

EROSIVE POTENTIAL OF LOW PH SWIMMING POOL WATER ON DENTAL ENAMEL

Chanya Chuenarrom*, Paitoon Daosodsai and Pojjanut Benjakul

Department of Prosthetic Dentistry, Faculty of Dentistry, Prince of Songkla University, Songkhla 90110, Thailand

ABSTRACT: The aim of this study was to evaluate enamel erosion due to immersion in low pH swimming pool water. Tooth enamel specimens were immersed in low pH swimming pool water for a 4 h period. Enamel loss was measured by using a focusing method of a measuring microscope and Vickers microhardness of enamel was measured with a microhardness tester. After immersion for 4 h, pool water with pH of 3.85 and titratable acidity of 1.4 ml of 0.1 N NaOH eroded 5.1 μm of enamel and resulted in hardness value of enamel decreased by 23.2%, whereas pool water with pH of 2.91 and titratable acidity of 9.5 ml of 0.1 N NaOH eroded 31.3 μm of enamel and resulted in hardness value of enamel decreased by 19.3%. This *in vitro* study supports the clinical reports on swimmer's dental erosion that the public should be warned of.

Keywords: dental erosion, measuring microscopy, swimming pool water

INTRODUCTION: A pH of 5.5 is considered to be the critical pH for enamel dissolution. Dental erosion is a painful, costly, irreversible condition which can be caused by low pH water of inadequately maintained chlorinated swimming pools¹. Thus it is important for people to know that the recommended pH of water for swimming pools is pH 7.2-8.0¹. Numerous *in vitro* studies have shown that acidic beverages cause dental erosion, for example cola drinks, energy drinks, sports drink and acidic juices²⁻⁴. In contrast, although there have been many clinical case reports on tooth erosion from swimming^{1,5-7}, there is only a small number of *in vitro* studies on dental erosion caused by swimming pool water. The literatures regarding studying by a microhardness tester^{8,9}, surface roughness⁹ and SEM^{9,10} were found, but there was nothing about studying the effect of low pH pool water on enamel loss, therefore lacking information makes it difficult to indicate the erosive potential of low pH swimming pool water on enamel. The objective of this study was to investigate enamel loss and hardness value of enamel after immersion in low pH swimming pool water.

MATERIALS AND METHODS: Two samples of pool water used in this study were taken from two chlorinated swimming pools in Songkhla, Thailand. The pH values were measured with a pH meter (Precisa, pH900, Precisa Gravimetrics AG, Dietikon, Switzerland). The titratable acidity was analysed

by titrating 20 ml of pool water with 0.1 N NaOH to raise their original pH to 7.0. The volume of 0.1 N NaOH used in the titration determined the titratable acidity (ml). The analysis showed the first sample of water to have an initial pH of 3.85 and a titratable acidity of 1.4 ml, whereas the second sample of water to have an initial pH of 2.91 and a titratable acidity of 9.5 ml.

With $\alpha = 0.05$ and power of test 80%, the sample size was determined based on the previous study of enamel loss (around 30 ± 3 micron). Eighteen human third molar teeth were selected from a collection of extract teeth which had been extracted as part of routine dental treatment in dental clinic. The protocol for collecting of extracted teeth was approved by the human research ethics committee of Faculty of Dentistry, Prince of Songkla University. Seventy-two longitudinal enamel sections were prepared using a diamond saw (Isomet 4000, Buehler, IL, USA) under water irrigation. From each tooth, four sections were cut accordingly: the distal, mesial, lingual and buccal. Each specimen was embedded in acrylic resin and an outer enamel surface of each specimen was ground flat using 320, 600 and 1200 grit silicon carbide paper (Wirtz-Buehler, Düsseldorf, Germany), and then polished with a 1 μm diamond suspension, to produce an approximate 2.5 x 2.5 mm² flattened window of enamel.

Specimens were assigned to one of the twelve groups. The results included four groups each for

*To whom correspondence should be addressed.
Tel. +66 7428 7562, Fax. +66 7442 9874
E-mail: chanya.ch@psu.ac.th,

four different exposure times in pool water with pH 3.85, the next four groups each for four different exposure times in pool water with pH 2.91, and the last four group for four different exposure times in tap water with pH 6.96 (the negative control). The enamel specimens were covered with nail varnish leaving an area of approximately 1.0 x 2.5 mm² in the center area for contacting the pool water. This procedure ensured comparison between the eroded and uneroded area; the uneroded area was used as a reference area for the erosion depth.

