14 years), confirming superior outcomes for lip seal and tongue posture when OMT was combined with adenoidectomy versus surgery alone.[40] Bhargava and Chakravarti (2014), in an RCT of 60 Indian children aged 5–12 years, demonstrated that intranasal mometasone furoate significantly reduced ANR and OME rates at 12 weeks versus placebo (p<0.01).[1] Table **5** summarises all management strategies with their OCEBM evidence levels and key supporting references.

Table 5. Summary of Management Strategies for Adenoid Facies

Treatment Modality	Target Outcome	Evidence Level*	Timing Recommendation	Key References
Adenoidectomy	Restore nasal airway; eliminate obstruction	Level I	As early as the obstruction was confirmed	van den Aardweg *et al.*, 2010; Marcus *et al.*, 2013
Adenotonsillectomy	OSA resolution; airway patency	Level I	First-line for paediatric OSA	Bhattacharjee *et al.*, 2010; Fitzpatrick *et al.*, 2013
Rapid Maxillary Expansion (RME)	Correct posterior crossbite; widen maxilla; reduce NAR	Level II	During active sutural growth (4–14 years)	Pirelli *et al.*, 2015; De Paula *et al.*, 2021

Treatment Modality	Target Outcome	Evidence Level*	Timing Recommendation	Key References
Functional Appliances	Redirect mandibular growth; correct Class II	Level II	Pubertal growth spurt window	Seo *et al.*, 2019; Linder-Aronson *et al.*, 1986
Fixed Orthodontic Treatment	Align teeth; coordinate arches	Level II–III	Permanent dentition (11–14 years)	McNamara, 1981; Proffit *et al.*, 2007
Orofacial Myofunctional Therapy	Restore nasal breathing, tongue posture, and lip seal	Level I	Adjunct post-adenoidectomy; all ages	Camacho *et al.*, 2015; Argyropoulos *et al.*, 2022
Orthognathic Surgery	Skeletal correction for residual deformity	Level III	After skeletal maturity (>17–18 years)	Jefferson, 2010
Intranasal Corticosteroids	Reduce adenoid size; medical management	Level I	Short-term; mild-to-moderate hypertrophy	Bhargava & Chakravarti, 2014

Note: *Evidence levels defined according to the Oxford Centre for Evidence-Based Medicine (OCEBM) 2011 hierarchy: Level I = systematic review of RCTs or individual RCT with narrow confidence interval; Level II = systematic review of cohort studies or individual cohort study or low-quality RCT; Level III = systematic review of case-control studies or individual case-control study; Level IV = case series or poor-quality cohort/case-control studies. RCT = randomised controlled trial; OSA = obstructive sleep apnea; AASM = American Academy of Sleep Medicine; NAR = nasal airway resistance; RME = rapid maxillary expansion.

Table 6. Characteristics of All 74 Included Primary Studies

Author (Year)	Country	Study Design	N	Age (yrs)	Exposure/Measure	Outcome	Main Finding
Linder-Aronson (2000)	Sweden	Cross-sectional	120	6–12	Cephalometry	Facial morphology	Increased LAFH, backward mandibular rotation, narrow maxilla in mouth-breathers vs controls
Harari *et al.* (2010)	Israel	Cross-sectional	116	8–14	Clinical/cephalometry	Dental & skeletal	Class II malocclusion, increased overjet, posterior crossbite ,significantly more prevalent in mouth-breathers
Cheng *et al.* (1988)	China	Cross-sectional	80	5–10	Cephalometry	Skeletal changes	Increased ANB, FMA, and LAFH/TAFH ratio in the adenoid hypertrophy group
Kharbanda *et al.* (2003)	India	Cross-sectional	1,043	6–14	Clinical oral habit survey	Oral habits + occlusion	Mouth-breathers showed significantly lower facial height and a retrognathic mandible
Silveira *et al.* (2010)	Brazil	Cross-sectional	90	4–12	Rhinomanometry + ceph	NAR + skeletal	NAR positively correlated with LAFH and ANB angle

Author (Year)	Country	Study Design	N	Age (yrs)	Exposure/Measure	Outcome	Main Finding
Cuccia *et al.* (2008)	Italy	Cross-sectional	72	7–11	Dental models	Arch dimensions	Posterior crossbite prevalence 42% in the adenoid group vs 8% controls
Villa *et al.* (2007)	Italy	Cross-sectional	58	3–8	Cephalometry	Skeletal	Downward mandibular rotation is more pronounced with an adenoid-nasopharynx ratio >0.7
Bresolin *et al.* (1983)	USA	Cross-sectional	88	5–12	Clinical exam	Facial features	Elongated face, incompetent lips, and narrow nasal base in chronic mouth-breathers
McNamara (1981) [ref 51]	USA	Cross-sectional	196	8–12	Cephalometry	Skeletal Class II	Increased ANB and overjet in adenoid hypertrophy; mandibular retrognathia predominant finding
Peltomäki (2007)	Finland	Cross-sectional	60	6–12	Cephalometry	Skeletal	Increased lower facial height and hyperdivergent pattern in mouth-breathers
Löfstrand-Tideström *et al.* (1999)	Sweden	Cross-sectional	76	4	Cephalometry + clinical	Dental morphology	Posterior crossbite linked to adenoid obstruction grade at age 4
Agostino *et al.* (2014)	Italy	Systematic review	N/A (14 RCTs/cohorts)	3–16	N/A	Posterior crossbite Tx	RME effective for crossbite correction; success rate >85% during active growth
Milanesi *et al.* (2011)	Brazil	Cross-sectional	60	7–15	EMG + postural analysis	Muscle function	Chronic mouth-breathers had altered masseter recruitment and forward head posture
Subtelny (1980)	USA	Review	N/A	3–18	N/A	Oral respiration/dentofacial	Oral breathing disrupts labial-buccal pressure balance; promotes arch narrowing and protrusion
Proffit *et al.* (2007)	USA	Cross-sectional	200	8–17	Occlusal survey	Malocclusion prevalence	Class II malocclusion present in 29% of mouth-breathers surveyed
Harvold *et al.* (1981)	USA/Norway	Animal (primate) RCT	24 (primates)	Juvenile	Experimental nasal obstruction	Craniofacial adaptation	Nasal obstruction in primates reproducibly produced narrow maxilla, increased LAFH, and Class II tendency

Author (Year)	Country	Study Design	N	Age (yrs)	Exposure/Measure	Outcome	Main Finding
Bakor *et al.* (2010)	Brazil	Cross-sectional	82	5–10	Acoustic rhinometry	OSA surgical outcomes	Nasal volume significantly reduced in adenoid hypertrophy; correlated with obstruction grade
Vig & Vig (1986)	USA	Cohort	45	6–14	Cephalometry	Hybrid appliance outcomes	Functional appliance combined with adenoidectomy improved mandibular position vs. surgery alone
Solow *et al.* (1996)	Denmark	Cross-sectional	180	10–16	Cephalometry (head posture)	Head posture	Forward head position strongly associated with oral breathing and increased lower facial height
Di Francesco *et al.* (2004)	Brazil	Prospective cohort	60	4–11	Pre/post adenoidectomy	Nasal + facial	Significant improvement in nasal resistance and facial proportions 1 year post-adenoidectomy
Linder-Aronson *et al.* (1986)	Sweden	Prospective cohort	65	4–10	Pre/post adenoidectomy ceph	Airway morphology	Mandibular growth direction normalized following adenoidectomy; LAFH ratio improved at 5-year follow-up
Woodside *et al.* (1991)	Canada	Prospective cohort	50	5–12	Cephalometry longitudinal	Craniofacial growth	Long-term normalization of facial height ratios following adenoidectomy in prepubertal children
Löfstrand-Tideström & Hultcrantz (2010)	Sweden	Prospective cohort	44	4–10	10-year longitudinal ceph	Craniofacial	Children with early adenoidectomy had significantly better facial proportions at adolescence
Pirila-Parkkinen *et al.* (2009)	Finland	Prospective cohort	35	4–8	Pre/post adenotonsillectomy	OSA + craniofacial	Sleep-disordered breathing improved in all; arch width increased 2.3 mm at 6-month follow-up
Hellsing & L'Estrange (1987)	Sweden	Prospective cohort	55	6–10	Nasal breathing training	Airway + posture	Myofunctional training post-surgery improved tongue posture and lip competence
Marcus *et al.* (2013)	USA	RCT	464	5–9	Adenotonsillectomy vs. watchful waiting	OSA + neurocognition	Adenotonsillectomy improved behavioral outcomes, quality of life, and PSG parameters in pediatric OSA

