

# Relationship between oral symptoms during diving work and preventative dental visits in Japanese male occupational divers

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**Abstract:** This cross-sectional study examined the relationship between dental symptoms experienced by occupational divers during diving and their participation in preventative dental visits. The questionnaire for this study was sent by post to 160 establishments and 215 members of the Japan Diving Association and participants were asked to complete a self-reported questionnaire. Data from 242 occupational divers (male, aged 20–79 yr) were analyzed. Multiple logistic regression analysis and correspondence analysis were performed to determine the relationship between dental symptoms experienced during diving and participation in preventative dental visits. We found that divers who experienced tooth pain while diving had not undergone preventative dental visits within the previous year (odds ratio: 2.76, 95% confidence interval: 1.12–6.80). This was also confirmed by correspondence analysis. These findings suggested that not undergoing preventative dental visits was related to tooth pain during diving.

**Key words:** Dental symptoms, Preventative dentistry, Occupational diver, Questionnaire, Tooth pain

## Introduction

Studies in the industrial field have reported many oral symptoms in individuals exposed to the low-pressure environments of the aviation industry<sup>1</sup>, but less attention has been paid to occupational divers exposed to high-pressure environments. As the demand for diving work in marine development is increasing worldwide<sup>2</sup>, the number of workers in this field may increase.

The body of a diver is exposed to significant pressure changes during dive<sup>3</sup>. As the diver descends and pressure

of water column increases, the volume of the gas in compressible spaces decreases. In spaces with rigid or semi-rigid walls, it can result in a relative negative pressure. Negative pressure can cause mucosal edema, hemorrhage, and even perforation if the pressure cannot be equalized. During ascent, the volume of gas increases as the ambient pressure decreases. If the pressure in an air-containing space cannot equalize with the surrounding pressure, the expanding volume of the gas may result in a variety of medical problems, including sinus pressure trauma, middle ear perforation, or pneumocephalus<sup>4</sup> and dental problems. Oral tissues affection and barodontalgia were previously reported in occupational divers<sup>5</sup>. The underlying pathology and mechanisms of barodontalgia appear to be varied. Common oral pathologies have been reported

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as possible sources of barodontalgia: inflammatory cysts in the mandible, dental caries, defective tooth restoration, pulpitis, pulp necrosis, apical periodontitis, periodontal pockets, and mucous retention cysts<sup>6–8</sup>). A physiological explanation involves the difference between the swelling behavior of tooth enamel and dental pulp. Additionally, it has been reported that the liquid moves from the dentin to the pulp cavity after forming a cavity in the enamel under high pressure conditions<sup>9, 10</sup>). However, the mechanism is not completely understood<sup>11</sup>). Changes in pressure may also cause detachment of dental prosthetic appliances<sup>12–14</sup>). Additionally, temporomandibular disorders have been reported to be caused by repeated biting of scuba mouthpieces<sup>15</sup>).

Preventative dental visits are widely known to reduce intraoral problems among adults in general<sup>16</sup>). However, to the best of our knowledge, there has been little research into the relationship between preventative dental visits and specific dental symptoms during diving of which occupational divers complain. The aim of this study was to clarify the relationship between preventative dental visits and dental symptoms in occupational divers during diving. We hypothesized that preventative dental visits could prevent oral symptoms during diving.

## Methods

### Selection of participants

This questionnaire survey was conducted in Japan from February 14, 2019, to April 1, 2019. Figure 1 presents the flowchart of participant enrollment. The questionnaire for the study was sent by mail to 160 establishments and 215 members of Japan Diving Association. Three hundred seventy-four individuals had agreed to participate and returned questionnaire. Review of received questionnaires, excluded 103, whose occupation was not diving, two submitted by women, as there were too few individuals of this sex, and 27 incomplete questionnaires. Eventually, data from 242 participants were analyzed in this study. Subjects provided written informed consent to participate. The ethical committee of Tokyo Dental College approved this study (Approval Number 907).