Six specimens each were exposed to 200 ml of pool water or tap water for 1 h, 2 h, 3 h or 4 h. The specimen beakers were agitated in a continuously vibrating water bath (Memmert, WNB22, Memmert GmbH, Büchenbach, Germany) for an assigned immersion time. Then, specimens were rinsed in tap water and dried at room temperature for 15 min. Nail enamel remover was applied over nail varnish that covered the uneroded area until clean. Height levels of eroded and uneroded areas were measured with a measuring microscope (Nikon, MM400, Nikon Corporation, Kanagawa, Japan). By using a focusing method, the different height in the z axis between the uneroded area plane and eroded area plane was measured to record enamel loss. Five enamel loss measurements were averaged for each specimen.

Surface microhardness (SMH) measurements of all enamel specimens were investigated using a

microhardness tester (Micromet II, Buehler, Lake Bluff, IL, USA) with an indentation load of 200 g for 10 s. Each specimen was indented three times, both on uneroded and eroded areas, to ascertain the average SMH. The percentage of surface microhardness (%SMH) was calculated based on the difference between the SMH of uneroded surface (SMH₀) and SMH of eroded surface (SMH₁), as follows: $(100 \times \text{SMH}_1) / \text{SMH}_0$.

Independent Sample t-test was used to compare the mean enamel loss and %SMH for two specimen groups which exposure to pool water with pH of 3.85 and pH of 2.91.

RESULTS: There was no change in the enamel surface which was exposed in tap water over the immersion time period whereas enamel did erode in pool water after exposure for 1 h. Figure 1 showed the change of enamel in the pool water with pH 3.85 and pH 2.91 respectively. Figure 2 represents the enamel loss in pool water over a 4 h period. This revealed that the pH level and titratable acidity of a swimming pool and immersion time had the effect of increasing enamel loss. The percentage of SMH of enamel after exposure to pool water over a 4 h period shows in Figure 3. Statistically significant differences of enamel loss were found ($p < 0.05$), whereas no significant differences of %SMH were found between specimen groups which exposure to pool water with pH of 3.85 and pH of 2.91 ($p > 0.05$).

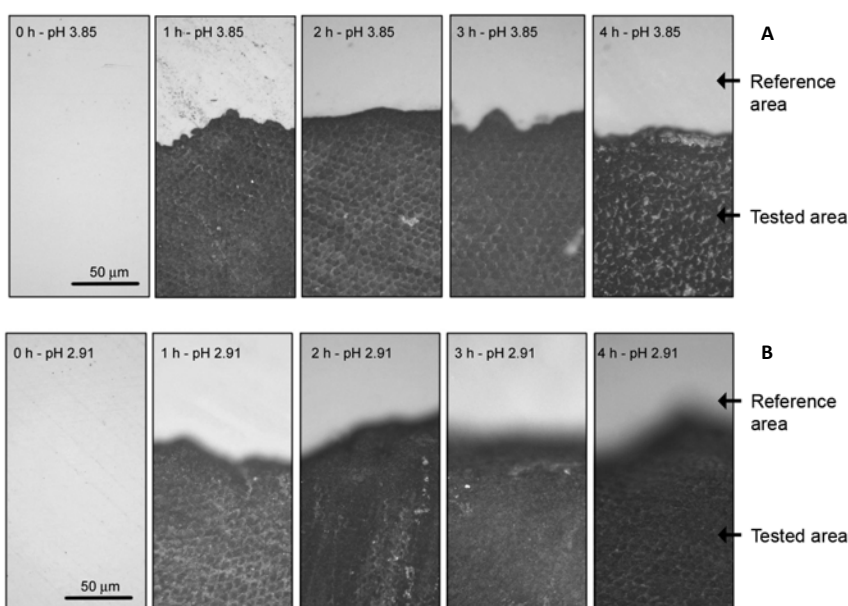


Figure 1 Micrograph of reference surface and tested surface of enamel specimens exposed to pool water with pH 3.85 (A) and pH 2.91 (B) over a 4 h period.

