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Assessing temporomandibular disorders: mouthpiece design considerations

Procena temporomandibularnih poremećaja u odnosu na dizajn ronilačkog usnika

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Abstract

Background/Aim. Scuba diving is one of the sports with the fastest growing popularity. Nowadays doctors of dental medicine meet divers-patients in their offices more often. Treatment of these patients has some specific features that are related to difficulties in the temporomandibular joint, masticatory muscles and soft tissues of the oral cavity. A set of those complaints represent a condition called „diver's mouth syndrome". Most scuba divers complain of temporomandibular joint and the masticatory muscles pain; inadequate mouthpieces can exacerbate temporomandibular dysfunction (TMD) even when its symptoms are not present in everyday life. The aim of this research was to find a decent substitute for a fully customised mouthpiece, that are not present at our market, to discover the qualities of a good mouthpiece and establish prevalence of TMD among divers. **Methods.** This study included 30 scuba divers. Scuba divers filled out the questionnaire before diving, then dived twice with each of the 3 different commercial mouthpieces provided for this research (Mares Universal, Seac sub, Mares LiquidSkin (Universal Mares, Seac sub, Mares LiquidSkin). After diving, they filled out the second part of the questionnaire and so they performed an assessment of the mouthpiece and gave insight into the prevalence of TMD symptoms caused by using the mouthpiece. **Results.** According to the average score of satisfaction (the least present symptoms such as pain, fatigue, and numbness of the masticatory muscles and the jaw joint), this research proved Mares LiquidSkin mouthpieces to be the best out of the 3 commercial mouthpieces. For its use, average satisfaction score among participants was 7.07 (out of 10) and none of the divers reported jaw and muscle stiffness during and after the dive with this mouthpiece. The smallest percentage of participants reported pain in the orofacial region and discomfort while swallowing when used it in comparison with other mouthpieces. The anatomy and material of the mouthpieces turned out to be an extremely important factor. **Conclusion.** Several factors contribute to a good mouthpiece design; the choice of material, its elasticity and softness, the thickness and length of the interdental bite platform and the width of the oral screen that is inserted into the vestibule. The preferred material should be soft silicone. The interdental bite platforms should support the posterior teeth and the oral screen should fit the jaws and not be too wide.

Key words:
diving; equipment and supplies; temporomandibular joint disorders.

Apstrakt

Uvod/Cilj. Ronjenje sa bocama je sport čija se popularnost izuzetno povećava. Danas se stomatolozi u svojim ordinacijama sve češće susreću sa pacijentima-roniocima. Prilikom tretmana pacijenta koji roni, stomatolozi bi trebalo da budu upoznati sa stanjem zvanim „sindrom ronilačkih usta", koji uključuje bol u zglobu i zubima, oštećenje desni ili hiperplaziju gingive – zubnog mesa. Većina ronilaca se žali na bol temporomandibularnog zgloba i mastikatornih mišića; neadekvatan usnik može pogoršati temporomandibularne poremećaje (TMP) čak i kada u svakodnevnom životu ne postoje njeni simptomi. Cilj ovog istraživanja bio je da se pronađe pristo-

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jna zamena za potpuno prilagođen usnik, koji nije prisutan na našem tržištu i da se otkrije koji su kvaliteti dobrog usnika i kolika je rasprostanjenost TMP među roniocima. **Metode.** U ovom istraživanju učestvovalo je 30 ronilaca sa bocama. Ronioci su ispunjavali upitnik nakon ronjenja po dva puta sa svakim od tri različita komercijalna usnika obezbeđenih za ovo istraživanje (Mares Universal, Seac sub, Mares LiquidSkin). Oni su procenjivali usnike i davali uvid u rasprostranjenost simptoma TMP-a izazvanih korišćenjem usnika. **Rezultati.** Prema prosečnoj oceni zadovoljstva (najmanje prisustvo simptoma kao što su bol, umor i ukočenost mastikatornih mišića i zgloba vilice), ovo istraživanje je pokazalo da je usnik Mares LiquidSkin najbolji od tri posmatrana komercijalna usnika. Prosečna ocena zadovoljstva je bila 7.07 (od ukupno 10) i pokazani su izuzetni rezultati – nijedan ronilac se nije žalio na ukočenost vilice i mišića za vreme i posle ronjenja sa ovim usnikom, a u poređenju sa drugim usnicima, on je kod manjeg broja ispitanika izazivao bol u orofacijalnoj regiji i nelagodnost prilikom gutanja. Anatomija i materijal usnika pokazali su se kao ekstremno važan faktor. **Zaključak.** Nekoliko faktora čine dobar dizajn usnika: izbor materijala, njegova elastičnost i mekoća, debljina i dužina interdentalne platforme ugriza i širina platforme koji se stavlja u vestibulum. Idealan materijal je mekani silikon, interdentalna platforma ugriza bi trebalo da podržava zadnje zube i širina bi trebalo da odgovara širini čeljusti.

