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SYSTEMATIC REVIEW

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Costs in dental care: a scoping review of methodologies and trends

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Abstract

Background Oral diseases remain among the most widespread non-communicable conditions globally, disproportionately affecting low- and middle-income populations. Despite the substantial and rising financial burden—estimated at US$ 298 billion in 2010—existing cost studies in dentistry often omit indirect costs and lack methodological consistency. These gaps hinder fair reimbursement, cost-effectiveness modeling, and equitable resource allocation. This scoping review aimed to map current methodologies for dental cost estimation, identify how frequently and by what means overhead costs are incorporated, extract standardized unit costs for common procedures, and assess the sources and valuation techniques underpinning these estimates.

Methods Following an a priori protocol registered with the Isfahan University of Medical Sciences Ethics Committee (Approval Code: IR.MUI.RESEARCH.REC.1402.1), we conducted a comprehensive search across six major databases and gray literature sources. Studies were screened using the Participants–Concept–Context (PCC) framework. Eligible studies were original economic evaluations in dentistry that reported detailed cost data. Data extraction was performed using customized charting forms, and all reported costs were standardized to 2024 international dollars (Int'l $) using exchange rates, U.S. Consumer Price Index (CPI) data, and purchasing power parity (PPP) adjustments. Results are reported in accordance with the PRISMA-ScR guidelines.

Results Out of 31,619 retrieved records, 124 studies met inclusion criteria. Most studies were conducted in urban, high-income settings and reported only direct costs (58.1%), while fewer accounted for overheads (41.9%). Advanced allocation techniques such as Activity-Based Costing (ABC) or Time-Driven ABC (TD-ABC) were used in less than 10% of studies. Bottom-up valuation was the predominant approach (72.5%). Unit costs for frequently reported procedures showed wide variation (e.g., surgical tooth removal: Int'l $6–501), driven by methodological and contextual heterogeneity.

Conclusions Despite increasing interest in dental cost estimation, major gaps remain—especially in rural settings, overhead cost inclusion, and methodological transparency. Standardizing costing frameworks, piloting ABC/TD-ABC in real-world settings, and developing open-access dental cost repositories could substantially improve future economic evaluations and reimbursement equity. This review offers a comparative foundation for dentists, researchers, and policymakers to support value-based oral health planning.

Keywords Costs and cost analysis, Dental economics, Dental fees, Health care costs, Dental care

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Background

Oral diseases are among the most pervasive non-communicable conditions, affecting an estimated 3.9 billion people, roughly half of the world's population. The World Health Organization (WHO) lists untreated caries in permanent teeth as the single most prevalent health problem, while severe periodontitis and complete tooth loss occupy positions within the top-twenty global burdens. Globally, direct spending on dental treatment was estimated at US $298 billion in 2010, approximately 4.6% of total healthcare expenditure—and is projected to rise steeply as populations age, restorative technologies proliferate, and aesthetic expectations increase [1, 2]. To effectively manage this staggering financial burden, health systems and policymakers require accurate evidence on costs.

Generating accurate cost evidence in dentistry, however, is far from straightforward. Studies diverge markedly based on two fundamental valuation strategies: top-down and bottom-up costing. Top-down approaches begin with a clinic's total budget and split those expenses down to individual services. Bottom-up methods do the opposite, building a total cost by identifying and adding up every resource—like staff time and materials—used for a single patient. A major challenge in either approach is accounting for overhead costs: the essential inputs like administrative salaries, utilities, rent, and sterilization that keep a clinic functioning but cannot be traced to a single patient encounter. While the direct costs of a procedure are visible, these indirect overhead items can represent 15% to 60% of the true cost, making their allocation and measurement critical.

To tackle the critical task of overhead allocation, methodologies range from simple estimates to more precise, activity-based approaches. The most basic method involves using straightforward proportional rules, such as distributing rent and utility costs based on clinic floor space or staff numbers. However, to achieve greater accuracy, more advanced techniques have been developed. Activity-Based Costing (ABC), for instance, provides a more granular picture by identifying all clinical and administrative activities and assigning overheads based on how much each activity consumes those resources. A more recent variant, Time-Driven ABC (TD-ABC), streamlines this process further by using the duration of each task as the primary driver for cost allocation. While these advanced methods aim to calculate both direct and overhead costs and estimate a more accurate unit cost, the choice of methodology significantly impacts the final estimate, creating challenges for comparing costs across different studies.

Beyond allocation, dental economics researchers also utilize complementary frameworks, such as value-based cost-effectiveness analyses to integrate patient outcomes, break-even analyses to determine minimum operational viability, and model-based techniques (decision trees, Markov models) to simulate long-term cost trajectories under alternative clinical scenarios (see Table 3 for an overview of these cost estimation methods in Appendix 2) [3–7]. This methodological heterogeneity, spanning from foundational costing techniques to broader economic models, creates significant challenges for evidence synthesis and underscores the urgent need for a comprehensive scoping review.

For practicing dentists, this methodological complexity has tangible implications. A key example is the practice of pricing services according to empirically measured, comprehensive unit costs rather than historical or arbitrary tariffs. Alongside chair-time benchmarking and investment appraisal, depends critically on accurately knowing procedure-specific costs, inclusive of both direct clinical and indirect operational resources [8]. Similarly, researchers conducting economic studies cannot credibly model cost estimation if unit costs differ substantially merely because of methodological discrepancies [9]. Policymakers face a related challenge too, insurance tariffs and public subsidies that neglect overheads risk undercompensating providers, discouraging their participation, and ultimately exacerbating inequities in service access [10].