### Questionnaire items

The questionnaire items were selected after considering the factors associated with dental symptoms during diving and the characteristics of professional divers. Also, oral hygiene status factors were selected as possible confounders. Information was collected on the working environment

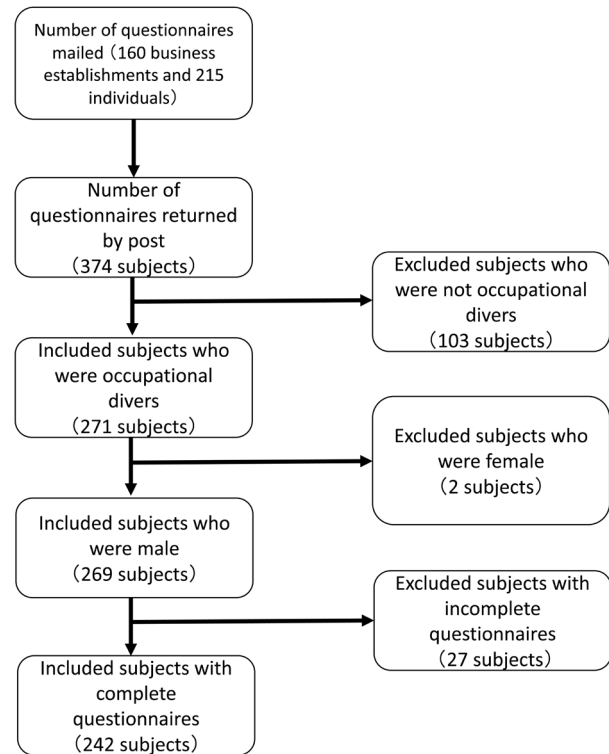


Fig. 1. The criteria for selection of the study subjects.

(number of dives: “How often do you do occupational diving per week?” categorized as 4 times a week or more, or 3 times a week or less; diving duration: “How long is the occupational diving duration?,” categorized as <300 min or  $\geq$ 300 min). Furthermore, information on dental symptoms during occupational diving (“do you have tooth pain”, “do your teeth feel uncomfortable”, “are your teeth sensitive”, “do you have swollen gums”, “are your gums painful”, “do you have pressure in your teeth”, “do you have temporomandibular joint pain”, “do you have detachment of an inlay or crown”; categorized as yes or no) was collected. Moreover, dental care utilization patterns (“Have you received dental treatment?”, categorized as within the past half a year or 1 yr: “How often do you visit the dentist’s office for prevention?”, categorized as not consulted, or consulted within the past two years, one year, six months, two to three months, or one month: “Have you received inlays or crowns within the past five years?”, and “Have you had teeth extracted in the past year?”, categorized as yes or no) were determined. Dental hygiene habits (frequency of daily brushing: “How often do you brush your teeth a day?” categorized as <3 or  $\geq$ 3; duration of brushing teeth: “How many minutes do you brush your teeth?” categorized as <3 min or  $\geq$ 3 min, were also recorded.

### Statistical analyses

First, a  $\chi^2$  test (or Fisher's exact test for cases with fewer than five cells in the contingency table) was used to make comparisons between oral symptoms during diving and individual factors. Odds ratios (ORs) and 95% confidence intervals (CIs) were determined using multiple logistic regression analyses (forced-entry method). Oral symptoms were used as dependent variables. Preventative dental consultation (defined as more than one dental consultation within a year) was set as an independent variable. In addition, for age, frequency of diving, diving duration per day, use of dental treatment, receiving inlays or crowns within the past five years, tooth extraction within the past one year, frequency of toothbrushing per day, and toothbrushing duration were set as independent variables for adjustment. Spearman's correlation coefficient was used to investigate the multicollinearity relationships among the independent variables.

In addition, correspondence analysis was used to compare each dental symptom experienced during occupational diving and the number of preventative dental visits. Correspondence analysis can be useful in understanding data overall, as well as the interrelationships between different responses. The relative positions of the category points in map indicates certain levels of similarity or association between the categories<sup>17</sup>.

Statistical analyses were carried out using SAS Version 9.4 for Windows (SAS Institute, Cary, NC, USA), *p*-values <0.05 were regarded as signifying statistical significance.

### Results

Table 1 shows the basic characteristics of the participants. The percentage of participants who dived four or more times a week for work-related reasons was 66.9%. The average diving duration in one day was 254.8 min. The average occupational diving work engagement years was 19.9 yr. In total, 46.3% of participants experienced some dental symptoms during occupational diving. Symptoms included tooth pain (17.8%), an uncomfortable feeling (not pain) in the teeth (9.9%), sensitive teeth (5.0%), swollen gums (4.1%), painful gums (6.6%), a feeling of pressure in the teeth (9.1%), pain in the temporomandibular joint (15.7%), and 12.0% had had detachment of inlays or crowns.

