

# Dental Erosion Associated with Intensive and Recreational Swimming in Chlorinated Swimming Pools: a Systematic Review

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## Abstract

**Introduction and Purpose:** Dental erosion is the pathologic chronic diminution of dental hard tissues due to chemical effect of extrinsic and/or intrinsic acids without bacterial involvement. The purpose of the systematic review is to underline current evidence for dental erosion in swimmers due to exposure in chlorinated swimming pools. The accumulated knowledge is further discussed.

**Materials and Methods:** Data has been retrieved from original scientific papers and case reports published in well-established sources including the Dental School Library of National and Kapodistrian University of Athens. Additional research has been conducted in PubMed and Medline using search terms: “dental” OR “enamel” AND “erosion” AND “swimming pool”. References list from detected papers were also searched to reveal further relevant data.

**Results:** The systematic investigation concluded that 21 papers would provide data concerning dental erosion, either as prevalence detection to relevant age groups, or directly linked to swimmers in chlorinated swimming pools. After careful selection the total of these papers, 11 were directly focusing on swimmers and thus assessed as suitable for the review, 9 were relatively important and 2 case reports were excluded. In all 11 mentioned papers, the swimmers either intensive or recreational demonstrated dental erosion of variable severity.

**Conclusion:** Swimming in a chlorinated swimming pool might increase the risk of dental erosion. Evidence indicates that frequency and duration of swimming sessions are correlated with the prevalence and severity of dental erosion. Further well-designed clinical studies are needed to fortify the suggestion that chlorinated water in swimming pools composes an aggravating factor for dental erosion.

## Introduction

Dental erosion is defined as a type of tooth wear. Dental erosion is characterized by the irreversible loss of dental architecture, due to chemical dissolution generated by acidic substances, which are not products of bacterial activity [1]. Dental erosion has been confirmed as the most common chronic disease within individuals 5-17 years old [2], while it has most recently been acknowledged as a Dental Health condition [3]. Increased research data indicate gradual inflation in dental Erosion's prevalence. However due to various indexes used, populations and examiners, it is not easy to estimate and evaluate these

conclusions. In adolescents (age 9 to 17years old), study has revealed that 11-100% of the individuals that underwent examination present with Dental erosion of various gravity. In comparison, a study conducted in Iceland showed that the prevalence of Dental erosion duplicates from 12 to 15yearsold [4]. Studies of Dental erosion's prevalence within adult populations have revealed a span between 4 to 82%. The prevalence of dental erosion is slightly higher in males. Allocation of dental erosion in the dentition is presented in higher percentages in the occlusal surfaces (mainly in the first lower molars), followed by the labial surfaces of the upper anterior teeth [5].



Studies have uncovered a direct correlation between the development of Dental erosion and the consumption of acidic foods and drinks, which have pH below 5.0 – 5.7 and are identified as facilitating agents in this development [6]. Furthermore, a number of studies report a correlation between Dental erosion and excessive consumption of alcoholic drinks, fruit juices, such as the orange juice (which contains citric acid) and carbonated beverages (in which the erosive consequence is not attributed to carbonic acid, but citric and phosphoric acid) [7]. Additionally, studies of dental erosion have been conducted within populations of intensive and recreational swimmers in gas chlorinated swimming pools. In a recent study, at the aquatics center in Szczecin Poland, where the pool water is assiduously analyzed and in accordance with the recommended criteria, the prevalence of dental erosion was determined for two groups. One group consisted of younger intensive swimmers that have been actively swimming for approximately 7years and the second group of older, recreational swimmers that have been active for approximately 10years. Results revealed that 26% of the intensive swimmers presented with dental erosion of some severeness [8]. The duration of each swimming session and the frequency of swimming training were identified as aggravating factors.

A study conducted in Kaunas Lithuania, focused on swimmers with a relatively high rate of training sessions in gas chlorinated swimming pools, utilizing questionnaire and clinical examination. The population was organized in two age groups, 12-17years old and 18-25years old. The results revealed the rate of dental erosion reaching 25% in the first group and 50% in the second. Furthermore, correlation between age and rate increase of dental erosion was also justified, while no correlation was detected with other aggravating factors (gastroesophageal reflux disease, regular vomiting, xerostomia, regular oral intake of acidic medication, consumption of carbonated beverages) [9]. In a pilot study directed in India at the Thame public swimming pool, the population included young intensive swimmers, 75 males of  $18.6 \pm 6.3$  years old and 25 females  $15.3 \pm 7.02$  years old. This study was presented with clinical examination to determine the prevalence of Dental erosion and the usage of questionnaires. Results demonstrated dental erosion appearing at 90%, 94% rate of rough surfaces and 88% presence of various severeness of pain [10].