Previous literature has explored the economic dimensions of dentistry from several angles but has not yet mapped the foundational cost estimation methodologies themselves. Syntheses of prior research have largely focused on the cost-effectiveness of specific interventions, the determinants of service utilization, and patient preferences. A significant body of work has concentrated on single preventive interventions, with reviews consistently finding that community water fluoridation (CWF) and school-based programs using fluorides and sealants are cost-effective or even cost-saving [11–14]. Methodologically, these evaluations are dominated by cost-effectiveness analysis; a 2019 scoping review by Eow et al. found that 75% of full economic evaluations fell into this category [15]. Another research stream examines factors driving inequalities in dental services, showing that utilization is heavily influenced by individual determinants like age and race, social factors like education, and economic status such as income and insurance coverage [16]. This body of research shows that dental care is geographically concentrated in high-income countries. A third field uses Willingness-to-Pay (WTP) methods to gauge patient preferences, but reviews note this area has significant methodological weaknesses, such as the frequent use of convenience samples, that limit generalizability [17]. While these streams of research are valuable, they sidestep the fundamental question of how the costs of dental services are calculated. Even the most relevant prior reviews, which focused on full economic evaluations, emphasized solely the outcomes of economic evaluations rather than the underlying methods used for measuring the costs of inputs and resources.

This scoping review is justified by a critical gap in the literature, as no previous review has systematically examined all economic studies within dental practice with a cost estimation framework. Furthermore, there is no existing evidence that details how economic studies within dental practice categorize and calculate direct versus overhead costs, or the specific methods used to allocate them. Similarly, no prior study has undertaken the task of extracting and standardizing the unit costs for a wide variety of dental services as reported in the literature.

Therefore, this scoping review aims to map methodological approaches utilized in dental cost estimation; quantify the frequency and methods of overhead cost allocation; standardize reported unit costs to facilitate robust cross-study comparisons using 2024 international dollars; and document valuation methods underpinning dental cost estimates. Through these objectives, we aim to illuminate methodological heterogeneity, highlight critical evidence gaps—particularly in rural and underserved contexts—and establish a transparent, comparative foundation for dentists and researchers interested in implementing rigorous economic evaluations and studies.

Materials and methods

Protocol and registration

This scoping review was conducted following an a priori protocol registered and approved by the ethics committee of Isfahan University of Medical Sciences (Approval Code: IR.MUI.RESEARCH.REC.1402.1; Date: April 9, 2023). Clinical trial number: not applicable, as this review did not involve human participants or clinical interventions.

Eligibility criteria

Eligibility criteria were structured using the Participants, Concept, Context (PCC) framework, with participants limited to studies explicitly evaluating the costs of dental services within healthcare systems, thus excluding those adopting societal or patient perspectives due to their broader cost implications. The concept included studies explicitly reporting detailed cost data, distinguishing direct and overhead (indirect) costs or providing unit costs for dental procedures; studies lacking detailed cost breakdowns or reporting solely clinical outcomes were excluded. The context encompassed all settings offering dental services (private practices, hospital-based services, public clinics, outreach/mobile units) across all specialties recognized by the American Dental Association (ADA), excluding studies unrelated to dentistry, such as general medical services. Additional criteria required studies to be original economic analyses (costing studies or partial economic evaluations) published in English or Persian, available as full-text articles online; systematic reviews, narrative reviews, commentaries, and editorials were excluded to maintain focus on primary economic data.

Information sources and search

A comprehensive search strategy was developed and conducted in October 2024 across six major electronic databases (PubMed, Scopus, Institute for Scientific Information (ISI) Web of Science, Ovid, Embase, and ProQuest) and Google Scholar for gray literature. The search combined controlled vocabulary (e.g., Medical Subject Heading (MeSH) terms) and free-text keywords, systematically covering cost-related concepts (e.g., cost analysis, economic evaluation, activity-based costing, micro-costing) and dental-specific terms (e.g., dental health services, orthodontics, prosthodontics). The full, replicable search strategy for PubMed and adaptations for other databases are provided in Appendix 1.

Selection of sources of evidence

All identified records were imported into Mendeley Reference Manager, with duplicates systematically removed. Two independent reviewers conducted pilot screening of randomly selected records to ensure consistency. Subsequently, title and abstract screening was independently conducted by both reviewers, guided strictly by the PCC-based eligibility criteria. Discrepancies were resolved through discussion or a third independent reviewer. Eligible studies progressed to full-text screening, applying identical inclusion/exclusion criteria. Reasons for exclusion at this stage (e.g., non-original studies, unavailable full-text, non-English/Persian language, societal or patient perspective, inadequate cost data) were carefully documented. The final selection process is comprehensively illustrated in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram depicted in Fig. 1.