Ključne reči:
ronjenje; oprema i pribor; temporomandibularni zglob, poremećaji.

Introduction

In the past years scuba diving became more popular, not only as a recreational, but also as a professional sport. Rather than focusing only on the impact of underwater high pressure on the human body, researchers have become more interested in scuba diving equipment design. As the number of scuba divers increases, doctors of dental medicine have the opportunity to treat such patients in their offices more often. For that reason, doctors of dental medicine should be educated to recognize and treat symptoms and complications in the orofacial region that are sometimes present among diver population [1]. These symptoms, known as „diver's mouth syndrome", include temporomandibular pain, tooth pain and gingival hyperplasia and can be caused by the mouthpiece [1–3].

Stomatognathic system is a very complex system which consists of temporomandibular joint (TMJ), teeth, orofacial muscles, facial bones and jaw, oral mucosa, nerves, blood and lymph vessels [4] and it enables the performance of the functions of mastication, speaking, breathing and deglutition. For the functioning of the stomatognathic system, it is essential that all elements are functioning properly, otherwise, disturbance of one of the factors can cause disruption of other factors of the system.

Temporomandibular dysfunction (TMD) represent a very serious health problem and occupy a leading place when it comes to the disease of the musculo-skeletal system in general [5]. Those disorders are present in a large percentage in general population and there is data in the literature showing that the symptoms are often present in females [6]. Temporomandibular disorders are caused by different etiological factors such as genetic factors, trauma, malocclusion, parafunctions, emotional stress, factors of inflammatory and noninflammatory nature and so on. A diagnosis is very complex and it is followed by a long-term therapy often requiring multidisciplinary approach (dentist, surgeon, physiatrist, otolaryngologist).

The association between TMD and scuba diving is the subject of many research and it is believed that these disorders is on the rise with the increasing interest in training for scuba diving certification [7].

The acronym SCUBA stands for self-contained underwater breathing apparatus, yet it is used as a noun. Mouthpieces are part of scuba diving equipment, inserted in the mouth, gripped by the teeth and held in place. They enable air flow from a regulator whilst ensuring a watertight seal. Main part of a mouthpiece are an airway tube connected to the demand valve which delivers breathing gas, oral screen inserted in the vestibule of the mouth, interdental bite platforms into which the diver bites and palatal lugs. Scuba diver mouthpiece is held by teeth. Mouthpiece is a part of the second stage of the regulator, which is connected by a hose with a scuba tank loaded with air. Except allowing air consumption, the shape and position of mouthpiece in the mouth vestibulum prevent water entry. There are plenty of different commercial mouthpieces on the market. Main parts of the mouthpiece are: connector tube to the demand valve of the second stage, vestibular shield, interdental bite platform and palatal flange (Figure 1).

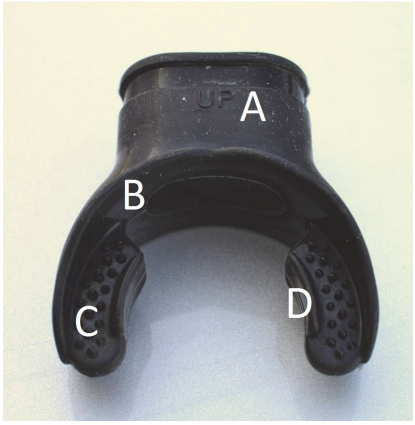


Fig. 1 – Mouthpiece parts.

The aim of our research was to determine the qualities of a good commercially available mouthpiece, ensuring both comfort while diving and causing minimal or no symptoms related to the temporomandibular joint. Other researchers took into consideration semi-customized and fully-customized

mouthpieces as well. Fully-customized mouthpieces are not available in Croatia, considering the complexity of their fabrication in dental laboratories and price, while semi-customized mouthpieces can only be seldom found.