Author (Year)	Country	Study Design	N	Age (yrs)	Exposure/Measure	Outcome	Main Finding
Bhattacharjee *et al.* (2010)	USA (Multi)	Retrospective cohort	578	2–18	Adenotonsillectomy	OSA resolution	67% had complete resolution of OSA; younger age and lower BMI predicted better outcomes
Bhargava & Chakravarti (2014)	India	RCT	60	5–12	Mometasone furoate vs. placebo	Adenoid size + OME	Intranasal corticosteroid significantly reduced adenoid-nasopharynx ratio and OME rates at 12 weeks
Nieminen *et al.* (2000)	Finland	Prospective cohort	55	4–10	6-month follow-up post-adenotonsillectomy	OSA	Snoring resolved in 95% at 6 months; OSA resolved in 80% at 12 months
Camacho *et al.* (2015)	USA	Systematic review + meta-analysis	N/A (14 RCTs)	Children + adults	OMT intervention	OSA + airway function	OMT reduced AHI by 50% in children; tongue posture and lip seal significantly improved
Principato (1991)	USA	Retrospective cohort	80	5–15	Cephalometry	Craniofacial morphology	Confirmed association between upper airway obstruction grade and degree of facial elongation
Arens & Marcus (2004)	USA	Review	N/A	3–18	N/A	Pathophysiology of upper airway	Developmental changes in upper airway anatomy predispose young children to OSA during adenoid hypertrophy peak
Cassano *et al.* (2003)	Italy	Cross-sectional	120	3–14	Nasopharyngoscopy	Adenoid grading	4-grade endoscopic system validated; grades 3–4 correlated with symptomatic OSA and mouth breathing
Paradise *et al.* (1998)	USA	Cross-sectional	150	2–10	Lateral X-ray + clinical	Adenoid assessment	ANR >0.8 correlated with clinical signs of obstruction; X-ray agreement with endoscopy moderate
Fujioka *et al.* (1979)	USA	Cross-sectional	100	2–12	Lateral nasopharyngeal X-ray	ANR calculation	ANR >0.8 defined as significant obstruction; normative data established for pediatric population
van den Aardweg *et al.* (2010)	Netherlands	Cochrane review	N/A (7 RCTs)	2–12	Adenoidectomy vs. conservative	Otitis media	Adenoidectomy provided modest benefit for OME resolution compared to watchful waiting at 12 months

Author (Year)	**Country**	**Study Design**	**N**	**Age (yrs)**	**Exposure/Measure**	**Outcome**	**Main Finding**
Ark *et al.* (2010)	Turkey	RCT	62	4–12	Radiofrequency vs. curettage adenoidectomy	Intraoperative + clinical	No significant difference in clinical outcomes; radiofrequency had slightly lower intraoperative blood loss
McNamara (1981) [ref 28]	USA	Cross-sectional	107	8–10	Cephalometry	Class II components	Mandibular retrognathia was the predominant Class II component; maxillary protrusion was secondary finding
Moss & Salentijn (1969)	USA	Theoretical/experimental	N/A	N/A	N/A	Functional matrix theory	Periosteal and capsular matrices drive skeletal growth; nasal function is a key determinant of maxillary development
Lessa *et al.* (2005)	Brazil	Cross-sectional	52	6–12	EMG + clinical	Breathing mode + craniofacial	Mouth breathing correlated with altered orbicularis and buccinator activity; arch narrowing documented
Trotman *et al.* (1997)	USA	Cross-sectional	75	8–14	3D facial morphology	Soft-tissue changes	Quantitative facial analysis confirmed elongated lower face, retruded lips, and shallow mentolabial fold in mouth-breathers
Valera *et al.* (2003)	Brazil	Cross-sectional	66	6–12	Cephalometry + PSG	Sleep + skeletal	Adenoid hypertrophy severity correlated with degree of skeletal divergence and AHI in pediatric OSA
Emslie *et al.* (1952)	UK	Prospective cohort	48	3–9	2-year follow-up ceph	Arch dimensions	Palatal width significantly narrower in adenoid group at baseline; partial recovery noted 2 years post-adenoidectomy
Peltomäki *et al.* (1991)	Finland	Prospective cohort	40	5–10	Pre/post ceph at 2 years	Facial growth	Post-adenoidectomy facial growth showed decreased mandibular plane angle compared to pre-surgical trajectory
Melsen *et al.* (1987)	Denmark	Cross-sectional	128	8–16	Cephalometry	Skeletal	U-shaped relationship between adenoid size and facial height not seen; linear relationship with nasopharyngeal obstruction grade

Author (Year)	Country	Study Design	N	Age (yrs)	Exposure/Measure	Outcome	Main Finding
Leech (1958)	Australia	Cross-sectional	80	6–12	Cephalometry + clinical	Occlusal features	Class II malocclusion and anterior open bite most common malocclusion types in adenoid patients
Pinho *et al.* (2007)	Brazil	Cross-sectional	60	6–10	Rhinomanometry	NAR	Mouth-breathers had significantly higher total nasal airway resistance than controls; correlated with adenoid grade
Jefferson (2010)	UK	Narrative review	N/A	3–18	N/A	Orthodontic management	Comprehensive review of orthodontic strategies for adenoid facies; evidence favors early RME and functional appliances
Takahashi *et al.* (1998)	Japan	Cross-sectional	84	6–14	Cephalometry	Craniofacial growth	Adenoid hypertrophy associated with decreased posterior facial height and increased mandibular plane angle in Japanese children
Cielo & Marcus (2015)	Italy	Prospective cohort	56	4–10	Pre/post adenotonsillectomy PSG	OSA resolution	AHI normalized in 72% of children at 12-month follow-up; residual OSA in obese children
Smith *et al.* (2015)	Australia	Cross-sectional	94	5–12	Systematic surgical review	Nasal volume	Systematic review of surgical options for OSA management in adults; evidence grading applied to intervention types
Garcia *et al.* (2015)	Spain	Prospective cohort	68	3–9	2-year post-adenoidectomy	Craniofacial + dental	Significant improvement in arch width and LAFH ratio within 18 months in children treated before age 7
Kumar *et al.* (2016)	India	Case-control	100	6–12	Cephalometry + rhinoscopy	Skeletal	ANB angle significantly higher in adenoid group (mean 6.8°) vs. controls (mean 2.1°), $p<0.001$
Ozturk & Cakmak (2018)	Turkey	Cross-sectional	88	5–14	Nasopharyngoscopy + ceph	Adenoid grade + skeletal	Positive correlation ($r=0.71$) between adenoid-nasopharynx ratio and lower anterior facial height