On the other hand, in a case study which was conducted in Cuba, it was revealed that a 72year old female swimmer, who was not diagnosed with major dental issues in the past and who had normal saliva flow rate, age considering, after two weeks of intensive swimming sessions in a falsely chlorinated swimming pool, she presented with meteoric loss of enamel at the anterior upper teeth. Dental erosion was diagnosed during the clinical examination, which was related to the qualitative elements of the falsely chlorinated swimming pool water [11].

Furthermore, in a study aiming to calculate the prevalence of den-

tal erosion in a population of 131 individuals, 62 (25 females and 37 males) were intensive swimmers in a chlorinated swimming pool at the sports club of Szczecin in a period of 2-16years. Each person spent 16-25hours per week in the swimming pool. The control group consisted of individuals that did not swim at all or swam occasionally. The study and the control group were matched for gender, age, and educational level. The statistical analysis indicated that Dental erosion was more often present in the study group than in the control group. The Dental erosion tended to be located more in the labial surfaces of the upper anterior teeth [12].

Another study which was held in Michigan University's swimming team with age range 18-23years old and consisting only of male athletes, an alteration in saliva parameters (reduction in saliva flow rate with simultaneous increase in Ca and F concentration), even in a properly chlorinated pool water, led to a surcharge of the demineralization of hydroxyapatite and the subsequent creation of Dental erosion [13].

On the other hand, an in vitro study of the fluoride agents' effect on 26 extracted teeth, which were retrieved from various age groups and placed in an environment which resembled that of a chlorinated swimming pool, indicated that the fluoride agents used (toothpaste, remineralization crème, fluoride varnish) had protective properties and effect [14]. We have observed a gradually increasing interest, in the scientific bibliography, concerning the dental erosion associated with chlorinated swimming pool water. In the above mentioned studies, we reported an indicative approach and determination of dental erosion's prevalence. This systemic review will examine possible bias concerning studies investigating the prevalence of dental erosion among swimmers in chlorinated swimming pools.

## Methods

### Study Identification

The following data bases were utilized to reveal the relevant studies. The procedure was narrowed for the period of 01/01/1985 till 01/01/2021. PubMed and SCOPUS were the platforms used. The search strategy was composed of the keywords "dental OR dentin AND erosion AND swimming AND pool". Furthermore, the selected studies were screened, and the reference tables were thoroughly viewed for relevant studies. The identification strategy can be viewed in Table 1. Additionally, the research was carried out in the Library of Dental School of Athens. This research led to a cross - sectional study which was retrieved from the Journal of Oral and Maxillofacial Research. Reports in the grey literature, defined as theses, dissertations, product reports, and unpublished studies through ClinicalTrials.gov, OpenGrey.eu, and ISRCTN registry, were also included. After electronic database and hand – searching, out of a total of 38 unique records screened, 25 studies were left for full – text assessment against eligibility criteria. Out of these, 5 were finally included.

**Table 1:** Search Findings.

	PubMed	SCOPUS	ARCHIVES
Observational	5	4	1
<i>In Vitro</i>	1	4	
Review	1	1	
Case/Clinical Report	5	3	
Exclusion due to irrelevant study subject	2	4	
Exclusion due to language other than English	3	4	
Total	17	20	1



**Study Selection**

Initial screening and assessment of relevancy were based on title and abstract, properties estimated by two of the reviewers (CR and VK). After initial screening, full texts were obtained for further assessment by the same reviewers and the selection criteria were developed.

For this systemic review, the observational studies were assessed for selection. The selection criteria based on abstracts, included:

Age group specification: Studies that stated the age groups were included.

Examination properties: Studies that manifested the examination methodology and properties were selected. This criterion was determined so that the examination properties followed specific steps and these steps could be assessed and displayed on sufficient detail.

Questionnaire details: Studies that included questionnaire were selected. The questionnaire should provide sufficient details concerning swimming habits and general ones that could influence dental erosion.