Methods

In this study, 30 scuba divers, from Croatia and Slovenia, aged 26–36 years, participated voluntarily and anonymously after signing the informed consent. The research included a questionnaire consisting of two parts. The first part was filled in before the test dive and it consisted of the issues related to oral health of the subjects (tooth status, problems related to TMJ and masticatory muscles), frequency and length of practicing scuba diving as well as mouthpieces that they used when diving (Appendex 1).

The study participants filled out the second part of the questionnaire after the test dives and it was related to comfort, discomfort and occurrence of different potential symptoms in the orofacial region during and after the dive (Appendix 2).

Scuba divers had been given 3 different mouthpieces to try out. They dived twice with each of them.

Mouthpieces chosen for this research were Mares universal mouthpiece (mouthpiece No 1), SEAC SUB mouthpiece (mouthpiece No 2) and Mares LiquidSkin Mouthpiece (Figures 2 and 3).

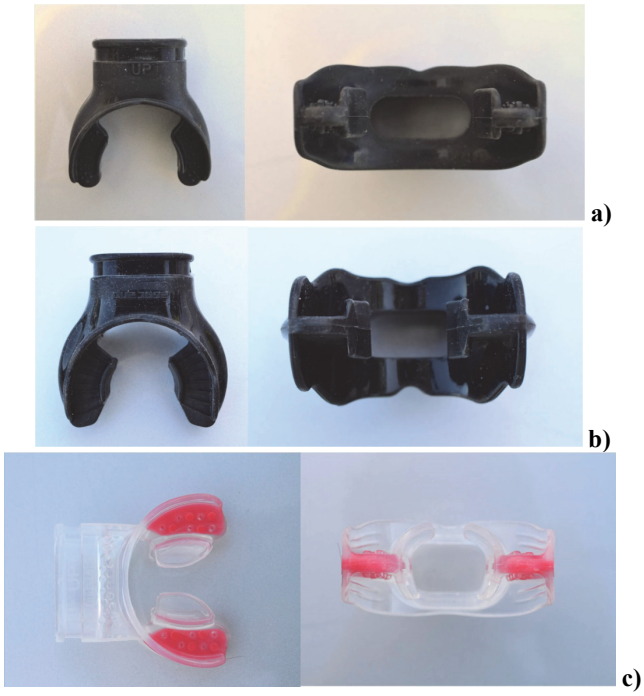


Fig. 2 – Mouthpieces used in the study: a) Mares universal mouthpiece – mouthpiece No 1; b) SEAC SUB mouthpiece – mouthpiece No 2; c) Mares LiquidSkin mouthpiece – mouthpiece No 3.

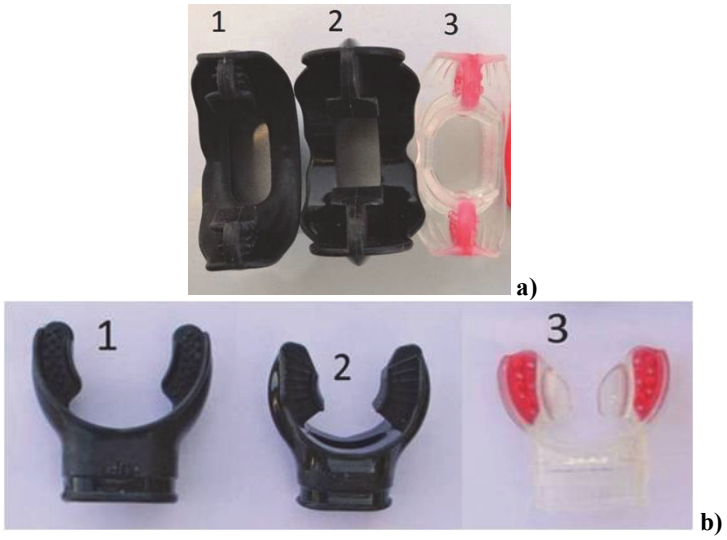


Fig. 3 – Comparison of mouthpieces used by a) size, and b) width.
1 – Mares universal mouthpiece; 2 – SEAC SUB mouthpiece; 3 – Mares LiquidSkin mouthpiece.

Scuba divers could use fully-customized and commercial mouthpieces. Commercial mouthpieces are the most common on the market. They are made of rubber or silicone and their shape is designed to fit each scuba diver. Fully-customised mouthpieces are made of termoformical material, which, after being in hot conditions, becomes soft when a scuba diver puts it in the mouth and takes a gentle bite. In this way the user forms a shape that fits him/her. Our criteria for choosing these 3 mouthpieces were their presence on the market and popularity among divers.