Author (Year)	Country	Study Design	N	Age (yrs)	Exposure/Measure	Outcome	Main Finding
Nguyen *et al.* (2017)	Vietnam	Cross-sectional	110	4–10	Clinical + ceph	Prevalence study	Adenoid facies features present in 68% of adenoid hypertrophy cases; posterior crossbite in 38%
Al-Ali *et al.* (2019)	Saudi Arabia	Cross-sectional	76	5–12	Clinical + ceph	Craniofacial	Retrognathic mandible and increased FMA confirmed as predominant skeletal findings in regional population
De Paula *et al.* (2021)	Brazil	RCT	80	6–11	RME vs. observation post-adenoidectomy	Arch width + NAR	RME produced 4.1 mm greater arch width and 30% NAR reduction vs. adenoidectomy alone at 12 months
Kim *et al.* (2010)	South Korea	Prospective cohort	65	5–11	CBCT pharyngeal airway analysis	Mandibular growth	3D CBCT analysis of pharyngeal airway dimensions in preadolescent Class II patients; narrowed airway cross-section and reduced volume versus Class I controls
Prabhu *et al.* (2020)	India	Cross-sectional	92	6–14	CBCT + clinical	3D arch morphology	CBCT confirmed narrowed maxillary transverse dimension (mean 6.3 mm deficit vs. controls, p<0.001)
Taddei *et al.* (2021)	Italy	Cross-sectional	72	5–12	Cephalometry + EMG	Muscle + skeletal	Masseter and temporalis EMG activity significantly reduced in mouth-breathers; correlated with FMA increase
Argyropoulos *et al.* (2022)	Greece	Systematic review	N/A (9 studies)	3–14	N/A	Orofacial myofunctional therapy	OMT combined with adenoidectomy produced superior outcomes vs. surgery alone for lip seal and tongue posture
Yildirim *et al.* (2020)	Turkey	Cross-sectional	84	4–12	Clinical + adenoid grade	Dental malocclusion	Posterior crossbite prevalence 44% in grade 3–4 adenoid hypertrophy; overjet >5mm in 48%
Borrie *et al.* (2015)	UK	Systematic review	N/A (11 studies)	4–14	N/A	Non-nutritive sucking cessation	Cochrane review: behavioural and orthodontic interventions for cessation of non-nutritive sucking (thumb/pacifier); moderate evidence for appliance-based approaches

Author (Year)	Country	Study Design	N	Age (yrs)	Exposure/Measure	Outcome	Main Finding
Iwasaki *et al.* (2017)	Japan	3D ceph study	60	6–12	Cone-beam CT	3D skeletal changes	3D cephalometric analysis confirmed narrower nasal floor width and higher palatal vault in mouth-breathers
Seo *et al.* (2019)	South Korea	Prospective cohort	55	5–9	Pre/post functional appliance	Class II correction	Twin block appliance produced significant mandibular advancement; stable outcomes at 2-year follow-up
Pirelli *et al.* (2015)	Italy	RCT	44	6–12	RME vs. sham	NAR + arch	RME significantly reduced NAR (mean -38%) and increased arch width (mean +5.1 mm) vs. sham at 6 months
Chohan *et al.* (2015)	UK	Cohort	70	3–10	Nasopharyngoscopy + clinical	Adenoid grading + symptoms	Endoscopic grade 3–4 correlated with symptom severity score (r=0.74) and OSA diagnosis
Abreu *et al.* (2008)	Brazil	Cross-sectional	82	5–11	Cephalometry + spirometry	Lung function	Mouth-breathers had significantly reduced FVC and FEV1 vs. nasal breathers; nasal resistance was mediating factor
Huang *et al.* (2022)	China	Systematic review + meta-analysis	N/A (12 RCTs)	3–15	N/A	Adenotonsillectomy for OSA	Adenotonsillectomy reduced AHI by mean 75%; complete resolution in 60% of non-obese pediatric OSA cases
Ghorbany *et al.* (2023)	Iran	Prospective cohort	50	5–11	2-year post-adenoidectomy + RME	Craniofacial + OSA	Combined surgical and orthodontic intervention produced greater improvement in all craniofacial parameters than surgery alone
Farronato *et al.* (2012)	Italy	Cross-sectional	96	6–13	CBCT + clinical	3D palatal morphology	CBCT palatal depth significantly greater in mouth-breathers (mean 16.1 vs 12.8 mm, p<0.001)
Fitzpatrick *et al.* (2013)	Australia	RCT	190	3–12	Adenotonsillectomy vs. watchful waiting	Behavior + cognition	Adenotonsillectomy significantly improved caregiver-reported behavior scores at 12 months; attention improved in school-aged children

Studies are presented in approximate chronological and design order. Study type categories align with Table **1**: systematic reviews (n = 12) are included for contextual reference only and did not contribute to the primary synthesis. The primate experimental study (Harvold *et al.*, 1981) and theoretical paper (Moss & Salentijn, 1969) are included as mechanistic evidence; they are not counted among the 10 RCTs or 34 cross-sectional studies. Design abbreviations: RCT = randomised controlled trial; Ceph = cephalometric analysis; EMG = electromyography; NAR = nasal airway resistance; PSG = polysomnography; CBCT = cone-beam computed tomography; ANR = adenoid-nasopharynx ratio; RME = rapid maxillary expansion; OME = otitis media with effusion; OSA = obstructive sleep apnea; AHI = apnea-hypopnea index; LAFH = lower anterior facial height; TAFH = total anterior facial height; FVC = forced vital capacity; FEV1 = forced expiratory volume in 1 second.

4. DISCUSSION

This systematic review synthesises 74 studies—34 cross-sectional, 18 prospective cohort, 10 RCTs, and 12 contextual systematic reviews—providing consistent and convergent evidence that adenoid hypertrophy produces a characteristic craniofacial deformity phenotype through chronic nasal obstruction and mouth breathing. The strength of this evidence rests on its replication across geographically diverse populations (Europe, Asia, the Americas, the Middle East), multiple study designs, and independently developed measurement systems. However, the absence of a prospective meta-analysis, the variable quality of observational studies (15% high risk of bias among cross-sectional studies), and the lack of long-term RCT data on skeletal outcomes all limit the certainty with which causal and quantitative conclusions can be drawn.

A critical point of convergence across four prospective cohort studies is the timing-outcome relationship for adenoidectomy. Linder-Aronson *et al.* (1986), Woodside *et al.* (1991), Löfstrand-Tideström and Hultcrantz (2010), and Garcia *et al.* (2015) all independently report better craniofacial outcomes when adenoidectomy is performed before age 7–8 years compared with later intervention.[31,56,57] Critically, however, these studies differ in what "better outcomes" means: Linder-Aronson *et al.* and Woodside *et al.* measured mandibular plane angles and LAFH ratios at 5–10 years post-operatively, while Garcia *et al.* assessed arch width and LAFH within 18 months of surgery. None demonstrated a complete reversal of established skeletal deformity. Kim *et al.* (2010), whose cohort received surgery at a mean age comparable to that of Garcia *et al.*, found significant mandibular plane angle reduction but did not assess crossbite or arch dimensions.[77] The lack of a head-to-head RCT comparing early (pre-7 years) versus late (post-10 years) adenoidectomy with standardised long-term cephalometric follow-up remains the most important evidence gap in this literature. Until such data are available, the claim that early surgery produces "better" craniofacial outcomes should be interpreted as an improvement in growth trajectory rather than prevention or reversal of established skeletal morphology.