Language: Studies that were published in English were selected. Assessment of bias risk and reporting quality of included studies.

Prevalence of dental erosion: Studies though cross - sectional that

did not focus on the prevalence of dental erosion was excluded from this systemic review.

The studies satisfying these criteria were the following:

- a) Prevalence of Dental Erosion among the Young Regular Swimmers in Kaunas, Lithuania [15]
- b) Prevalence Of Dental Erosion Among Young Competitive Swimmers: A Pilot Study [16]
- c) Prevalence of dental erosion in adolescent competitive swimmers exposed to gas-chlorinated swimming pool water [17]
- d) The effect of swimming on oral health status: competitive versus non-competitive athletes [18]
- e) Prevalence of dentinal hypersensitivity and dental erosion among competitive swimmers, Kerala, India [19]

Predefined criteria determined the methodological adequacy of the included studies. Unfortunately, there is no assessment tool existing in bibliography to perform this task. The criteria were defined by the reviewers and followed the principles of reporting, performance, and selection. The evaluation was executed by scoring “specified”, “not specified” or “partly specified”, depending on the quality of data presented. The risk of bias assessment is displayed on Table 2.

**Table 2:** Reporting calibration and risk of bias configuration.

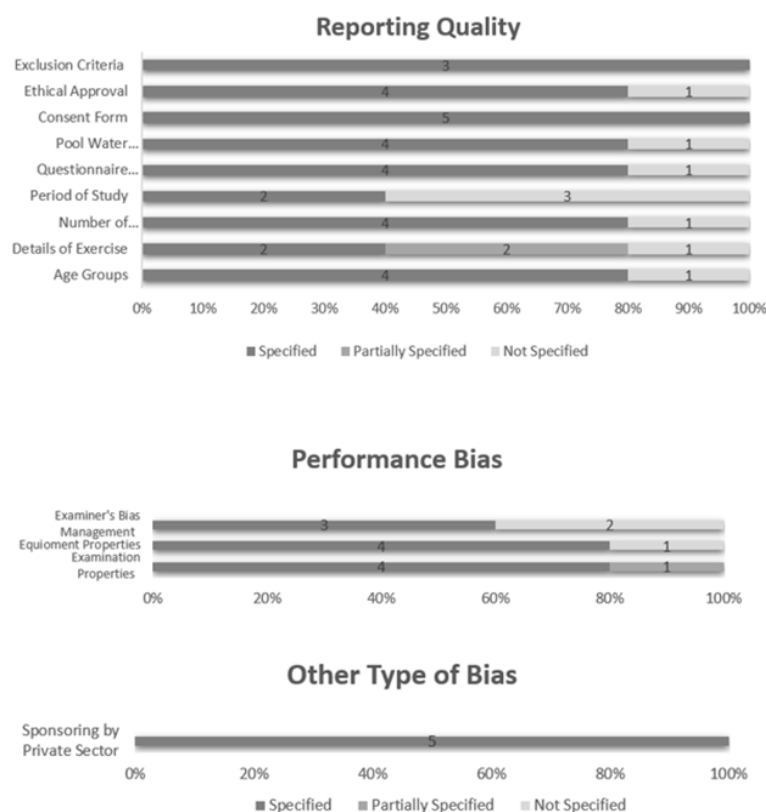
			Specified	Partially Specified	Not Specified
Reporting Quality	Age Groups				
	Details of Exercise				
	Number of Examiners				
	Period of Study				
	Questionnaire Details				
	Pool Water Properties				
	Consent Form				
	Ethical Approval				
Performance bias	Exclusion Criteria				
	Examination Properties				
	Equipment Properties				
Other Type of Bias	Examiner’s Bias Management				
	Sponsoring by Private sector				

**Results**

The small number of relevant studies create the environment to assess dental erosion’s prevalence in the swimming pools community, though generalization of these outcomes would require further study. The selected studies were evaluated using the reporting calibration

and risk of bias configuration tool as presented in methods section. The selected studies were numerated and estimated. All the features selected to be evaluated and used as a comparison measurement fulfilled the criteria determined. These features could be objectified and present the appropriate data, to achieve an evaluation of the studies. The results can be viewed in Figure 1.





**Figure 1:** Reporting Quality, Performance Bias, and Other Type of Bias. Results demonstrated in percentages for all 5 selected studies.