Results

Three commercially available mouthpieces were tested after 180 dives; 30 divers dived twice with each of the chosen mouthpieces.

Rigidity and stiffness of face and jaw muscles during and after the dive with all 3 mouthpieces are shown in Figure 4a. The divers ranked mouthpiece No 3 as the best one, with no pain noticed during or after the dive. On the contrary, mouthpiece No 2 was given the lowest rating – 16.67% of examinees felt pain in the course of diving while 20% felt pain after the dive.

Experienced jaw and muscle pain during and after the dive was presented in Figure 4b. As shown, mouthpiece No 3 caused the least, or to be more precise, no pain after the dive while 6.67% of the divers felt pain during the dive. Both other mouthpieces, No 1 and No 2, caused greater pain during and after the dive.

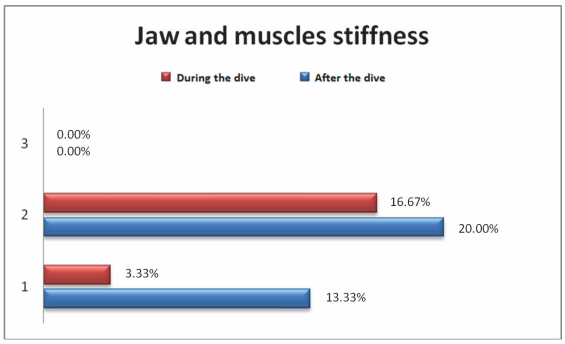
The occurrence of discomfort while swallowing saliva is shown in Figure 4c. The least percentage of divers felt discomfort while diving with the mouthpiece No 3 and none after the dive while the biggest percentage of discomfort occurred both during and after diving with the mouthpiece No 1.

All in all, the divers reported to be most pleased with the mouthpiece No 3, with an average satisfaction score of 7.07. The mouthpiece No 1 was ranked as the second best and the mouthpiece No 2 as the third one (Figure 5).

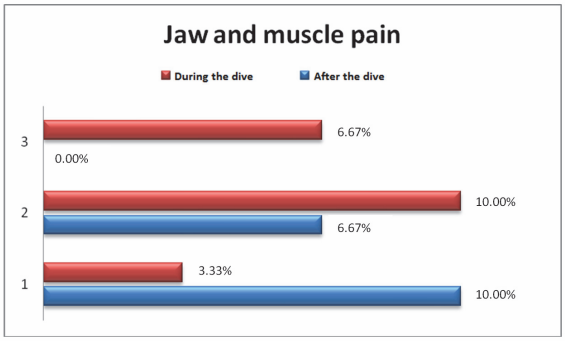
Discussion

Data collected during this study were obtained from a relatively small sample of 30 examinees, yet, in studies similar to this one, the number of examinees ranged from only 6 to a maximum of 72 examinees [1, 8, 9]. Despite this relatively small sample of examinees, valuable information about the prevalence of TMD symptoms and the importance of the mouthpiece design can be drawn from the collected data. The highest average grade, considering satisfaction with the used mouthpiece was given to Mares LiquidSkin mouthpiece (mouthpiece No 3). Mouthpiece No 3 showed the best results considering seldom occurrence of TMD symptoms which makes it the best ranked mouthpiece in this research.

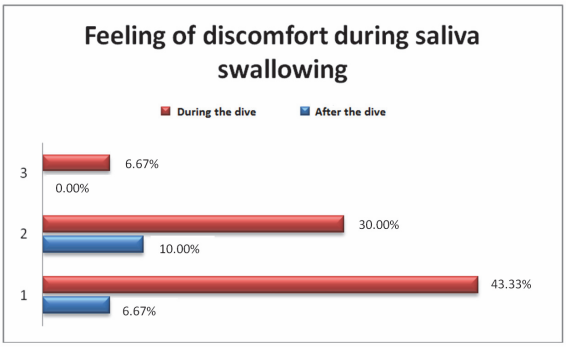
A point of this study was to determine the qualities of a good mouthpiece and not to promote any specific brand. Results of different studies have shown that pain and jaw stiffness are strongly connected with the type of material and the length, thickness and position of interdental bite platforms.



a)



b)



c)

Fig. 4 – Comparison of complaints caused by monthpieces tested:
a) Rigidity and stiffness of face and jaw muscles;
b) Jaw and muscle pain;
c) Discomfort during swallowing.
1 – Mares universal mouthpiece;
2 – SEAC SUB mouthpiece;
3 – Mares LiquidSkin mouthpiece.