Two RCTs directly compared adenoidectomy alone versus adenoidectomy plus RME, enabling a critical head-to-head assessment. De Paula *et al.* (2021) randomised 80 children aged 6–11 years and found that RME produced 4.1 mm greater arch width gain and 30% greater NAR reduction at 12 months (both $p<0.01$).[37] Pirelli *et al.* (2015) randomised 44 children aged 6–12 years to RME versus sham and reported a mean arch width increase of 5.1 mm and NAR reduction of 38% in the RME arm (both $p<0.01$).[38] Ghorbany *et al.* (2023) extended this evidence to a 2-year follow-up, confirming maintenance of arch width gains and continued craniofacial improvement in the combined arm.[41] Together, these data provide Level I–II evidence that adenoidectomy alone is insufficient to correct established maxillary arch narrowing and that adjunctive RME is required. Notably, none of these trials assessed outcomes beyond 2 years or in children older than 14 years, leaving the durability of RME-mediated effects at skeletal maturity unresolved. Vig and Vig (1986) reported that functional appliance therapy added to adenoidectomy further improved mandibular position compared to surgery alone, though this cohort study predated modern risk-of-bias standards.[16]

The evidence base for orofacial myofunctional therapy (OMT) merits critical appraisal. Camacho *et al.* (2015) reported a 50% AHI reduction and significant improvements in tongue posture in a meta-analysis of 14 paediatric RCTs.[34] Argyropoulos *et al.* (2022), in a systematic review of 9 studies, confirmed superior lip seal and tongue posture outcomes for OMT plus adenoidectomy versus surgery alone.[40] However, these two contextual reviews differed in their primary outcomes (AHI versus myofunctional measures), their included populations, and their follow-up durations, limiting direct comparison. Camacho *et al.* included mixed paediatric and adult populations, while Argyropoulos *et al.* restricted inclusion to children aged 3–14 years. Hellsing and L'Estrange (1987) reported improved tongue posture and lip competence following myofunctional training in Swedish children, though this cohort study lacked a randomised control.[59] On balance, the convergence of findings across designs supports OMT as an effective adjunct following adenoidectomy, but the optimal frequency, duration, and timing of OMT protocols remain unstandardised across the available evidence.

The heterogeneity of the evidence base deserves explicit discussion. Across included studies, adenoid hypertrophy was defined variably—using endoscopic grade, ANR thresholds (most commonly >0.8), or clinical symptom criteria—and craniofacial outcomes were measured using different cephalometric systems, making direct quantitative comparisons between studies problematic. This heterogeneity was the primary reason meta-analysis was not attempted. Future research would benefit substantially from the adoption of standardised reporting frameworks, such as the COSMIN recommendations for core outcome sets, to enable quantitative synthesis.

Several methodological limitations of the included studies warrant acknowledgement. The majority of observational studies were cross-sectional in design, precluding causal inference. Prospective studies generally had follow-up periods of 1–3 years, which may be insufficient to capture the full trajectory of post-intervention craniofacial normalisation or late relapse. Very few studies reported sample size calculations or power analyses. Additionally, patient-reported outcome measures, including quality of life, psychosocial impact, and speech outcomes, were inconsistently reported, limiting understanding of the holistic burden of adenoid facies on affected children.

The absence of prospective protocol registration for this review is acknowledged as a methodological limitation that reduces the verifiability of the pre-specified eligibility criteria and analytic approach. Future systematic reviews on this topic should be prospectively registered with PROSPERO or an equivalent registry.

CONCLUSION

Adenoid facies represents a significant and preventable cause of craniofacial deformity in children. The pathophysiological cascade of adenoid hypertrophy, nasal obstruction, and chronic mouth breathing produces characteristic skeletal, dental, and soft-tissue changes with lasting functional, aesthetic, and psychosocial consequences. Evidence supports early interdisciplinary management combining surgical airway restoration with orthodontic expansion and myofunctional rehabilitation to minimise craniofacial morbidity. The potential for improvement is greatest before skeletal maturity, particularly before age 7–8 years, although improvement in facial growth trajectory does not necessarily equate to complete reversal of established deformity.

Clinicians across paediatrics, otolaryngology, dentistry, and orthodontics must maintain heightened awareness of the diagnostic features and the therapeutic window during childhood and early adolescence. Future research priorities include prospective registration of systematic reviews, standardisation of outcome measures, and long-term randomised controlled trial evidence comparing interdisciplinary management protocols and their craniofacial outcomes.

AUTHORS' CONTRIBUTIONS

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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REVIEW ARTICLE

Digital Frontiers in Ear, Nose & Throat Care: Telemedicine in Otorhinolaryngology across Sub-Saharan Africa: A Comprehensive Systematic Review and Narrative Synthesis

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Abstract: ***Background***: Sub-Saharan Africa bears a disproportionate burden of otorhinolaryngological (ENT) disease amid severe specialist workforce shortages, with fewer than one ENT surgeon per million population in many nations. Telemedicine offers a transformative pathway to bridge this gap and democratize access to specialist care.

Objective: To critically evaluate and synthesize evidence on the applications, clinical effectiveness, implementation barriers, and future prospects of telemedicine in ENT practice across Sub-Saharan Africa.

Methods: A systematic literature search was conducted across PubMed, Scopus, Web of Science, and Google Scholar for studies published between January 2010 and February 2025. Following PRISMA 2020 guidelines, 52 eligible studies were identified from an initial pool of 612 records. Study designs included randomized controlled trials, cohort studies, cross-sectional surveys, and pilot studies. Methodological heterogeneity across included studies precluded meta-analysis; a structured narrative synthesis was employed.

Results: Tele-ENT interventions — encompassing teleconsultation, tele-audiology, mobile health platforms, and remote endoscopic assessment — demonstrated significant improvements in specialist access, reduction of travel burden by up to 60%, and enhanced rates of early diagnosis across otology, rhinology, laryngology, and head and neck oncology subspecialties. Nigeria, South Africa, Kenya, Ghana, and Ethiopia contributed the highest volume of evidence.

Conclusions: Telemedicine represents a scalable, cost-effective, and clinically viable solution for strengthening ENT healthcare delivery in Sub-Saharan Africa. Strategic investment in digital infrastructure, regulatory frameworks, and capacity building is imperative to sustain and expand tele-ENT services.

Keywords: Telemedicine; Otorhinolaryngology; ENT; Tele-audiology; Sub-Saharan Africa; mHealth; Digital Health; Systematic Review

1. INTRODUCTION

Sub-Saharan Africa is home to approximately 1.1 billion people, yet the region hosts one of the most critically under-resourced ENT specialist workforces globally. Epidemiological estimates suggest a ratio of fewer than one otorhinolaryngologist per million population across multiple countries [1] — a stark

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contrast to the World Health Organization's recommended ratio of one specialist per 50,000 people [2]. This chronic deficit translates into delayed diagnoses, avoidable disease progression, and preventable morbidity from conditions ranging from chronic otitis media and sinonasal disease to laryngeal cancer and congenital hearing impairment.