As can be sighted in Figure 1 concerning the Reporting quality 60% of the studies did not specify the period of study, while 20% did not specify the swimming pool properties, the questionnaire used details, the number of examiners involved, the age groups and whether an appropriate Committee acquired ethical approval.

Additionally, 40% had partially specified the details of exercise by the swimmers (timetable etc.). This percentage, along with the 20% that did not specify the details of exercise, by the swimmers, indicate the possibility of existing factors that negatively influence the objectiveness of their outcomes. On the other hand, when in the Performance Bias section, 40% of the studies did not specify the Examiner's Bias Management as they did not provide data on this matter's strategy. This fact creates possible indications of a negative effect on the objectiveness of the examinations performed on the swimmers. Additionally, 20% did not specify the equipment used properties, as they lacked data on this issue. Finally, 20% of the studies partially specified the examination properties as they did not fully describe the examination procedure, and 100% of the studies presented the exclusion criteria with specification and the absence of private funding.

## Discussion

Studies have revealed problematic protocol-based procedures in acquiring and standardizing the pH in swimming pools, which led to an acidic environment, which causes dental erosion [20]. These types of outcomes are occasionally published as case studies, and they always are related to inadequate preservation of the appropriate pH of the swimming pool water [21,22]. The chemical events, however, that lead to dental erosion are complicated. Every solution before contacting the enamel must diffuse through the pellicle (biofilm) which is developed and naturally adhered to the dental tissues. This film consists mainly of salivary proteins and glycoproteins. The Calcium chelation properties of the solution play an important role as well, as it binds the released calcium. This means that the swimming pool's water even

if it has a neutral pH, when it is low in Ca saturation, it can promote the erosion procedure through the constant interaction with the oral cavity (e.g. by swishing) [23].

This view has been suggested by J. Buczkowska-Radlińska et al. in a study which has been examined in this systemic review. In the mentioned study the investigators revealed that though dental erosion was detected in 26% of regular and 10% of recreational swimmers with rendered Grade 1 according to Lussi index classification, lesions tended to appear in labial and palatal surfaces of anterior teeth of the intensive swimmers and exclusively in labial surfaces of the recreational ones.

Additionally, when examined the pool water they found that it was undersaturated in hydroxyapatite minerals. This data enforced the idea of Ca and P (phosphorus) chelation solution properties to play a long-term role in the development of dental erosion in swimming pool athletes, especially when no other aggravating factors being present [17].

Following these, the bibliography reported that overall maintenance of swimming pools exhibited high prevalence of impropriety. The report by CDC (Centers for Disease Control and Prevention) during 2008, refers to 121,020 routine pool inspections that occurred in 15 jurisdictions. Among the 121,020 inspections, the number of code violations identified ranged from 0 to 28 (median: 1), and 73,953 (61.1%) inspections identified one or more violations. A total of 13,532 (12.1%) of 111,487 inspections identified serious violations that threatened the public's health and resulted in immediate pool closure. Of 120,975 inspections, 12,917 (10.7%) identified disinfectant level violations; of 113,597 inspections, 10,148 (8.9%) identified pH level violations. Other water chemistry violations were documented during 12,328 (12.5%) of 98,907 inspections, with the number identified per inspection ranging from zero to four.



Circulation and filtration violations were documented during 35,327 (35.9%) of 98,361 inspections, with the number identified per inspection ranging from zero to nine. The following violations also were identified: improperly maintained pool log (12,656 [10.9%] of 115,874 inspections), unapproved water test kit used (2,995 [3.3%] of 90,088 inspections), valid pool license not provided and/or posted (741 [2.7%] of 28,007 inspections), and operator training documentation not provided and/or posted (1,542 [18.3%] of 8,439 inspections) [24].

The data provided and the limited number of studies examining the prevalence of dental erosion among swimmers in swimming pools create an environment that necessitates further studies to be conducted bearing in mind that imponderable factors exist in swimming pools due to poor conformity to the legislature and regulations. The studies examined in this systemic review present with a relevant high number of unspecified or not fully specified data, which leaves an amplified bias risk.

## Conclusion

Swimmers in swimming pools are susceptible to developing dental erosion. This systemic review attempted to examine the bias risk of studies focusing on detecting dental erosion prevalence among swimmers. The results highlight the requirement of further studies in this field to reach more accurate conclusions, mainly because various factors are involved in swimming pools and are associated with each other.

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