Data charting process

A standardized, structured data-charting process was developed using customized extraction forms created in Microsoft Excel (online version). Given the absence of pre-existing standardized forms specific to dental cost estimation, two tailored forms were designed to comprehensively capture data aligned explicitly with the study's objectives. Data form 1 gathered general information, study characteristics, and detailed methodological data on cost identification, measurement, and valuation. Form 2 was specifically dedicated to systematically collecting

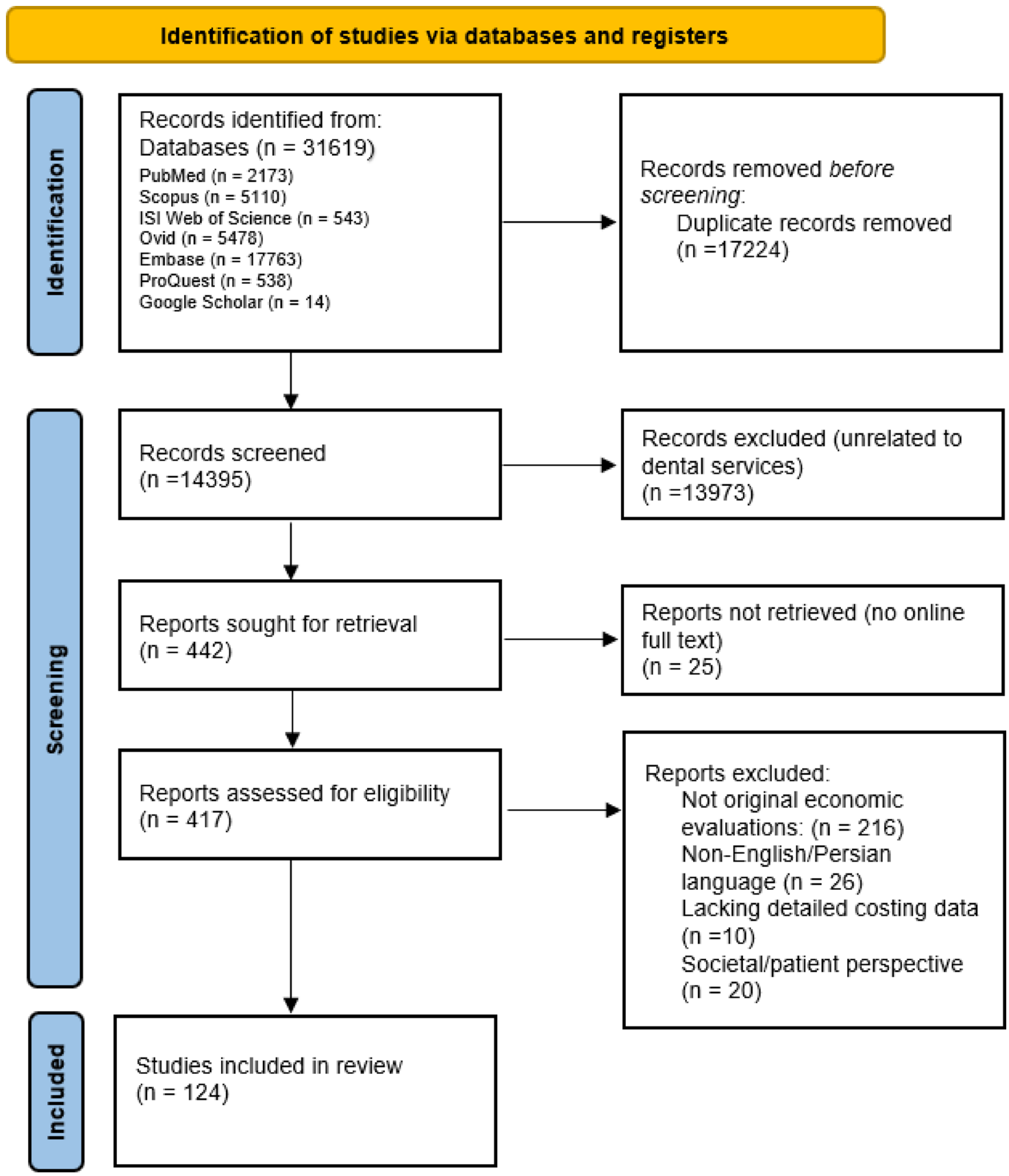

Fig. 1 PRISMA 2020 flow diagram

and organizing reported unit costs across various dental procedures.

Data items

The data-charting forms systematically captured key variables to support the descriptive and comparative analysis of included studies. Form 1 collected detailed bibliographic data (authors, publication year, country, journal), contextual factors (geographical location: urban, rural, or mixed), dental specialties (according to ADA classifications), and a structured assessment of costing methodologies used. Specifically, methodological variables included the type of cost evaluated (direct, overhead), overhead cost allocation methods (traditional vs. activity-based), costing approaches (top-down, bottom-up), the source of cost data (primary data, secondary sources, standardized cost references, expert opinions), price years, and reported currencies. Form 2 focused exclusively on recording detailed unit cost data for dental procedures, structured in a matrix format to facilitate direct comparisons between studies. Each distinct dental procedure formed one row, and each included study was represented in separate columns, clearly displaying unit cost variability across different studies.

Critical appraisal of individual sources of evidence
Given the descriptive nature and broad methodological scope of this scoping review, a critical appraisal of the methodological quality of individual studies was not conducted, consistent with standard scoping review methodology.

Synthesis of results
Extracted data were managed, analyzed, and synthesized using Microsoft Excel to ensure comprehensive descriptive and comparative analysis. The synthesis focused on identifying key trends in the literature regarding dental specialties and settings, methodological approaches used for cost estimation (direct vs. overhead costs, top-down vs. bottom-up methods, and overhead allocation methods), and the diversity of data sources utilized. To standardize costs across studies, we converted the reported values into international dollars (int'l $) for 2024. This involves three steps: converting the original currency to the U.S. dollar (USD) via historical exchange rates, adjusting for U.S. inflation to align with 2024 prices based on U.S. consumer price index (CPI) data from sources such as the U.S. Bureau of Labor Statistics, and then applying the 2024 purchasing power parity (PPP) conversion factor. This approach ensures that all costs reflect equivalent global purchasing power, enabling consistent cross-country and temporal comparisons. The results were presented in detailed tabular and graphical formats, clearly illustrating cost variability, methodological preferences, and trends across different contexts and procedures.