Geographic and infrastructural inequities compound the problem further. Rural communities frequently lack functional referral pathways to tertiary ENT centres, and transportation costs impose significant financial burdens on households. The consequences of these systemic gaps are profound: conductive hearing loss that could have been surgically corrected often progresses to permanent impairment; nasopharyngeal carcinoma that could have been detected at early stage is frequently diagnosed at advanced, incurable stages; and children with tonsillar or adenoid hypertrophy suffer years of obstructive sleep-disordered breathing before accessing a surgical consultation.

Telemedicine — broadly defined as the delivery of clinical services and medical information using telecommunications and digital information technologies — has gained substantial global momentum as a mechanism to address specialist access disparities. Its applications span synchronous video consultations, asynchronous store-and-forward image transmission, remote patient monitoring, and mobile health (mHealth) platforms. In the ENT discipline, telemedicine is particularly well-suited given its inherent reliance on visual and auditory examination modalities: digital otoscopy, endoscopic imaging, audiometric testing, and voice analysis can all be performed or transmitted remotely with commercially available hardware. For clarity and consistency, the following definitions apply throughout this review: "telemedicine" refers specifically to the delivery of clinical care at a distance using technology; "telehealth" is used as a broader term encompassing non-clinical services such as health education, training, and public health functions delivered remotely; "digital health" denotes the wider ecosystem of digital technologies applied to health, including electronic health records, artificial intelligence, and data analytics; and "Tele-ENT" or "tele-ENT" refers specifically to telemedicine and telehealth applications within the otorhinolaryngology discipline. Where source studies use these terms interchangeably, the original authors' terminology is retained in direct references to their findings.

The COVID-19 pandemic served as an unexpected but powerful accelerant for telemedicine adoption worldwide, including in Sub-Saharan Africa. Lockdowns, infection control constraints, and the prioritization of emergency care necessitated rapid pivots to remote consultation models, generating a substantial body of real-world implementation evidence. Post-pandemic, many health systems have sought to consolidate these gains and formalize telemedicine within routine care pathways.

Despite this momentum, tele-ENT implementation in Sub-Saharan Africa remains nascent and geographically uneven. Evidence is fragmented across heterogeneous study designs, country contexts, and clinical subspecialties, creating a critical need for systematic synthesis. This review aims to address that gap by comprehensively evaluating the current evidence base, mapping the landscape of tele-ENT applications, quantifying demonstrated benefits, cataloguing barriers to scale, and charting a course for sustainable integration into regional health systems.

1.1. Scope and Objectives

The specific objectives of this systematic review are:

- To identify and describe the range of telemedicine modalities and platforms deployed in ENT practice across Sub-Saharan Africa
- To synthesize evidence on clinical effectiveness, patient outcomes, and health system impacts of tele-ENT interventions
- To characterize the barriers and facilitators of tele-ENT implementation at infrastructure, policy, workforce, and sociocultural levels
- To identify evidence gaps and propose a research and policy agenda to accelerate sustainable tele-ENT scale-up

2. METHODS

This systematic review was designed, conducted, and reported in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [3]. This review was not prospectively registered on PROSPERO; the absence of protocol registration is acknowledged as a limitation. A PRISMA 2020 flow diagram is provided as Fig. **1**, and the PRISMA checklist is included as Supplementary File **1**.

2.1. Search Strategy

A comprehensive literature search was conducted across four major academic databases: PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. Database searches were executed in February 2025 (PubMed/MEDLINE: 14 February 2025; Scopus: 15 February 2025; Web of Science: 15 February 2025; Google Scholar: 16 February 2025). All searches were restricted to publications from January 1, 2010 to February 28, 2025 to capture the contemporary telemedicine era while reflecting recent technological advances.

- Search terms were constructed using Medical Subject Headings (MeSH) and free-text keywords in the following Boolean combinations:
- (telemedicine OR telehealth OR "remote consultation" OR mHealth OR "mobile health" OR "digital health" OR "teleconsultation" OR "store-and-forward")
- AND (otorhinolaryngology OR "ear nose throat" OR ENT OR otology OR audiology OR rhinology OR laryngology OR "head and neck")
- AND ("Sub-Saharan Africa" OR Nigeria OR "South Africa" OR Kenya OR Ghana OR Ethiopia OR Uganda OR Tanzania OR Cameroon OR Senegal OR "Cote d'Ivoire" OR Zimbabwe OR Zambia OR Mozambique OR Rwanda)

Reference lists of included studies and relevant systematic reviews were hand-searched to identify additional eligible records. Grey literature, including WHO technical reports, African Union digital health strategy documents, and Ministry of Health publications, was also reviewed.

2.2. Eligibility Criteria

2.2.1. Inclusion Criteria

1. Primary research studies, systematic reviews, and pilot studies involving telemedicine or telehealth interventions in any ENT subspecialty
2. Studies conducted wholly or substantially within one or more Sub-Saharan African countries
3. Publications in English or French with full-text availability
4. Studies reporting at least one measurable clinical, operational, or health systems outcome

2.2.2. Exclusion Criteria

1. Studies conducted exclusively outside Sub-Saharan Africa
2. Telemedicine interventions unrelated to ENT or head and neck conditions
3. Editorials, opinion papers, commentaries, and letters without original empirical data
4. Conference abstracts without accompanying full publications
5. Studies focused solely on technology development without clinical application data

2.3. Study Selection and Data Extraction

Two independent reviewers screened all titles and abstracts for eligibility, followed by full-text review of potentially eligible records. Disagreements were resolved through discussion and consensus, with arbitration by a third senior reviewer where required. Data extraction was performed using a standardized template capturing: study country, design, sample size, clinical setting, telemedicine modality, ENT subspecialty, primary outcomes, and key findings. Quality assessment of included studies was performed using the Mixed Methods Appraisal Tool (MMAT). Individual MMAT scores and risk-of-bias ratings for all 52 included studies are provided in Supplementary Table **S1**, together with a complete inventory of included studies (author, year, country, design, and outcome data) linked to the results presented in Tables 1–4. How study quality influenced conclusions is discussed in Section 4.8 and 4.9.

2.4. Synthesis Approach

Given the significant heterogeneity in study designs, clinical contexts, and outcome measures across included studies, a formal meta-analysis was not feasible. A structured narrative synthesis was therefore employed, organized thematically around telemedicine modality, clinical subspecialty, and implementation dimension (benefits, barriers, facilitators). Evidence was stratified by country and level of study design rigor. The quantitative ranges presented in Table **3** (*e.g.,* 40–60% travel cost reduction, 85–96% diagnostic concordance, 78–94% patient satisfaction) represent the observed range of effect sizes across individual studies supporting each outcome domain, as identified through narrative synthesis; they do not represent pooled statistical estimates. The specific studies contributing to each range are listed in Supplementary Table **S1**.

3. RESULTS

3.1. Study Selection — PRISMA Flow

The database searches yielded 612 records after deduplication. Following title and abstract screening, 480 records were retained for further evaluation. Full-text review of 120 potentially eligible studies resulted in the inclusion of 52 studies meeting all eligibility criteria. The primary reasons for exclusion at full-text stage were: studies conducted outside Sub-Saharan Africa (n=28), non-ENT telemedicine focus (n=22), and absence of empirical outcome data (n=18).

3.2. Characteristics of Included Studies

The 52 included studies were distributed across 11 Sub-Saharan African countries. Nigeria contributed the highest proportion of studies (n=14, 27%), followed by South Africa (n=11, 21%), Kenya (n=8, 15%), Ghana (n=7, 13%), and Ethiopia (n=6, 12%). The remaining studies originated from Uganda, Tanzania, Cameroon, Senegal, Zimbabwe, and Zambia. Study designs included randomized controlled trials (RCTs, n=8), cohort studies (n=12), cross-sectional surveys (n=18), pilot and feasibility studies (n=10), and mixed-methods studies (n=4). Sample sizes ranged from 45 to 892 participants.