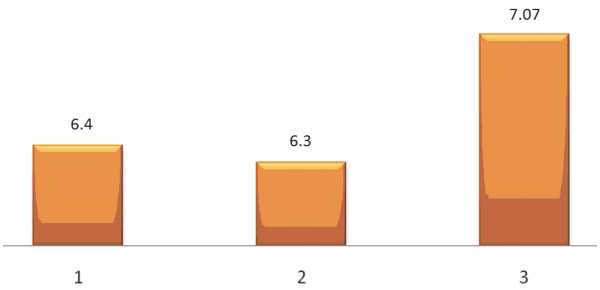


Fig. 5 – Average satisfaction score with monthpieces tested.
1 – Mares universal mouthpiece;
2 – SEAC SUB mouthpieces;
3 – Mares LiquidSkin mouthpiece.

Commercially available mouthpieces used in this study are all made out of silicone which is thought to be a better material choice than rubber. While other two mouthpieces tested in this study, No 1 and No 2 (Mares Universal and Seac Sub, respectively) are stiffer, which was often mentioned in the fulfilled questionnaires, Mares LiquidSkin is, according to the manufacturer, made out of two kinds of very soft silicone. Interdental bite platforms are made out of softer silicone while the rest of the mouthpiece is also soft and very flexible and because of that they can adapt to the vestibule of the mouth easily. It seems that the main reason behind such good ranks of mouthpiece No 3 (Mares LiquidSkin) is its softness. Very strong bite into the interdental platforms is usual during the dive – it can be caused by the cold water, exhilaration or anxiety and it puts high pressure on the TMJ. Biting into a softer material to keep the mouthpiece in place causes less muscle tension, less jaw fatigue, pain, muscle and jaw stiffness and less discomfort during saliva swallowing making in this way a dive more pleasant.

Another important factor in the design of a mouthpieces is the length of the interdental bite platforms and its position. Interdental platforms in many, if not almost all commercially available mouthpieces, reach from canines to second premolars or mesial surface of the first molar, and thus do not provide support for the posterior teeth. Increased pressure, specifically on canines and premolars distributes inadequately the occlusal force to the TMJ and masticatory muscles which can cause the inflammation of the TMD. The distribution of the occlusal force is greatest at the molar region – molars have the largest occlusal and root surface.

Some authors recommend that interdental platform should stretch from premolars to molars [8, 10–12], while some had an opinion that it was necessary to include canines, premolars and molars to reduce stress on the temporomandibular joints. Increased pressure on the interdental platform was due to efforts to keep that part in the mouth during the dive [13] and it was considered that this caused higher prevalence of TMD in inexperienced divers [7]. In a study conducted on a large number of participants, it was found that in 44.1% of subjects, who were without disorders before dive, symptoms in stomatognathic system occured as a result of a strong bite on the interdental platform [14].

Oral screen, which gets inserted in the vestibule, can cause discomfort during the dive. Oral screen should not be wide, or it could interfere with the upper and lower frenula and cause pain and discomfort. Mouthpiece No 2 (Seac Sub), ranked as the last, has an oral screen a few mm wider than others which has largely contributed to its poor rank. The scuba divers also noted that this mouthpiece was too big and too wide. Wide and stiff oral screens can lead to gingival injuries and irritations which could later cause wounds and gingival hyperplasia [15]. Although fully customized mouthpieces are considered to be the best, it is possible to find an adequate alternative. A well designed commercially available mouthpiece would have to fulfil several requirements: type of material, its softness and flexibility, length and thickness of the interdental platform, width of the oral screen and its overall size.

It is believed that it is necessary that dentists perform periodic monitoring of the situation in the mouth of the divers in order to prevent the consequences that may appear in the joints, muscles and other tissues in the oral cavity. For the health of the oral structure, a design of scuba diving equipment is very important, especially the part in the mouth of divers, which, if is inadequate, can lead to deterioration of oral health [16].

Conclusion

It is essential that every scuba diver, whether it is engaged in professional or recreational scuba diving, try more mouthpieces which are available in the market and choose for themselves the most appropriate ones. The further research are of great importance in order to improve the design of the mouthpiece with the aim to reduce the possibility of occurrence and progressive disease of the stomatognathic system and thus contribute to maintaining the health of the individual.