Results
Selection of sources of evidence
The initial search of databases retrieved 31,619 records (PubMed, Scopus, ISI Web of Science, Ovid, Embase, ProQuest, and Google Scholar). After removing duplicates (n = 17,224), 14,395 unique records underwent initial screening by two independent reviewers. During this stage, 13,973 studies unrelated to dental service costing were excluded. Consequently, 442 studies proceeded to full-text review. Of these, 25 reports lacked accessible full-text versions, leaving 417 studies for eligibility assessment. Subsequently, 216 articles were excluded for not being original economic studies, 26 for language issues, 10 due to insufficient costing details, and 20 due to societal/patient perspectives. Ultimately, 124 studies met all eligibility criteria and were included for final analysis (see Fig. 1 for the PRISMA flowchart).

Characteristics of included studies
Included studies were published between 1973 and 2024, with a median publication year of 2017. A pronounced increase in publication frequency is evident from 2010 onward, reflecting the growing interest in cost estimation within dental services and highlights peak publication activity between 2016 and 2022. Geographically, the United States contributed the largest share (27.4%) of studies, followed by Brazil (9.6%), Germany (7.2%), and England (7.2%). Most studies were conducted in urban settings (85.4%), with public/community dental clinics (27.4%) being the most common study sites, followed by academic/university-affiliated clinics (21.7%) and hospital-based departments (14.5%), as detailed in Appendix 2 (Table 4). This diverse setting distribution reflects both global research interest and variations in service delivery models that impact dental cost estimation.

Dental specialties and subfields
The distribution of included studies across dental specialties shows dental public health dominated the landscape, comprising 41.1% of studies and encompassing subfields such as health policy and advocacy (19 studies), epidemiology (18 studies), and community-based prevention programs (14 studies). Prosthodontics was the second most represented specialty at 19.4%, split between removable (13 studies) and fixed prosthodontics (11 studies). Other specialties were less frequently analyzed: Oral/Maxillofacial Surgery (9.7%), Endodontics (7.3%), Orthodontics/Dentofacial Orthopedics (7.3%), Pediatric Dentistry (4.8%), Periodontics (5.6%), and Dental Anesthesiology (2.4%). Detailed counts and references for these subfields are provided in appendix 2 (Table 5).

Cost types, allocation, and valuation methods
Among the 124 included studies, direct costs—covering clinical procedures, materials, and professional fees—were reported in 72 studies (58.1%), while overhead costs (administrative support, utilities, facility maintenance) appeared in 52 studies (41.9%). Traditional overhead allocation methods (e.g., apportioning by hours or floor space) were most common (45 studies; 36.3%), with advanced techniques such as Activity-Based Costing (ABC) used in just 7 studies (5.6%). For valuation, the bottom-up approach prevailed, applied in 90 studies (72.5%) to provide granular, itemized cost assessments, whereas the top-down method—relying on aggregated financial data—was used in 33 studies (26.6%). Detailed frequencies for cost types, overhead allocation, and valuation methods are summarized in Table 1. This table presents the frequency of studies for each characteristic. The column "Number of studies (citation numbers)" shows the total count of studies in that category, with the associated reference numbers listed in parentheses for transparency and traceability.

Methodological landscape of economic evaluations
The included studies were categorized based on their economic evaluation type and the analytical approach

Table 1 Characteristics of costs

Characteristic	Category	Number of studies (citation numbers)
Type of included costs	Direct costs	72 [1, 18–87], [146]
	Overhead costs	52 [2, 10, 11, 88–136]
	Not applicable	72 [1, 18–87], [146]
Overhead cost allocation method	Traditional cost allocation	45 [10, 11, 88, 90, 91, 93, 95, 96, 98–121, 123–129, 131–136]
	Activity-based costing (ABC)	7 [2, 89, 92, 94, 97, 122, 130]
Valuation method	Bottom-up	90 [1, 10, 11, 18, 20–23, 25–30, 32–36, 38, 41, 43–53, 55–73, 75, 76, 78–82, 84–87, 90, 93, 95, 96, 98, 99, 101, 106, 109, 112, 114–120, 123–126, 128, 129, 131, 133–135], [146]
	Top-down	33 [2, 19, 24, 31, 37, 39, 40, 42, 74, 77, 83, 88, 89, 91, 92, 94, 97, 100, 102–105, 107, 108, 110, 111, 113, 121, 122, 127, 130, 132, 136]
	Not applicable	1 [54]

used. A clear distinction was found between studies performing a comprehensive comparison of alternatives versus those focused only on costing. Of the 124 studies, a majority (64%, n = 79) were identified as Full economic evaluations, where two or more interventions were compared on both costs and consequences. The remaining 36% (n = 45) were Partial Economic Evaluations (costing studies). Among full economic evaluations, Cost-effectiveness analysis (CEA) was the most common specific design, while Cost analysis or Cost description was the most frequent among partial evaluations.