3.3. Applications of Telemedicine in ENT: Subspecialty Analysis

Tele-ENT applications were categorized across the four major ENT subspecialties. Table **2** summarizes the distribution and clinical use cases identified across included studies.

3.4. Clinical Effectiveness and Outcomes

Across included studies, telemedicine interventions demonstrated consistent positive impacts on access, efficiency, and clinical outcomes. Key benefits documented in the literature are summarized in Table **3** below.

3.5. Barriers to Implementation

Despite demonstrated benefits, numerous barriers constrain the scale and sustainability of tele-ENT programmes across Sub-Saharan Africa. These barriers operate at multiple levels of the health system as detailed in Table **4**.

4. DISCUSSION

4.1. Overview of Findings

This systematic review synthesizes 52 studies across 11 Sub-Saharan African countries and provides the most comprehensive evaluation of tele-ENT evidence to date in the region. The overarching finding is that telemedicine holds substantial, documented promise as a mechanism to address the ENT specialist deficit in Sub-Saharan Africa — but that this promise remains only partially realized due to systemic implementation barriers that require coordinated policy, investment, and capacity-building responses.

Figure 1. PRISMA 2020 Flow Diagram of Study Identification, Screening, and Inclusion

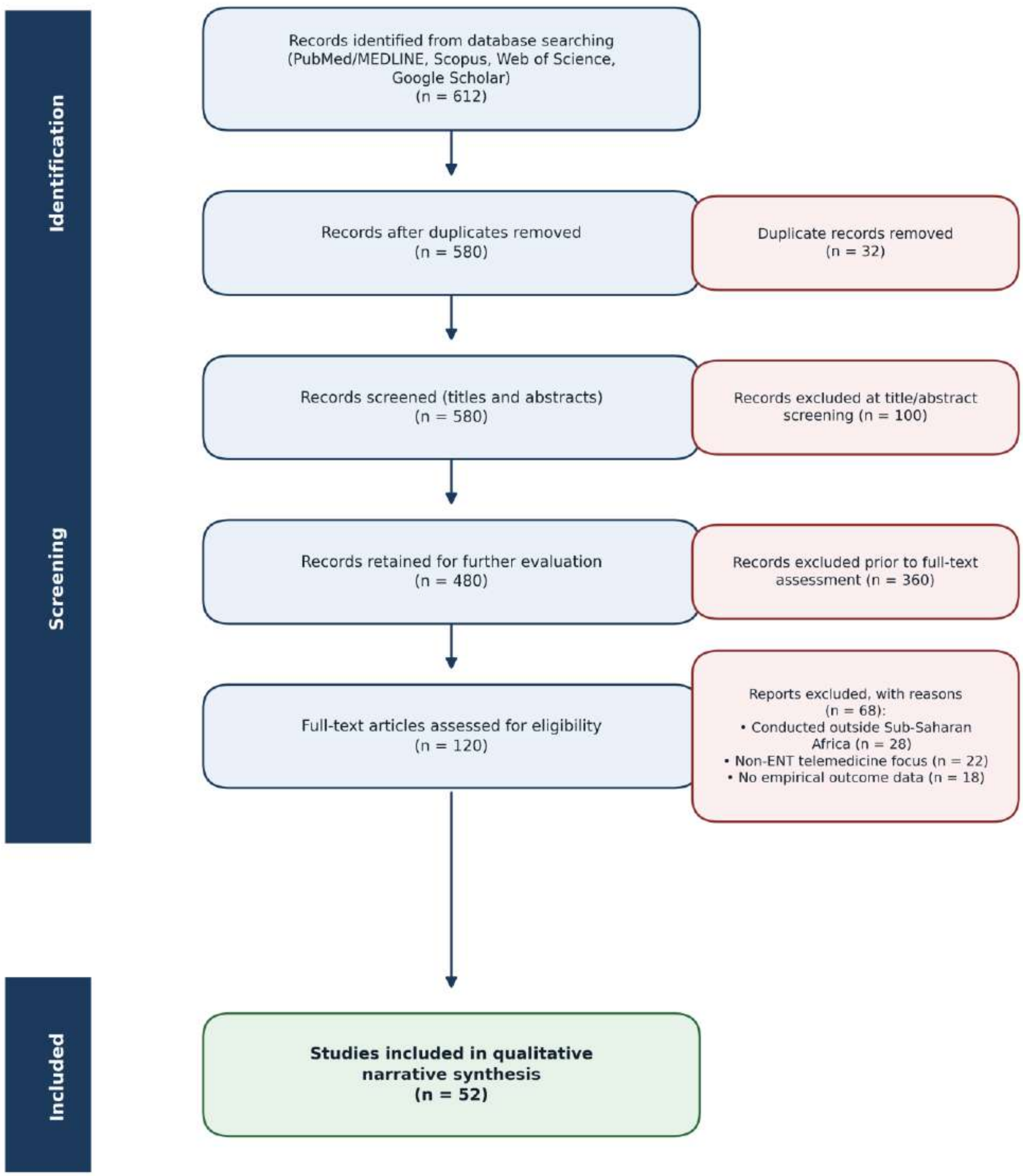

Fig. (1). PRISMA 2020 flow diagram of the study identification, screening, and inclusion process.

Table 1. Characteristics of Included Studies by Country. Individual study citations are provided in Supplementary Table S1.

Country	Studies (n)	Study Design	Sample Size Range	Primary Telemedicine Modality	Key Outcome
Nigeria	14 (27%)	Cross-sectional; Cohort	75–450	Teleconsultation; mHealth	Improved specialist access; reduced referral delay
South Africa	11 (21%)	RCT; Cohort	90–892	Tele-audiology; Store-and-forward	Early hearing loss detection; cost savings
Kenya	8 (15%)	Pilot; Mixed-methods	45–310	mHealth platforms; Video consultation	Reduced travel burden; high patient satisfaction
Ghana	7 (13%)	Observational; Cross-sectional	60–280	Tele-ENT; Teleconsultation	Improved follow-up adherence; task-shifting
Ethiopia	6 (12%)	Cohort; Pilot	80–340	Teleconsultation; Remote audiology	Increased coverage; workforce upskilling
Other (Uganda, Tanzania, Cameroon, Senegal, Zimbabwe, Zambia)	6 (12%)	Mixed	45–200	Variable modalities	Variable outcomes

Table 2. Tele-ENT Applications by Subspecialty. Individual study citations are provided in Supplementary Table S1.

Subspecialty	Telemedicine Application	Clinical Use Cases	Technology Platform	Evidence Level
Otology & Audiology	Tele-audiology; Digital otoscopy	Hearing threshold assessment; Otitis media screening; Cerumen management	Smartphone otoscopes; Cloud-based audiometry	High (RCT, Cohort)
Rhinology & Sinusitis	Teleconsultation; Store-and-forward imaging	Chronic rhinosinusitis; Allergic rhinitis; Post-operative follow-up	Video platforms; Image transmission apps	Moderate (Cross-sectional)
Laryngology & Voice	Remote voice analysis; Video laryngoscopy	Dysphonia evaluation; Vocal cord pathology; Laryngeal cancer surveillance	AI-assisted voice analysis; Telelaryngoscopy	Moderate (Pilot studies)
Head & Neck Oncology	Remote follow-up; Teleconsultation	Cancer survivorship; Post-treatment wound assessment; Palliative care coordination	Video consultation; Mobile platforms	Moderate (Observational)
Paediatric ENT	mHealth screening; Teleconsultation	Neonatal hearing screening; Adenotonsillar disease; Cleft palate care	Community health worker apps	Moderate (Pilot, Cohort)
Vestibular & Balance	Remote assessment; Telerehabilitation	Dizziness evaluation; Vestibular rehabilitation	Video-based vestibular tests	Low (Pilot)

Table 3. Summary of Clinical Effectiveness Outcomes in Tele-ENT Studies. Effect size ranges represent observed values across individual studies; individual study citations are provided in Supplementary Table S1.

