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Unravelling the benefits of thermal waters enhancing oral health: a pilot study

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Abstract

Background Oral health represents a public health problem due to its remarkable social impact and medical costs. Crenotherapy with sulfur water is shown to be a complementary, less toxic, and traumatizing therapy, but the number of studies that evaluate the effect of natural mineral waters effect on oral health are scarce. The aim of this pilot study is to evaluate the impact of thermal water therapy on the oral health of the participants, assessing parameters such as plaque index, gingival bleeding index and periodontal probing depth as well on the perception of symptoms of oral mucosa diseases (OMD).

Methods An observational, longitudinal and comparative study was designed, and 90 thermalists were randomly allocated to two treatment groups for 14 days: Thermal sulfuric natural mineral water of the Amarante Thermal baths group (TW_TA group) ($n=45$) or saline solution (control group) ($n=45$), in May 2022. The study was based on clinical observation and application of a self-response questionnaire involving sociodemographic data and quality of life assessment. The evaluation was carried out in 2 different moments: before and at the end of treatment (14 days).

Results The study involved 90 thermal practitioners, evenly split between the TW_TA group and a control group. Most participants were women (70%), with a similar average age in both groups. Oral examination showed a high prevalence of filled and missing teeth, and around 25% of participants used removable prostheses, predominantly in the control group. Thermal treatment had a positive impact on oral health. In the TW_TA group, gingival bleeding significantly decreased from 68.9% to 40%, while it remained unchanged in the control group. Periodontal health improved, with no participants in the TW_TA group having pockets deeper than 5 mm by the end of the study, indicating reduced periodontal pathology. Also, plaque levels dropped in both groups after treatment, as assessed by the O'Leary index. Additionally, quality of life related to OMD improved, particularly in the TW_TA group. The overall reduction in symptoms was significant, although the differences between groups were not statistically significant.

Conclusions This study demonstrates the positive effects of thermal water treatment on oral health, including reduced gingival bleeding and plaque levels, along with improved quality of life related to OMD. Further targeted research is needed to explore the benefits of thermal water effects and optimize oral health practices in Portugal using thermal waters.

Keywords Fluoridated sulfur waters, Thermal waters, Oral health, Oral mucosa disorders, Quality of life assessment

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Background

Thermal waters (TW) are an underground mineral treasure, known for containing a complex mixture of minerals such as sulfur, selenium, zinc, calcium, among others [1]. It is currently accepted that their medicinal properties are related to the mineral composition and the high temperature of these waters. In recent years, several studies demonstrated the importance of these waters and thermal products as treatment approaches in different pathologies namely associated with respiratory [2] and rheumatic/musculoskeletal diseases [3].

Medicinal benefits of TW have been known since ancient times and are assigned to its specific characteristics such as temperature, organic and inorganic constituents, pH and treatment applications [4]. Sulfurous thermal waters are used to treat dermatological conditions due to their anti-inflammatory, antioxidant, antiseptic, and anti-irritation properties. They are also beneficial for reducing the frequency of upper respiratory tract infections, as their immunomodulatory effects contribute to the therapeutic outcomes [5]. Chlorinated TW are considered anti-inflammatory, antipyretic, and disinfectant that can stimulate gastric and intestinal secretions and motility, favourable to healing and bone-related afflictions [6].

Despite its widespread use, limited studies validate the effects of TW. Research on Avène TW has shown antioxidant [7], anti-allergic effect [8], and anti-inflammatory effect, such as protecting keratinocytes from oxidative stress and reducing inflammation [9]. Also, La Roche Posay and Avène TWs have been shown to inhibits inflammatory cytokines and ROS formation in UV-irradiated cells [10]. In fact, France has the use of TW well established in the community, with a range of therapeutic indications such as rheumatic, respiratory, gynecologic, cardio-vascular, dermatologic and oral mucosa disorders. In the case of the last one, the application of TW for the treatment of oral mucosa disease (OMD) is indicated for aphthous, lichen planus, and gingivitis [11]. In this case, therapeutic applications are delivered through local contact methods such as gargles and sprays, often supported by mechanical and thermal effects [12]. Castéra-Verduzan thermal institution created a line of oral hygiene products under the name Buccotherm® with therapeutical indication for periodontal disease [13], xerostomia [14], halitosis, mouth ulcers and inflammation of mouth and diseases of the mucous membrane [15].

In Portugal, the popularity of thermal waters (TW) and the establishment of the National Health Service (SNS) have led to the recognition of thermalism's importance [6]. Legislation ensures quality control of natural mineral waters and sets standards for their use. Amongst the thermal centers of Portugal that have therapeutic indications, mainly for respiratory and rheumatic/musculoskeletal afflictions, Termas de Amarante stands out for its rich sulfur, sodium, and other mineral content, making it effective for treating respiratory, musculoskeletal, and rheumatic conditions. This TW has been classified by *Direção-Geral de Energia e Geologia* (DGEG) and exhibits the typical profile of a genuine sulfuric water from the pH > 9 subgroup, being a weakly mineralized water, sodium carbonated, fluoridated and sulfhydrated, with a temperature at emergence of 22.9ºC and hypothermal (less than 35ºC) (https://www.dgeg.gov.ptn.d). Furthermore, none of the Portuguese TW were tested for OMD treatment or other oral pathologies.

OMD encompasses a range of common conditions, such as lichen planus, aphthous stomatitis, herpes simplex infections, and candidiasis, along with recurrent ulcerations, chronic mouth pain, and xerostomia, often linked to autoimmune diseases or medications [16–19]. Additionally, oncological treatments can lead to oral sequelae like mucositis and salivation disorders [20]. In this cases, TW could be useful not only for its local effects on the mouth and teeth, but also for its general effects on nervous and psychological tension [21].