Analysis of methodological approaches

The analytical approaches used to conduct economic evaluations in the included literature varied significantly, with studies being primarily retrospective (41%), model-based (31%), or trial-based (28%). A strong correlation was observed between the evaluation type and the analytical approach used. Full economic evaluations, which compare the value of different interventions, frequently used model-based or trial-based analytical approaches. In contrast, partial economic evaluations, which focus on quantifying costs, were overwhelmingly conducted using retrospective analysis of historical data. Trial-based evaluations are those where economic data on costs and consequences are collected prospectively from participants enrolled in a single clinical study, most often a Randomized controlled trial (RCT). This approach, often called a "piggyback" study, provides high-quality evidence by linking costs and outcomes directly to the same patient cohort under controlled conditions. CEA was used to compare costs and clinical effectiveness of interventions. For example, the trial-based CEA by Hichens et al. (2007) used a large RCT to show that vacuum-formed orthodontic retainers were a "dominant" strategy—both less costly and clinically more effective—than Hawley retainers, providing strong evidence for a change in clinical practice [137]. Cost-Minimization Analysis (CMA) was the appropriate design when clinical trials assumed no significant difference in the effectiveness of the compared interventions. The study by Joda & Brägger (2015) is a key example; using a powerful crossover RCT design, the authors demonstrated that a digital workflow for implant crowns was significantly less costly in terms of time and materials than the conventional workflow, for a clinically equivalent outcome [138].

Hybrid trial-based and modeling approaches

Some studies used trial data as the primary input for a simulation model to analyze uncertainty. For instance, Olegário et al. (2020) conducted an RCT comparing different glass ionomer cements for ART restorations. They then used the cost and survival data from their trial to power a Monte Carlo simulation model, which confirmed that the higher initial cost of the standard material was justified by its superior long-term survival, making it the most cost-effective option [139].

Model-based evaluations

Model-based evaluations use mathematical or computer-based simulations to project costs and outcomes over time, often for a hypothetical cohort of patients. This approach is essential for estimating the long-term value of interventions when long-term trial data is unavailable. The most common model types were Markov models and decision trees. Markov Models simulate the movement of a cohort between different health states (e.g., "healthy," "diseased," "treated") over a series of time cycles, making them ideal for chronic diseases. The CUA by Naved et al. (2024) is a classic example, using a Markov model to project the lifetime cost per Quality-Adjusted Life-Year (QALY) gained for different endodontic treatments [140]. Similarly, Schwendicke et al. (2017) used a Markov model powered by real cohort data to analyze the cost-effectiveness of different strategies for managing periodontally affected molars [141]. Decision Trees map out short-term clinical decisions and their potential outcomes based on branching probabilities. The CEA by Jameson et al. (2007) provides a clear example, using a simple decision tree to calculate the average cost of sedation by incorporating the probability and high cost of treatment failure that would require a subsequent hospital-based general anesthetic [142]. Budget Impact Analysis (BIA) modelling was used to forecast the financial impact of an intervention on a large healthcare system. For example, Du et al. (2021) used a BIA model to estimate the total annual cost savings to the entire Chinese dental care system if the population increased its use of sugar-free gum [143]. Breakeven Analysis was used to determine the point at which an investment becomes profitable. Murdock et al. (2010) used this approach to model the number of Medicaid patients an orthodontic practice would need to treat to cover its overhead costs, directly addressing a key financial barrier to provider participation [4].

Cost estimation (costing) studies

Cost estimation studies, which focused on quantifying costs rather than comparing value, predominantly used retrospective analysis of existing data. Cost-of-Illness (COI) Studies aimed to quantify the total economic burden of a disease. A key example is McArdle et al. (2016), who built a cost projection model to estimate the total annual cost to the UK's NHS of treating a specific third molar complication, thereby making a policy argument for prevention [144]. Another unique example is Colthirst et al. (2013), who performed a retrospective COI study by analyzing military records to determine the total operational cost of dental emergencies in a combat zone, which included the cost of soldiers' lost time. Cost-Description and Cost-Analysis Studies focused on the costs of specific services or technologies, using a variety of costing methods [145]. A prime example of high-quality costing is the prospective micro-costing study by Dassonville et al. (2017), which meticulously tracked every resource used to determine the cost of a single complex surgical procedure [88]. In contrast, Jones et al. (2019) used a model-based cost-analysis to assess the profitability of different office-based surgical procedures from a private practice perspective [89].

This methodological diversity demonstrates that the field of dental health economics uses a wide and sophisticated range of analytical tools to answer different types of clinical and policy questions, from assessing the long-term value of a new technology to quantifying the real-world cost of a single procedure.

Advanced costing methodologies: ABC and TD-ABC

Among the included studies, a small but significant subset (n = 8) moved beyond traditional costing methods to employ advanced accounting techniques for more precise cost allocation. These studies utilized either ABC or its more recent evolution, TD-ABC to provide a granular analysis of resource consumption.

Activity-based costing

ABC is a top-down-micro costing method that identifies all the discrete activities required to deliver a service and allocates costs to those specific activities. The total cost of the service is the sum of the costs of all activities consumed, providing a more accurate picture than traditional methods that use broad overhead percentages. The study by Tewfik et al. (2021) provides a clear example of ABC in a hospital setting. To determine the true cost of orthognathic surgery, the authors used their hospital's existing ABC system. This system calculated the cost of a single patient's hospitalization by summing the costs from three distinct "activity centers" the patient passed through: the inpatient ward, the surgery/operating room, and other hospital services. Each center had its own detailed cost items (e.g., medical personnel, nursing staff, drugs, devices). This allowed for a precise calculation of the total direct hospital cost, which was then compared to the inadequate national tariff, highlighting a major policy issue [18].