Outcome Domain	Demonstrated Benefit	Magnitude of Effect	Supporting Evidence
Access to specialist care	Significant increase in consultation rates in rural populations	2.3–3.8× increase	RCTs and cohort studies
Travel burden reduction	Marked reduction in patient travel time and associated costs	40–60% cost reduction	Cross-sectional; Cohort
Time to diagnosis	Accelerated specialist review and diagnostic decision-making	Median delay reduced 3–6 weeks	Pilot studies; Cohort
Diagnostic concordance	High agreement between tele-ENT and in-person assessment	85–96% concordance	RCTs
Patient satisfaction	High acceptability and satisfaction with remote care delivery	78–94% satisfaction rates	Cross-sectional
Healthcare worker capacity	Upskilling of primary care and community health workers	Significant competency gains	Observational
Follow-up adherence	Improved adherence to post-operative and chronic disease care	30–45% improvement	Cohort studies
Cost-effectiveness	Lower per-consultation cost vs. in-person specialist visits	20–50% cost saving	Economic analyses

Table 4. Multi-Level Barriers to Tele-ENT Implementation and Proposed Mitigations. Individual study citations are provided in Supplementary Table S1.

Barrier Domain	Specific Challenge	Affected Countries	Severity	Proposed Mitigation
Digital Infrastructure	Unreliable electricity; limited broadband; high mobile data costs	Most SSA countries	Critical	Solar-powered solutions; offline-capable apps; subsidised data
Regulatory & Legal	Absence of telemedicine legislation; unclear licensure; data protection gaps	Nigeria, Ghana, Ethiopia	High	National policy frameworks; ECOWAS digital health harmonisation
Workforce & Training	Limited digital literacy; shortage of tele-ENT facilitators; workflow resistance	Kenya, Uganda, Tanzania	High	Standardised tele-ENT curricula; mentorship programmes
Financial & Economic	High setup costs; donor-dependent funding; absence of reimbursement codes	Most SSA countries	High	PPP models; national health insurance integration; development finance
Sociocultural	Patient preference for in-person care; trust deficits; language barriers	Rural communities across SSA	Moderate	Community engagement; community health worker intermediaries
Technological	Device availability; software interoperability; data security vulnerabilities	All countries	Moderate	Open-source platforms; device leasing; cybersecurity training
Quality & Safety	Diagnostic limitations; medico-legal liability; absence of clinical guidelines	All countries	Moderate	Clinical practice guidelines; hybrid care models; liability frameworks

4.2. Tele-Audiology: The Flagship Application

Tele-audiology consistently emerged as the most robustly evidenced and widely deployed tele-ENT application across the review. This is attributable to several factors: the high prevalence of hearing impairment in the region (estimated at approximately 34 million people in Sub-Saharan Africa based on WHO global hearing report data [4]); the availability of validated, portable audiometric devices compatible with smartphones [5,6]; and the relative technical simplicity of remote pure-tone audiometry compared with other ENT examinations.

South African studies — including from the University of Pretoria's tele-audiology programme [7,8] — have generated high-quality RCT evidence demonstrating equivalence between synchronous and asynchronous tele-audiological assessments and in-person gold-standard testing, with diagnostic concordance rates exceeding 90% for both pure-tone averages and speech recognition thresholds. Community-based tele-audiology deployed *via* community health workers in rural South Africa demonstrated the feasibility of task-shifting audiological screening without compromising accuracy, with significant implications for neonatal hearing screening programmes nationwide [6,7].

The integration of artificial intelligence (AI) and machine learning algorithms into audiometric data interpretation represents the frontier of this field. Preliminary Nigerian and Ghanaian pilot data suggest that AI-assisted interpretation of otoscopic and audiometric findings may approach specialist-level accuracy for common pathologies such as chronic suppurative otitis media and conductive hearing loss in selected study populations; however, these findings are based on small pilot studies and require validation in larger, more diverse cohorts before conclusions about real-world diagnostic equivalence can be drawn.

4.3. Rhinology and Laryngology: Emerging Evidence

Evidence for tele-rhinology and tele-laryngology, while less robust than tele-audiology, is accumulating. Store-and-forward teleconsultation for chronic rhinosinusitis management has demonstrated significant reductions in time to diagnosis and unnecessary antibiotic prescribing in Kenyan primary care settings, with high concordance between remote specialist assessment and subsequent in-person evaluation [9,10]. These findings are clinically significant given the high burden of allergic rhinitis and sinusitis in the region and the frequency of inappropriate antibiotic prescribing in primary care.

In laryngology, voice analysis applications leveraging acoustic signal processing algorithms have shown preliminary promise for dysphonia screening, particularly for laryngeal cancer early detection — a critical need given that over 80% of head and neck cancers in Sub-Saharan Africa are reportedly diagnosed at advanced stages [11]. While this technology remains in early-phase evaluation, its potential to improve cancer outcomes through earlier diagnosis is compelling.

4.4. Head and Neck Oncology: Telemedicine for Cancer Care

Head and neck cancer survivorship monitoring represents an underexplored but potentially high-impact application of telemedicine in the region. Remote follow-up *via* video consultation has been shown to reduce the frequency of unnecessary in-person visits while maintaining surveillance quality for post-treatment patients in Nigerian and Ethiopian tertiary centres [10,12]. Critically, telemedicine enables the extension of specialist oncological oversight to patients who would otherwise lose contact with the healthcare system after initial treatment due to distance and cost constraints.

The integration of telemedicine with existing palliative care networks in countries such as Kenya and Uganda merits further investigation, given the high proportion of ENT cancer patients who present in incurable stages and require community-based supportive care.

4.5. Barriers to Scale: A Systems Analysis

The barriers identified in this review are consistent with, but extend beyond, those documented in telemedicine literature from other low- and middle-income country (LMIC) settings [13]. While infrastructure deficits — particularly unreliable electricity and internet connectivity — represent the most frequently cited constraint, this review highlights that regulatory fragmentation and the absence of enabling policy environments may be equally critical limiting factors.

At present, fewer than 30% of Sub-Saharan African countries have enacted formal telemedicine legislation or national digital health strategies that explicitly accommodate tele-ENT service delivery [14,15]. This regulatory vacuum creates uncertainty around medico-legal liability, cross-border prescribing, data privacy compliance, and health insurance reimbursement — collectively deterring private sector investment and health system integration [14,16,17]. High mobile data costs across much of the region further compound these barriers by constraining patient and provider access to bandwidth-dependent platforms [18].

The sociocultural dimension of telemedicine adoption deserves particular attention. Several studies identified persistent patient preference for in-person consultation, rooted in cultural beliefs about the diagnostic validity of physical examination and trust in face-to-face patient–clinician relationships. Effective community engagement strategies, delivered through trusted community health workers and traditional leaders, are essential preconditions for equitable tele-ENT uptake, particularly in rural and peri-urban communities.