Table 2 shows the relationship between oral symptoms during occupational diving, age, the diving environment, dental consultation status, and personal oral care. "Tooth symptoms other than pain" correlated significantly with the "Detachment of inlays or crowns within the past five years" (*p*=0.002). "Periodontal symptoms" correlated significantly with "age" (*p*=0.023), "occupational diving work engagement year" (*p*=0.042) and "Dental treatment within the past six months" (*p*=0.022). However, none of the dental symptoms during occupational diving were correlated significantly with "preventative dental visits".

Table 3 shows the relationship between the oral symptoms and health behavior for occupational divers, as assessed by multiple logistic regression analysis. There was a strong relationship ( $|r|>0.4$ ) between the age and the

**Table 1. Basic characteristics of participants**

	Age (yr)											
	20–29		30–39		40–49		50–59		60–69		70–79	
	%	n	%	n	%	n	%	n	%	n	%	n
Frequency of diving												
≥4 times a week	68.4%	26	61%	30	74%	50	67.2%	41	65.2%	15	0	0
2–3 times a week	10.5%	4	27%	13	21%	14	24.6%	15	26.1%	6	100%	3
≤1 time a week	21.1%	8	12%	6	6%	4	8.2%	5	8.7%	2	0	0
Duration of diving per day (min)		223		238		281		263		263		120
Occupational diving work engagement years	4.6		10.9		19.9		29.7		37.7		26.7	
Tooth pain	10.5%	4	24%	12	18%	12	19.7%	12	13.0%	3	0	0
Uncomfortable feeling in the teeth	2.6%	1	10%	5	12%	8	13.1%	8	8.7%	2	0	0
Sensory sensitivity	2.6%	1	6%	3	7%	5	4.9%	3	0.0%	0	0	0
Swollen gums	0.0%	0	6%	3	4%	3	6.6%	4	0.0%	0	0	0
Painful gums	0.0%	0	6%	3	4%	3	11.5%	7	13.0%	3	0	0
Feeling of pressure in the teeth	5.3%	2	8%	4	9%	6	9.8%	6	17.4%	4	0	0
Pain in temporomandibular joint	18.4%	7	14%	7	22%	15	11.5%	7	8.7%	2	0	0
Detachment of inlays or crowns	2.6%	1	14%	7	10%	7	21.3%	13	4.3%	1	0	0

**Table 2. Relationship between individual factors and oral health symptoms using the  $\chi^2$  test (n=242)**

	n	Tooth pain		Tooth symptoms other than pain		Detachment of inlay or crown		Pain in Temporomandibular joint		Periodontal symptoms	
		YES	Test	YES	Test	YES	Test	YES	Test	YES	Test
		%	<i>p</i>	%	<i>p</i>	%	<i>p</i>	%	<i>p</i>	%	<i>p</i>
<b>Age (yr)</b>											
20–44	122	14.8	0.216	17.2	0.381	8.2	0.067	14.8	0.683	4.9	0.023
45–79	120	20.8		21.7		15.8		16.7		13.3	
<b>Frequency of diving</b>											
≤3 times/week	80	13.8	0.250	22.5	0.395	13.8	0.552	21.3	0.096	10.0	0.730
≥4 times/week	162	19.8		17.9		11.1		13.0		8.6	
<b>Diving duration</b>											
<300 min	112	20.5	0.296	17.0	0.370	8.0	0.079	36.5	0.617	10.7	0.415
≥300 min	130	15.4		21.5		15.4		14.6		7.7	
<b>Occupational diving work engagement years</b>											
<20 yr	116	17.2	0.837	16.4	0.251	9.5	0.250	16.4	0.781	5.2	0.042
≥20 yr	126	18.3		22.2		14.3		15.1		12.7	
<b>Dental treatment within past 6 months</b>											
No	172	15.7	0.187	19.2	0.887	9.9	0.115	16.3	0.700	6.4	0.022
Yes	70	22.9		20.0		17.1		14.3		15.7	
<b>Preventative dental visits</b>											
Yes	74	12.2	0.130	18.9	0.896	13.5	0.627	13.5	0.535	10.8	0.537
No	168	20.2		19.6		11.3		16.7		8.3	
<b>Receiving of inlays or crowns within past 5 yr</b>											
No	105	15.2	0.367	10.5	0.002	10.5	0.527	17.1	0.590	6.7	0.251
Yes	137	19.7		26.3		13.1		14.6		10.9	
<b>Tooth extraction within past 1 yr</b>											
No	208	16.3	0.152	18.3	0.262	11.5	0.573	14.9	0.398	8.7	0.525
Yes	34	26.5		26.5		14.7		20.6		11.8	
<b>Number of toothbrushing per day</b>											
≥3 times	10	30.0	0.389	40.0	0.106	20.0	0.342	10.0	0.613	10.0	1.000
≤2 times	232	17.2		18.5		11.6		15.9		9.1	
<b>Toothbrushing duration per time</b>											
≥3 min	168	19.0	0.433	17.9	0.354	9.5	0.076	14.3	0.361	7.7	0.270
≤2 min	74	14.9		23.0		17.6		18.9		12.2	