Time-driven activity-based costing

TD-ABC is a refined version of ABC that simplifies the process by focusing on the single most valuable resource: time. It involves two steps: 1) calculating a "capacity cost rate" (e.g., cost per minute) for each resource (such as a clinician, an assistant, or a specific clinical space), and 2) multiplying that rate by the amount of time the resource was used for a particular patient or procedure. This method was used in two key studies to analyze the cost of complex surgical planning, demonstrating its adaptability to different study designs, for example a Prospective Study by Ganske et al. (2021) used TD-ABC to compare the cost of two different presurgical infant orthopedic techniques. Researchers prospectively followed patients and, using stopwatches, timed every single step of the clinical encounter in real-time. They created detailed process maps of the patient journey and calculated the capacity cost rate for each staff member and facility type. The final cost was determined by multiplying the time spent on each activity by the corresponding cost rate. This provided a highly accurate, real-world cost for each treatment pathway [90]. Another study design was employed In a Retrospective Study by Resnick et al. (2016) also used TD-ABC but applied it retrospectively. They analyzed the records of patients who had undergone orthognathic surgery and created a process map for two different planning workflows (standard vs. virtual). For each case, they calculated the time spent on each activity. They then used national salary and overhead data to determine the capacity cost rates for the personnel involved. This allowed them to perform a direct, paired comparison of the two workflows for each patient, demonstrating that the virtual planning method was significantly less costly due to a large reduction in high-cost surgeon time [91]. The use of these advanced costing methodologies, while not common across the entire body of literature, represents a clear move toward more precise, context-sensitive cost estimation in dentistry, driven by the need for both detailed resource tracking and a more accurate understanding of the value of different clinical workflows [18, 19, 90, 92, 93].

Unit costs

The 124 studies reported unit prices for 87 distinct dental services, and the resulting dataset shows pronounced price heterogeneity. Variation stems from differing costing methods, country-specific economic conditions, and even how individual procedures are defined (e.g., “denture fabrication” or “extraction” can involve different clinical steps across studies). Consequently, only a handful of services appear often enough, and with sufficient consistency, to support pooled estimates. Key observations demonstrate high variability in most services which exhibited wide cost ranges (e.g., *dental sealant*: Int’l 7.2–100.7 or tooth removal by surgery: *Int’l*6.33–501.5), reflecting contextual and methodological differences. A subset of services (e.g., *scaling*, *PFM crown per teeth*) showed narrower price ranges, suggesting greater consistency in cost reporting or procedural standardization and Relative homogeneity. All estimates were converted to 2024 International Dollars to improve comparability, though contextual factors (e.g., local labor costs, subsidies) remain critical for interpretation. Detailed information on unit costs is illustrated in Table 2. This table lists up to four cost estimates for each type of dental service reported. The columns “Cost (Int $) Study A–D” represent the first, second, third, and fourth studies that provided a unit price for each type of dental service and the number inside the parenthesis is the study’s citation number in our bibliography.

Table 2 Reported unit costs for dental services (Presented in Int’l $)

Type of service	Cost (Int $) Study A (citation number)	Cost (Int $) Study B (citation number)	Cost (Int $) Study C (citation number)	Cost (Int $) Study D (citation number)
Denture Fabrication	1,372 [20]	539 [21]	577 [94]	-
PFM crown per teeth	219 [19]	263 [95]	144 [96]	439 [22]
Extraction	38.5 [23]	32.5 [95]	162 [24]	198 [97]
Dental Sealant	7.2 [98]	59.9 [93]	100.7 [25]	8.5 [26]
Large Amalgam Restorations	38.3 [99]	116 [8]	109.2 [27]	141.1 [28]
Panoramic Radiograph	23.7 [20]	290 [29]	37 [100]	125.9 [101]
Examination	44.35 [20]	93.89 [99]	43.5 [30]	95 [97]
Tooth Removal by surgery	54.2 [19]	6.33 [21]	501.5 [89]	264 to 440 [144]
Scaling	23.95 [19]	30.47 [23]	32.25 [93]	31.12 [99]
Atraumatic Restorative Treatment (ART)	268.28 [25]	25.07 [31]	20.96 [32]	-

Discussion

Summary of evidence

This scoping review of 124 studies shows that published work on dental-care costs has grown rapidly since 2010 yet remains concentrated in high-income countries and urban centers. Most investigations report only direct clinical expenses; fewer than half measure overheads, and fewer than one in ten use advanced allocation techniques such as ABC or Time-Driven ABC. Consequently, unit prices for identical procedures diverge widely—for example, surgical tooth removal ranged from Int’l $ 6 to $ 501. For dentists, more complete and standardized cost data would enable accurate fee setting, investment decisions, and efficiency benchmarking. For oral-health researchers, consistent reporting would strengthen economic evaluations and multicenter trial budgets. Policymakers could use robust, overhead-inclusive estimates to calibrate reimbursement schedules, safeguard preventive programs, and direct subsidies to underserved regions.