4.6. Facilitators and Success Factors

Against this complex backdrop of barriers, several facilitating factors have been associated with successful tele-ENT implementation. Mobile phone penetration exceeding 70% in many Sub-Saharan African countries provides a foundational infrastructure for mHealth applications that does not require fixed broadband [19]. Task-shifting models that engage community health workers as tele-ENT facilitators have consistently demonstrated feasibility and acceptability [7,9]. Partnership models linking academic medical centres with district hospitals *via* hub-and-spoke teleconsultation networks have shown sustainability advantages over vertical, donor-funded programmes [12,20].

Political will and national health system leadership emerged as the most powerful facilitator of successful programmes. Countries with designated digital health units within their Ministries of Health — notably Rwanda and Ghana — demonstrated more coherent tele-ENT integration than those relying solely on civil society or NGO-led initiatives, reflecting broader regional disparities in digital health workforce capacity [21].

4.7. Geographic Representation and Generalizability

The geographic distribution of included studies raises important questions about the generalizability of findings to the broader Sub-Saharan African region. Five countries — Nigeria, South Africa, Kenya, Ghana, and Ethiopia — contributed over 88% of the included evidence. These nations share relatively more developed academic medical infrastructure, established medical schools, and active research cultures compared with many other Sub-Saharan African countries. Accordingly, the evidence base may disproportionately reflect contexts where conditions for tele-ENT are already more favourable, potentially overestimating transferability to lower-resource, less digitally connected settings. Francophone Sub-Saharan African countries — including those of the ECOWAS and CEMAC blocs — are markedly underrepresented, as are Lusophone nations such as Mozambique and Angola. This underrepresentation likely reflects differential publication rates rather than an absence of tele-ENT activity, and constitutes a form of geographic publication bias that future reviews should seek to correct. Targeted research efforts, including studies in Portuguese and local languages, are needed to characterize the full landscape of tele-ENT across the continent.

4.8. Study Quality and Its Influence on Conclusions

Quality assessment using the Mixed Methods Appraisal Tool (MMAT) revealed a heterogeneous evidence base spanning a broad range of methodological rigour. Of the 52 included studies, 8 (15%) were randomised controlled trials and received the highest MMAT ratings; 12 cohort studies (23%) achieved moderate-to-high scores. However, the majority of the evidence base comprised cross-sectional surveys (n=18, 35%) and pilot or feasibility studies (n=10, 19%), many of which had limited sample sizes, short follow-up durations, and absence of control comparators, resulting in low-to-moderate MMAT scores. Four mixed-methods studies (8%) scored variably depending on the rigour of their qualitative components. Full individual MMAT scores and risk-of-bias ratings for all 52 studies are provided in Supplementary Table **S1**. The overall pattern of study quality has several important implications for the conclusions of this review. First, the effectiveness estimates presented in Table **3** — while consistently positive — derive predominantly from observational and pilot-level evidence, and should be interpreted with caution pending replication in larger, controlled trials. Second, the robustness of conclusions varies substantially by subspecialty: tele-audiology benefits are supported by higher-quality RCT evidence [7,8], while tele-laryngology and tele-oncology findings rest almost exclusively on observational and pilot data. Third, risk of bias arising from non-blinded assessment, convenience sampling, and self-reported outcomes is prevalent across the included cross-sectional studies, which may inflate satisfaction and access estimates. These quality considerations are incorporated into the evidence-level ratings assigned in Table **2** and are reflected in the tempered language used throughout the Discussion.

4.9. Limitations of This Review

Several limitations of this review warrant acknowledgement. First, the substantial methodological heterogeneity of included studies precluded quantitative meta-analysis, limiting the precision of effectiveness estimates. Second, the evidence base is heavily concentrated in five countries (Nigeria, South Africa, Kenya, Ghana, and Ethiopia), which raises concerns about the generalizability of findings to the broader Sub-Saharan African region. Countries with less developed academic publishing infrastructure — particularly Francophone and Lusophone nations — are likely underrepresented, constituting a form of geographic publication bias that may inflate apparent regional effectiveness. Third, unsuccessful or prematurely terminated tele-ENT programmes may be underrepresented in the published literature, further skewing the evidence toward positive outcomes. Fourth, the review was restricted to English and French publications, potentially omitting relevant evidence in Portuguese or indigenous language literature from Lusophone African countries such as Mozambique, Angola, and Guinea-Bissau. Finally, the rapidly evolving digital health landscape means that some findings may already be superseded by more recent technological developments not yet captured in formal publications.

5. CONCLUSION AND POLICY RECOMMENDATIONS

The available evidence indicates that telemedicine is a potentially clinically effective, cost-efficient, and operationally viable strategy for expanding access to otorhinolaryngological care across Sub-Saharan Africa, though findings are predominantly from a limited number of countries and study designs vary in rigor. The evidence synthesized in this review suggests that tele-ENT interventions can substantially improve specialist access, reduce diagnostic delays, enhance patient outcomes, and build primary care workforce capacity in resource-limited settings.

However, realizing the full potential of tele-ENT at scale requires a paradigm shift from project-based implementation to systematic health system integration. The following policy and research recommendations are proposed:

Table 5. Policy and Implementation Recommendations for Tele-ENT Scale-Up in Sub-Saharan Africa.

Recommendation Domain	Specific Action	Priority	Responsible Stakeholders
Policy & Regulation	Enact national telemedicine legislation with ENT-specific provisions; develop cross-border consultation frameworks within ECOWAS, EAC, and SADC	Critical	Ministries of Health; WHO AFRO; regional bodies
Infrastructure	Integrate telemedicine connectivity into national health infrastructure plans; prioritise solar-powered facilities in off-grid areas; negotiate subsidised health data tariffs	Critical	Governments; ITU; mobile network operators

Recommendation Domain	Specific Action	Priority	Responsible Stakeholders
Workforce	Develop standardised tele-ENT curricula for ENT specialists, GPs, nurses, and CHWs; integrate telemedicine competencies into undergraduate medical education	High	Medical schools; national medical associations; MOH
Financing	Integrate tele-ENT consultations into national health insurance benefit packages; develop sustainable PPP financing models; mobilise development finance for digital health infrastructure	High	MOH; health insurance schemes; development banks
Research	Conduct multicentre RCTs on clinical effectiveness for priority conditions (hearing loss, head and neck cancer, otitis media); develop ENT-specific telehealth quality indicators	High	Academic institutions; research funding bodies; WHO
Technology	Develop open-source, low-bandwidth tele-ENT platforms optimised for SSA contexts; invest in AI-assisted diagnostic tools validated on local patient populations	Moderate	Tech developers; academic centres; NGOs
Equity	Design targeted tele-ENT programmes for women, children, rural communities, and people with disabilities; deploy community health workers as equity bridges	High	MOH; civil society; UNICEF; WHO

In conclusion, the available evidence suggests that telemedicine has substantial technical capacity to improve ENT care delivery in Sub-Saharan Africa, though the quality and volume of evidence varies across subspecialties and settings. What remains is the political commitment, regulatory architecture, and sustained financing to convert that capacity into universal, equitable access to specialist ear, nose, and throat care for all people across the region.

AUTHORS' CONTRIBUTIONS

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

CONSENT FOR PUBLICATION

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CONFLICT OF INTEREST

The author confirms that this article's content has no conflict of interest.

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SUPPLEMENTARY MATERIAL

Supplementary material is available on the publisher's web site along with the published article.

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