number of occupational diving work engagement years, based on Spearman’s correlation coefficient. Therefore, occupational diving work engagement years was excluded as an independent variable to avoid multiple collinearity. The independent variables judged to be correlated with “Tooth pain” was dental consultation for prevention within the past one year (OR: 2.76, 95% CI: 1.12–6.80). “Tooth symptoms other than pain” was the independent variable that correlated with loss of an inlay or a crown-wearing within the past five year (OR: 3.25, 95% CI: 1.47–7.16). Diving duration (300 min or more per day) was correlated with “Detachment of an inlay or crown” (OR: 2.59, 95% CI: 1.06–6.35). Age (45 yr or older) correlated with “Peri-

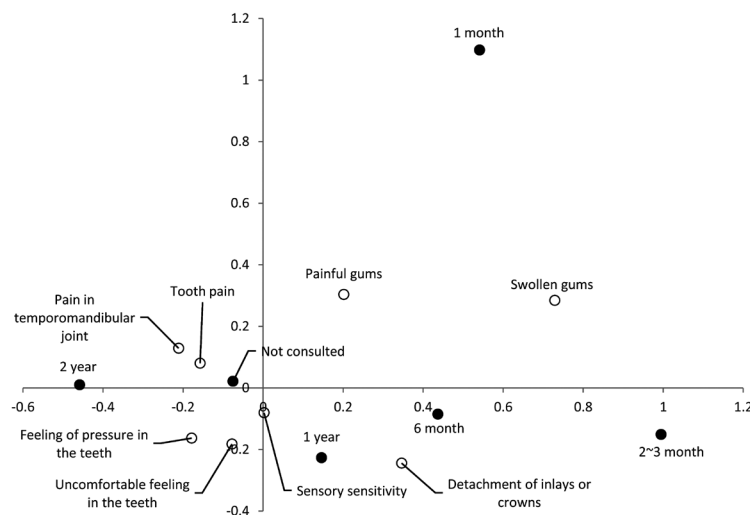
odontal symptoms” (OR: 2.73, 95% CI: 1.00–7.43).

Figure 2 shows the biplot of the relationship between dental symptoms during occupational diving and the frequency of preventative dental visits. In this study, two dimensions were adopted from the cumulative contribution ratio and the category scores were plotted. Subjects who responded with “Not consulted” were plotted near “Tooth pain”, “Pain in the temporomandibular joint”, “Sensory sensitivity”, “Feeling of pressure in the teeth”, and “Uncomfortable feeling in the teeth”. Responses of “1 month” and “2–3 months” was located far from the other points. In the upper right of the plot, periodontal symptoms of “Painful gums” and “Swollen gums” were located, and

**Table 3. Factors contributing to individual indicators and oral health symptoms by multiple logistic regression analysis (n=242)**