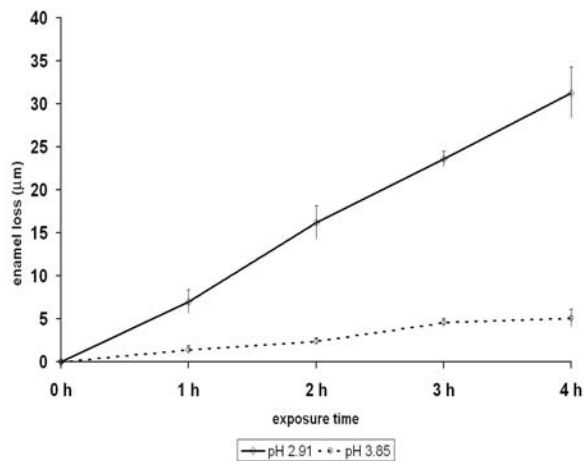


Figure 2 Erosive potential of swimming pool water with different pH on tooth enamel over a 4 h period

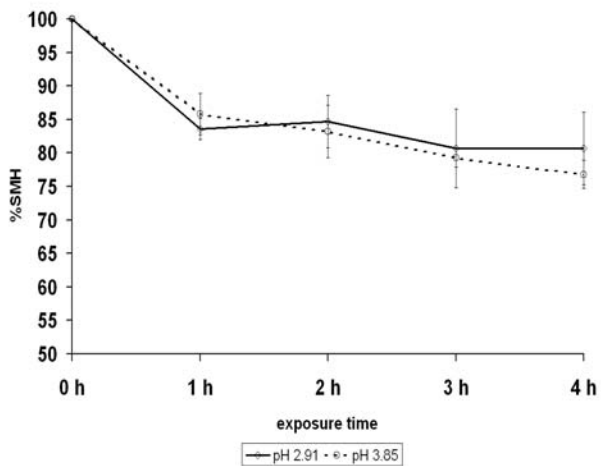


Figure 3 %SMH of enamel after exposure to pool water with different pH over a 4 h period

DISCUSSION: Chlorine is the chemical most often used to keep swimming pools free of bacteria. When chlorine was added into water, it produced hypochlorous acid (HOCl) and hypochloride ion (OCl⁻). Therefore, extremely high levels of chlorine in the water caused decreasing of the pH level in swimming pool water. By using a measuring microscope in this study, changes in enamel morphology after treatments were observed clearly. The micrographs of the uneroded area and the eroded area of enamel after exposure to acidic pool water were represented in Figure 1. The micrographs showed the eroded area was in focus as the uneroded area was blurred (out of

focus) due to the eroded plane being lower than the uneroded plane after exposure to pool water. The micrograph of immersion for 4 h in pool water with pH 2.91 visibly showed the greatest blurred uneroded area. The eroded enamel surface showed a honeycomb-like etch pattern and the enamel prism dissolution can be clearly observed.

Figure 2, the pool water with pH 2.91 had six times higher erosive potential on enamel than the pool water with pH 3.85, indicated that an increase in enamel loss related to the lower pH of water and increasing contact time. This supported a clinical case study which reported that competitive swimmers have more symptoms compatible with dental enamel erosion than non-swimmers and swimmers who were not members of the swim team¹). The changing of enamel surface was confirmed by the %SMH as showed in Figure 3. However, the pattern of surface softening behaves in a different way than enamel loss, because enamel loss progresses faster than surface demineralization¹¹). It was not surprised by the difference patterns of enamel loss and %SMH because it was reported in previous studies^{11, 12}).

Although the results in this study cannot interpret to realistic because it has tend overestimate the enamel loss over 4 h. However, the erosive potential of pool water can also compared to the previous studies which investigated the erosive potential of acidic drinks on enamel over 1 h, found that cola drink with pH 2.38 eroded 3.0 µm of enamel¹³), immersion in the baby juices with pH range 3.5-4.0 resulted in the order loss of 1-5 µm of permanent enamel³). In this study, enamel loss produced by pool water with pH 3.85 and pH 2.91 were 1.4 µm and 7.0 µm respectively. Additionally, when swimming there is longer contact time than drinking thus swimming in an improperly maintained pool probably has a higher risk of dental erosion than acidic drink consumption.