Our finding of a sharp post-2010 rise in dental-economics publications echoes the bibliometric trends noted by Eow et al. (2019) and Beck et al. (2022) who link this growth to escalating health-care expenditure and greater policy demand for cost evidence [15, 33]. Consistent with earlier reviews, high-income nations (United States, Germany, United Kingdom) continue to dominate the field, a pattern commonly attributed to stronger research infrastructure and funding [34]. Nevertheless, the increasing presence of middle-income countries—particularly Brazil and Iran—signals a welcome broadening of geographic scope, albeit still largely confined to urban settings. Like Kalman et al. (2015) and Špacírová et al. (2022), we confirm that most dental studies report only direct costs; fewer than 40% quantify overheads, leading to systematic under-estimation of true economic burden [9, 35]. Traditional proportional allocation remains the norm, while advanced techniques such as ABC and TD-ABC appear in fewer than 10% of studies—a gap also highlighted in wider health-care costing literature [102, 103]. This underutilization persists despite evidence that micro-costing improves accuracy and decision relevance. Our results complement Mogyorosy et al. in showing bottom-up as the preferred valuation strategy [36]. Yet practical constraints—time, data access—often force hybrid approaches that blend micro- and gross-cost elements. The resulting methodological heterogeneity, coupled with divergent data sources and currency conventions, produces the wide unit-cost ranges observed here and in prior work by Lessard et al.[104]. Conversion to international dollars mitigates but does not eliminate cross-country variability, mirroring concerns raised about PPP adjustments in health settings [37, 105, 106].

Although micro-costing (patient-level resource tracing) and gross costing (aggregated averages) are often presented as mutually exclusive [107], the studies we reviewed seldom adhered to each category. Many papers combined detailed time-tracking for chairside labor—characteristic of micro-costing—with broad national fee schedules for overheads, blurring the boundary between the two approaches. Fee structures themselves are opaque: some charges derive from in-house accounting systems, while others reflect bundled market tariffs, and authors rarely disclose the calibration process. Even longitudinal "micro-costing" studies must apportion shared resources such as sterilization or building costs by top-down rules, because measuring each patient's exact share is impractical. With no accepted threshold for how granular data must be to qualify as micro-costing, any strict dichotomy risks misclassification. We therefore focused on valuation method—bottom-up versus top-down—and highlighted explicitly hybrid methods. This choice avoids oversimplifying a field where fully pure micro- or gross-cost studies are the exception rather than the rule.

Several limitations should be considered when interpreting these findings. The analysis included only English- and Persian-language studies, and without formal quality appraisal of the primary literature, methodological weaknesses could influence the synthesis. Significant heterogeneity existed in costing methodologies; studies often blended micro- and gross-costing elements without standardized definitions or transparent fee-schedule construction. Furthermore, inconsistent definitions of cost terms (e.g., "direct," "indirect") and diverse data sources, ranging from hospital ledgers to national fee schedules, likely contributed to cross-study variability. Currency conversions relied on World-Bank PPP factors, which may mask intra-country price variations, lag behind inflation, and potentially distort health-sector prices. Finally, while grey literature was searched, some unpublished work may have been omitted, and the exclusive focus on cost data precludes any conclusions regarding cost-effectiveness.

With these limitations in mind, three priority gaps emerge. First, rural and low-resource settings are almost absent from current costing evidence; dedicated multicenter studies that capture overheads in community clinics are needed to inform equitable reimbursement. Second, fewer than 10% of studies used ABC or TD-ABC; pilot projects that implement these methods—ideally aligned with the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) 2022 reporting checklist would test feasibility and generate reference protocols. Third, cost data are reported in heterogeneous formats. Creating an open, dental-specific cost repository with standard fields (currency year, allocation method, cost components) would enable meta-analysis and benchmarking. Future work should also embed sensitivity analyses for currency conversion and inflation to improve cross-country comparability and pair economic data with clinical outcomes to guide value-based oral-health policy.

Conclusion

Reliable, overhead-inclusive costing is foundational to fair reimbursement, efficient clinic management, and credible oral-health research. Yet current evidence remains fragmented, with indirect costs under-reported and precise allocation methods seldom used. By adopting standardized reporting frameworks, expanding studies to rural and underserved settings, and piloting ABC/TD-ABC in routine practice, the dental community can generate the robust, comparable cost data that dentists, researchers, and policymakers need to deliver financially sustainable, high-quality oral care.

Appendix 1

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Appendix 2

See Tables 3, 4 and 5.

Table 3 Summary of findings on methodologies

Method	Strengths	Limitations	Use cases
Activity-based costing (ABC)	Delivers granular cost tracking by linking expenses to specific clinical activities (e.g., materials, chair time, sterilization)	Requires considerable time investment and granular data collection; challenging in fast-paced clinical workflows	Cost transparency for discrete procedures (e.g., fillings, crowns) and resource optimization in high-volume dental clinics
Time-driven ABC (TD-ABC)	Captures time variability in clinical workflows (e.g., chairside minutes, staff multitasking); enables real-time adaptation to workflow variations	Demands integration with digital tools (e.g., practice management software); requires calibration for dental-specific time metrics	Multistage treatments (e.g., implant placements, orthodontic adjustments) and capacity planning in clinics with fluctuating patient volumes
Value-based cost-effectiveness analysis	Integrates patient-reported outcomes (e.g., oral health-related quality of life) with costs, emphasizing long-term value over episodic care	Relies on subjective metrics (e.g., OHIP-14 scores) that lack standardized valuation for decision-makers; struggles to quantify social determinants (e.g., socioeconomic disparities)	Prioritizing preventive care (e.g., fluoride programs) and chronic disease management (e.g., periodontal therapy); evaluating policy interventions for oral health equity
Break-even analysis	Provides a clear threshold for covering fixed costs (e.g., salaries, rent) in high-overhead dental settings; simplifies financial planning for high-margin procedures	Relies on unrealistic assumptions (linear cost-revenue relationships, static pricing); ignores market competition and demand variability	Evaluating practice startups (e.g., $500 k turnover target for suburban clinics) and new services (e.g., dental implants, in-house membership plans)
Model-based estimations	Integrates diverse datasets (e.g., Medicaid claims, fee schedules, demographics) to simulate long-term outcomes; employs advanced techniques (e.g., Markov models, decision trees) for granular cost projections	Vulnerable to data gaps (e.g., incomplete treatment histories) and heterogeneity in dental coding standards; requires calibration for procedure-specific variables (e.g., caries progression rates)	Predictive cost modeling (e.g., capitation rate design); policy evaluation (e.g., Medicaid reimbursement, water fluoridation programs); long-term sustainability analysis for chronic conditions (e.g., periodontitis)
Decision trees	Provides explainable, flowchart-like models to map clinical pathways (e.g., differential diagnosis of oral ulcers); supports transparent decision-making in time-constrained settings	Struggles with probabilistic outcomes (e.g., variable treatment responses) and oversimplifies multifactorial conditions (e.g., chronic pain syndromes)	Differential diagnosis (e.g., oral mucosal lesions); comparing treatment pathways (e.g., root canal vs. extraction, surgical vs. nonsurgical periodontal therapy)
Markov models	Simulates long-term disease progression (e.g., caries to pulpitis) and cost trajectories, enabling sustainability assessments of preventive vs. curative strategies	Requires precise transition probabilities (e.g., carries recurrence rates) and assumptions about static patient behavior; computationally intensive for multistate scenarios	Evaluating preventive programs (e.g., water fluoridation cost-effectiveness); projecting lifetime costs of chronic conditions (e.g., periodontal disease)