	Tooth pain			Tooth symptoms other than pain			Detachment of inlay or crown			Pain in Temporomandibular joint			Periodontal symptoms		
	OR	95%CI	<i>p</i>	OR	95%CI	<i>p</i>	OR	95%CI	<i>p</i>	OR	95%CI	<i>p</i>	OR	95%CI	<i>p</i>
Age (yr)															
20–44	1		0.266	1		0.725	1		0.172	1		0.743	1		0.049
45–79	1.49	0.74–2.99		1.13	0.58–2.22		1.8	0.78–4.16		1.13	0.55–2.32		2.73	1.00–7.43	
Frequency of diving															
≤3 times/week	1		0.160	1		0.523	1		0.324	1		0.076	1		0.837
≥4 times/week	1.76	0.80–3.88		0.79	0.39–1.61		0.65	0.28–1.53		0.51	0.25–1.07		0.90	0.34–2.37	
Diving duration															
<300 min	1		0.242	1		0.175	1		0.037	1		0.635	1		0.564
≥300 min	0.66	0.32–1.33		1.62	0.81–3.27		2.59	1.06–6.35		0.84	0.41–1.74		0.76	0.30–1.94	
Dental treatment within past 6 months															
No	1		0.317	1		0.312	1		0.137	1		0.774	1		0.099
Yes	1.54	0.66–3.56		0.66	0.29–1.48		2.07	0.79–5.42		0.87	0.34–2.21		2.45	0.84–7.10	
Preventative dental visits															
Yes	1		0.027	1		0.565	1		0.987	1		0.538	1		0.998
No	2.76	1.12–6.80		1.25	0.58–2.68		0.99	0.41–2.43		1.30	0.57–2.98		1	0.37–2.72	
Receiving of inlays or crowns within past 5 yr															
No	1		0.595	1		0.004	1		0.864	1		0.342	1		0.878
Yes	1.23	0.57–2.67		3.25	1.47–7.16		0.92	0.37–2.30		0.68	0.31–1.50		1.09	0.38–3.15	
Tooth extraction within past 1 yr															
No	1		0.257	1		0.345	1		1.000	1		0.250	1		0.731
Yes	1.73	0.67–4.48		1.57	0.62–3.98		1	0.32–3.18		1.82	0.66–5.08		0.80	0.23–2.85	
frequency of toothbrushing per day															
≥3 times	1		0.230	1		0.066	1		0.345	1		0.779	1		0.770
≤2 times	0.39	0.08–1.82		0.26	0.06–1.09		0.43	0.08–2.46		1.37	0.16–12.03		1.40	0.15–13.33	
Toothbrushing duration per session															
≥3 minutes	1		0.308	1		0.473	1		0.092	1		0.291	1		0.408
≤2 minutes	0.66	0.30–1.46		1.30	0.64–2.63		2.05	0.89–4.73		1.50	0.71–3.17		1.49	0.58–3.84	

Above factors were simultaneously analyzed by forced entry. OR: odds ratio; 95%CI: 95% confidence interval.



**Fig. 2. Biplot diagram for dental symptoms in occupational diving and preventative dental visit frequency.**

“Detachment of inlays or crowns” was located between “1 yr” and “6 months.”

## Discussion

This study investigated the relationship between preventative dental visits and dental symptoms experienced by occupational divers. The results suggested that the dental pain experienced by occupational divers during diving is related to a lack of preventative dental visits. Multiple logistic regression analysis comparing factors related to dental symptoms during diving showed that divers who did not undergo preventative dentistry in the previous year were at high risk of tooth pain.

Tooth pain during diving was experienced by 17.8% of the participants. According to the Comprehensive Survey of Living Conditions by the Japanese Ministry of Health, Labour and Welfare, 14.4% of Japanese males with symptoms of tooth pain were in their 20s, 18.7% in their 30s, 15.4% in their 40s, 18.1% in their 50s, 22.1% in their 60s, and 29.9% in their 70s<sup>18</sup>), and Locker and Grushka reported that 13.5% of Canadian citizens had experienced discomfort other than pain as an oral symptom<sup>19</sup>). In our study, the proportion of people with complaints of tooth pain in their 20s, 30s, and 40s was higher than that reported for Japanese men, and tooth symptoms other than pain were experienced by 19.4% of participants. The reason may be related to the difference between atmospheric pressure conditions and the diving environment. Tooth pain during diving is can potentially be life-threatening by causing sudden incapacitation<sup>6</sup>). Hence each symptom experienced by divers deserves special consideration. Taylor *et al.* reported the incidence of tooth pain as 11.4% in leisure and professional divers<sup>20</sup>). In addition, Al-Hajri *et al.* reported this rate as 17.3% in a group of military personnel and diving school students<sup>21</sup>). In Japan, this incidence is reported as 15.8% among Japan Maritime Self-Defense Force divers<sup>22</sup>). The incidence in this study was similar to these previously reported values.