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Appendix 1

THE FIRST PART: QUESTIONNAIRE BEFORE DIVING

Participant's number: _____
Name, Surname: _____
Date of birth: _____
Professional qualifications, profession: _____
Gender: M F

1. Status of teeth

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38

T - intact tooth
A - anodontia
EX - extraction
RR - radix relicta
F – filling plomba
CR - crown
P - pontic
C – cantilever
IN - inlay
OV - overlay
D - dentures tooth
CL - clasp
SC - surveyed crown
DC - double crown
Ca - caries
S - sealant
IM - implant

The difference in height of rest position and maximum intercuspation	___ mm
The width of the upper incisors	___ mm
The front width of the dental arch 4-4	___ mm
The rear width of the dental arch 6-6	___ mm
Front length of the dental arch	___ mm
Front length of the dental arch	___ mm
The back length of the dental arch	___ mm
Height palate	___ mm

2. How many years have been you diving? __ __ year(s) __ __ month(s)

3. How often do you dive?

1–10 per year	1
11–20 per year	2
21–30 per year	3
31–40 per year	4
41–50 per year	5
51–60 per year	6
61–70 per year	7
71–80 per year	8
More than 80 per year	9

4. Do you dive over the whole year or only in season (summer time)?

over the whole year	1
in season (summer time)	2

5. Do you use commercial (standard) or personal (adjusted) mouthpiece ?

commercial	1
personal (adjusted)	2

6. (For those who use personal (adjusted) mouthpiece) Have you ever used a commercial (standard) mouthpiece ?

No	0
Yes	1

7. How long have you been using commercial mouthpiece ? ___ year(s) ___ month(s)

8. Rate on the scale 0 to 10 how much you feel satisfied with your mouthpiece, where 0 – very displeased, 10 – very pleased

Very displeased Very pleased

0 1 2 3 4 5 6 7 8 9 10

Questions	Every day	During the dive	After the dive
9. Have you ever felt problems in temporomandibular joint (TMJ)?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
10. Have you ever felt pain in the face?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
11. Have you ever felt a headache?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
12. Have you ever felt a neck pain?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
13. Have you ever felt a ear pain?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
14. Have you ever felt buzzing in the ears?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
15. Have you ever felt pain in chewing muscles?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
16. Have you ever felt pain in jaws?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
17. Have you ever felt of face/jaws stiffness?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
18. Have you ever felt face/jaws muscule fatigue?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
19. Have you ever had problems to open your mouth as you wish, due to jaws joint/chewing muscule pain?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
20. Have you ever had problem with opening your mouth due to jaw joint/chewing muscule pain?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
21. Have you ever noticed “clicks” in jaws joint?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
22. Have you ever had problems or feel discomfort while (when) chewing food, due to jaw joint pain?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
23. Have you ever felt discomfort while swallow saliva?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1
24. Have you ever felt dry mouth?	No 0 Yes 1	No 0 Yes 1	No 0 Yes 1

The study participants filled out the second part of the questionnaire after the test dives and it was related to comfort, discomfort and occurrence of different potential symptoms in the orofacial region during and after the dive, (Appendix 2).

Appendix 2

THE SECOND PART: QUESTIONNAIRE AFTER TESTING THE MOUTHPIECE

Participant's number:

1. Rate on the scale 0 to 10 how much you feel satisfied with your mouthpiece, where 0 – very displeased, 10 – very pleased

Very displeased Very pleased

0 1 2 3 4 5 6 7 8 9 10

Questions	During the dive	After the dive
2. Have you ever felt pain in chewing muscles?	No 0 Yes 1	No 0 Yes 1
3. Have you ever felt pain in jaws?	No 0 Yes 1	No 0 Yes 1
4. Have you ever felt pain of face/jaws or stiffness?	No 0 Yes 1	No 0 Yes 1
5. Have you ever felt face/jaws muscule fatigue?	No 0 Yes 1	No 0 Yes 1
6. Have you ever felt discomfort while swallow saliva?	No 0 Yes 1	No 0 Yes 1
7. Have you ever felt dry mouth?	No 0 Yes 1	No 0 Yes 1

8. How easy can you breath with this mouthpiece compared to the commonly used one?

Smaller Same Bigger
1 0 2

9. Have you had problems with ear compensation while diving with this kind of mouthpiece?
Yes 1 No 0

10. Please write any suggestion and idea you may have after mouthpieces testing