Table 4 Characteristics of the included studies

Characteristic	Category	Number of studies (n = 124)	Percentage (%)
Publication year	Range	[1973]–[2024]	
	Median	[2017]	
Dental specialty	Dental public health	51	(41.1)
	Prosthodontics	24	(19.3)
	[Other Specialties]	49	(39.5)
Geographic location	United States	34	(27.4)
	Brazil	12	(9.6)
	Germany	9	(7.2)
	England	9	(7.2)
	[Other Countries]	60	(48)
Setting	Public or Community Dental Clinic	34	(27.4)
	Academic/University-Affiliated Dental Clinic	27	(21.7)
	Hospital-Based Dental Department	18	(14.5)
	[Other settings]	45	(36.2)
Geographic context	Urban	106	(85.4)
	Rural	9	(8)
	Mixed	10	(6.4)

Table 5 Distribution of disciplines included across specialties

Dental specialty	Subfield within specialty	Frequency
	Health policy and advocacy	19 (8, 26, 32–34, 36, 41, 48, 53, 67–76)
Dental public health	Epidemiology	18 (18, 37, 38, 44, 46, 50, 54, 77–87)
	Community-based prevention programs	14 (24, 43, 45, 88–98)
Prosthodontics	Removable prosthodontics	13 (35, 99–110)
	Fixed prosthodontics	11 (6, 19, 39, 40, 49, 111–116)
Endodontics	Root canal therapy	7 (21, 117–122)
	Endodontic surgery	1 (55)
	Trauma management	1 (120)
Oral/Maxillofacial radiology	Diagnostic imaging	3 (27, 123, 124)
	Corrective jaw surgery (Orthognathic Surgery)	7 (3, 25, 29, 31, 125–127)
Oral/Maxillofacial surgery	Facial trauma reconstruction	4 (42, 128–130)
	Dental implant surgery	1 (28)
Orthodontics/ Dentofacial orthopedics	Braces and clear aligners (Arch alignment)	5 (4, 52, 131–133)
	Craniofacial Orthopedics	4 (30, 134–136)
Pediatric dentistry	Restorative pediatric dentistry	5 (20, 55, 137–139)
	Behavioral management	1 (140)
Periodontics	Gum disease treatment (Periodontal disease treatment)	6 (7, 47, 51, 141–143)
	Implantology	1(51)
Dental anesthesiology	General anesthesia	3 (23, 144, 145)

Abbreviations

ABC	Activity-based costing
TD-ABC	Time-driven activity-based costing
US $	United States Dollar
WHO	World Health Organization
ADA	American Dental Association
CPI	Consumer price index
Int'l $	International dollar
ISI	Institute for Scientific Information
MeSH	Medical subject headings
PCC	Participants, concept, context
PPP	Power purchasing parity
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
USD	United States Dollar
CHEERS	Consolidated Health Economic Evaluation Reporting Standards
PFM	Porcelain-fused-to-metal

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

PT made substantial contributions to the analysis of data and drafting of the manuscript. MR contributed significantly to the conception and design of the work and substantively revised the manuscript. FR played a key role in the design of the study and the interpretation of data. All authors have approved the submitted version of the manuscript and agree to be personally accountable for their own contributions. They also ensure that any questions related to the accuracy or integrity of any part of the work, even those in which they were not personally involved, are appropriately investigated, resolved, and documented in literature.

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Data availability

Data generated or analyzed during this study are included in this published article and its supplementary files. Additionally, any further data or details supporting the findings of this study will be made available at reasonable request to the corresponding author. If required, data will be submitted to the journal or relevant repositories as needed.

Declarations

Ethics approval and consent to participate

The study adhered to a priori protocol, approved by the Ethics Committee of Isfahan University of Medical Sciences (Approval Code: IR.MUI.RESEARCH.REC.1402.1, Date: April 9, 2023). This study does not involve any individual person's data in any form, including personal details, images, or videos. As a scoping review, the research is based entirely on previously published literature and does not include case reports or patient-specific information requiring consent. Consent to participate is "not applicable".

Consent for publication
Consent for publication is "not applicable".

Competing interests
The authors declare no competing interests.

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