Gunepin *et al.* reported that there is less tooth pain during diving among military divers who routinely visit the dentist once a year or more<sup>23</sup>). However, our results did not show this to be a significant factor in the univariate analysis by  $\chi^2$  test but did reveal a significant association in multiple logistic regression analysis. This association may be influenced by the fact that civilians may have less ready access to healthcare than active military workers<sup>24</sup>), although in Japan, the national insurance system covers a wide range of dental treatments<sup>25</sup>), and the whole nation

has easy access to dental consultations, which may have made it difficult to distinguish a difference.

From the results of the correspondence analysis, the relationship between the frequency of preventative dental visits and each symptom during occupational diving was investigated in an exploratory manner. The horizontal axis of the biplot represents the frequency of preventative dental visits, increasing toward the right of the plot. Subjects who answered, “Two years”, were located to the left of “Not consulted”. There was a mixture of individuals who did not require preventative visits because of their low risk of dental disease and those that did not engage in preventative visits, although they had a high risk, among subjects who answered, “Not consulted”. Subjects who answered “1 month” were located far from the other points. This reflected a special group with high risk factors for oral conditions, who were instructed by a dentist to be followed-up regularly. “Tooth pain” and “Pain in the temporomandibular joint”, which is considered to be caused by water pressure, were located near the subjects who answered, “Not consulted”. Thus, both of these symptoms may be related to not engaging in preventative dental visits. We first considered that “Uncomfortable feeling in the teeth”, “Sensory sensitivity”, and “Feeling of pressure in the teeth” may be early stage symptoms of tooth pain, but correspondence analysis showed that these three symptoms form a group apart from “Tooth pain”, and thus they may be independent symptoms. Also, “Detachment of inlays or crowns”, which is said to be caused by the destruction of cement, were located near the subjects who answered “6 months”. The weakening of dental cement may not be prevented by preventative dental visits. However, dental visits may be related to early recognition of incompatibility of inlays or crowns. The condition of the two periodontal tissues was located equally far apart from the item of each preventative dental visit frequency. The reason is that they already had periodontal disease, and they may have symptoms of the periodontal disease not only during diving but also outside of diving. Because they were undergoing maintenance treatment, the occurrence of symptoms may be low.

In Japan, occupational divers need to obtain a national qualification. All workers who work in special environments that affect health also need to undergo special health check-ups by a doctor under the Industrial Safety and Health Act of Japanese law<sup>26</sup>). Medical problems caused by diving have been reported, such as bone necrosis<sup>27</sup>) and otorrhinal diseases<sup>4</sup>). Hence, a special medical checkup of divers is performed in Japan, and the items for medical history and work history, pain in joints, pain in hips or

lower legs, tinnitus, the examination of the motor function of the extremities, the examination of the tympanic membrane and hearing, measurement of blood pressure, urinalysis, and spirometry is reported annually<sup>28</sup>). A previous study has recommended preventative dental consultation for divers<sup>6</sup>). However, although in some countries and regions, divers are also eligible for dental examinations, in many countries, including Japan, they are not. Dental examinations for divers may be effective for preventing dental symptoms during diving.

This study had some limitations. This study made use of a self-reported questionnaire; there was no information on actual oral diseases. Therefore, our study may have included not only symptoms caused by diving, but also pre-existing symptoms. However, Zadik stated that common oral pathologies could result in barodontalgia and that existing asymptomatic oral diseases also cause pain<sup>7</sup>). Subjects were occupational divers who worked for a company or belonged to the Japan Diving Association. In Japan, about 2,000 occupational divers take part in a special health check-up, but there are about 5,000 licenses issued every year. Small-scale fishermen and individual business owners who do not work for a company or belong to the association may not have been included in this study. This study did not include occupational divers performing saturation diving that involves very deep dives<sup>29</sup>). However, since factors such as educational background, use of diving and scuba, gear, and diving depth, and information on the number of dives per day, and the timing of pain occurrence could not be controlled for in this questionnaire-based survey, it is possible that these factors can be confounding factors. Finally, this cross-sectional study could not examine causal relationship between dental symptoms experienced during diving and its risk factors because of the nature of study design; therefore, further research is required to demonstrate a causal relationship.

## Conclusion

There was relationship between poor participation in preventative dental visits and tooth pain while diving among occupational divers. These results indicated that engaging in regular preventative dental visits may reduce tooth pain during occupational diving.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Acknowledgement

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