In year 2003, 139 swimming pools in 15 provinces of Thailand were identified by The Dental Public Health Division, Department of Health to assess risk of dental erosion among swimmers. The results showed that the pH value of 31.2% of swimming pools was lower than 5.5

which increase risk to swimmer.¹⁴⁾ In the Netherlands, the pH value of pool water has to be checked daily¹⁵⁾ and monitored monthly by independent test laboratories¹⁶⁾, therefore, for Dutch swimmers there is only a slight possibility of dental conditions arising from pool-water.¹⁵⁾ The study emphasized that the best prevention against dental erosion for swimmers is a standard quality control of water in public swimming pools. Also, swimming pool managers should realize the importance of monitoring the pH and chemicals of pool water and swimmers should be warned of the risk of dental erosion.

Increase in enamel loss related to the lower pH of water and increase in exposure time. This *in vitro* study supports the clinical reports on swimmer's dental erosion and the public should be warned about it.

REFERENCES:

1. Centerwall BS, Armstrong CW, Funkhouser LS, Elzay RP. 1986. Erosion of dental enamel among competitive swimmers at a gas-chlorinated swimming pool. *Am J Epidemiol* 123: 641-7.
2. Hunter ML, Patel R, Loyn T, Morgan MZ, Fairchild R, Rees JS. 2008. The effect of dilution on the *in vitro* erosive potential of a range of dilutable fruit drinks. *Int J Paediatr Dent* 18: 251-5.
3. Hunter L, Patel S, Rees J. 2009. The *in vitro* erosive potential of a range of baby drinks. *Int J Paediatr Dent* 19: 325-9.
4. Chuenarrom C, Piempring C, Benjakul P. 2005. Effect of energy drinks and sports drinks on dental enamel erosion. *J Dent Assoc Thai* 5-6: 330-6.
5. Geurtsen W. 2000. Rapid general dental erosion by gas-chlorinated swimming pool water. Review of the literature and case report. *Am J Dent* 13: 291-3.
6. Caglar E, Kargul B, Tanboga I, Lussi A. 2005. Dental erosion among children in an Istanbul public school. *J Dent Child (Chic)* 72: 5-9.
7. Dawes C, Boroditsky CL. 2008. Rapid and severe tooth erosion from swimming in an improperly chlorinated pool: case report. *J Can Dent Assoc* 74: 359-61.
8. Kitsahawong K, Rattanathongkam A, Lertsiriworakul J. 2003. Effect of Mouthguard on surface hardness of dental enamel after exposing to chlorinated water. *KKU Res J* 3: 76-89.
9. Lekluangarm S. 2008. Effect of a chlorinated swimming pool water on micro-hardness and profile changes of tooth surface. Songkhla: Prince of Songkla University.
10. Gabai Y, Fattal B, Rahamin E, Gedalia I. 1988. Effect of pH levels in swimming pools on enamel of human teeth. *Am J Dent* 1: 241-3.
11. Eisenburger M, Addy M. 2003. Influence of liquid temperature and flow rate on enamel erosion and surface softening. *J Oral Rehabil* 30: 1076-80.
12. Chuenarrom C, Benjakul P. 2010. Dental Erosion Protection by Fermented Shrimp Paste in Acidic Food. *Caries Res* 44: 20-3.
13. Chuenarrom C, Benjakul P. 2008. Comparison between a profilometer and a measuring microscope for measurement of enamel erosion. *J Oral Sci* 50: 475-9.
14. Chanduaykit S, Ungchusuk C, Promma S, Sukanwarani S. 2005. Risk factors assessment to identify dental erosion among swimmers. *Thailand J Health Promot Environ Health* 28: 50-8.
15. Scheper WA, van Nieuw Amerongen A, Eijkman MA. 2005. [Oral conditions in swimmers]. *Ned Tijdschr Tandheelkd* 112: 147-8.
16. Lokin PA, Huysmans MC. 2004. [Is Dutch swimming pool water erosive?]. *Ned Tijdschr Tandheelkd* 111: 14-6.