In addition to OMD, periodontal disease has a high prevalence in population worldwide and is the main cause of tooth loss [22]. It is characterized by is characterized by the destruction of periodontal tissues due to dysbiotic microbial communities and immune responses [23]. Due to the inflammatory profile and high prevalence of these conditions, TW application could be considered as an adjuvant therapeutic approach for these disorders.

The present study aims to investigate the impact of TW from TA (TW_TA) application via gargles and oral (gum) showers on the oral health of participants, using indexes and parameters recognized in the assessment of oral health, such as plaque index, gingival bleeding index and periodontal probing depth. Additionally, it is proposed to explore the effects of natural mineral waters on the oral mucosa, by evaluating the perception of the symptoms of OMD, identifying potential adverse reactions or side effects and developing strategies to prevent or manage them. This is crucial for ensuring patient safety and well-being, as well as enhancing the outcomes of dental treatments that utilize thermal water.

Methods

This observational, longitudinal and comparative study was approved by the Ethics Committee for Health of the Universidade Católica Portuguesa in the scope of Project nº205_CES-UCP and the consent from the Clinical Director and the TA management board. All patients eligible for this investigation completed and signed the Explicit, Free and Informed Consent Form.

Study design

An observational, cross-sectional and comparative study was designed in which 90 thermalists were randomly allocated to two treatment groups for 14 days:

- Thermal water of *Termas de Amarante* (TW_TA) group ($n=45$): TW from TA was applied daily via gargles and oral (gum) showers. Both techniques are thermal methods where mineral water contacts with oral mucosa, in which the TW used acquires the temperature and density required for each type of application
- Control group ($n=45$): saline solution (0.9%) was applied in the same conditions applied in the TW_TA control.

For the TW and saline solution applications, the liquid was placed in contact with the mucous membranes to be treated, through devices that allow perfusion of the mucous membranes, for adequate water absorption. Gargling is carried out by the thermalist him/herself, with warm water (36ºC) and has the therapeutic effect of humidifying the oral mucosa and consequently improving its trophism, according to the physical and chemical composition of the water. Thermalists were instructed to avoid ingesting the water after mouthwash, and the water should be expelled under pressure, to force the washing effect, at the same time as a forced exhalation exercise is carried out. The amount of water per day was between 15 – 20 cc depending on the doctor's prescription. In gingival sprays, 1 to 2 L of water are applied, depending on medical prescription, at 36ºC, in droplets that reach directly into the oral cavity.

This study took place in May 2022, with the thermal practitioners that agreed to participate in the study. The duration of crenotherapy was 2–3 weeks, the ideal time for the development of the chronobiological effects that varies between the 7th and 14th day of treatment. In TA, the protocol indicates treatments carried out during 14 days, which is in accordance with the current recommendations of the Portuguese Society of Hydrology**.**

The following criteria were considered for the inclusion of thermalists in this study: thermal therapists from both sexes and no age limit, carrying out a thermal treatment lasting 14 days that agreed to collaborate in the study. The exclusion criteria correspond to some clinical conditions and precautions common to TW treatments according to the rules of good practice manuals for thermal establishments [24], such as: general contraindications to thermal treatment: decompensation of organic systems (immunosuppression and/or immunosuppression, arterial hypertension, diabetes mellitus, insufficiency decompensated liver and/or kidney); history of cancer in the last 2 years; thermalist undergoing dialysis and kidney transplant, recipients receiving cyclosporine or corticosteroids in the last 2 months before the thermal treatment. Thermalists with psychoneurotic disorders, unable to join the study, pregnant women and smokers were also excluded.

Data collection

Data relating to the participants were collected by direct interview, which included demographic and behavioral characteristics and the participants' perception of oral health. All participants were also subjected to a clinical examination (intra and extraoral), at two moments, coinciding with the assessment of TA doctors: on the first day (before the thermal treatment), on the last day (after the last treatment). The 3 and 6-month time points were chosen based on multiple studies in the field of thermalism, which indicate that most effects become significant after 6 months or longer.

Due to the lack of studies of the impact of TW in oral health, the questionnaire used was based on the nasosinus impairment test—Sino-Nasal Outcome Test-20 (SNOT-20), validated at national and international level [25, 26]. However, due to the specific nature of the area and the need to address various types of questions in this investigation, it was essential to develop a questionnaire tailored specifically for this purpose. The resulting questionnaire is divided into two main parts:

- Sociodemographic data—including name, age, profession, residence and telephone number.
- The Visual Analogue Scale (VAS) was applied as a pain rating scale which is well-accepted and is a sensitive assessment parameter for pain perception.
- The "Clinical assessment" subsection comprises a set of 10 clinical parameters, which reflect the main symptoms associated with oral conditions (localized facial pain, sensation of pressure inside the face, pain on palpation or local percussion, localized facial swelling, total or partial inability to eat, bad breath (halitosis), dry mouth (xerostomia), headaches, ear pain, multiple episodes of fever).

Clinical oral examination

The intra and extra oral clinical examination was carried out focusing on clinical history on the oral cavity and OMD. In this examination, all participants were evaluated regarding the number of decayed, missing and filled teeth, with registration of DMFT (permanent dentition) [27], periodontal health status, with registration of the gingival bleeding index, Community Periodontal Index (IPC), and the O`Leary Oral Hygiene Index. Clinical examinations were carried out in a room adapted for this

purpose, installed in the establishment, and the following were used to obtain data. Observation kit (intraoral mirror, WHO probe and tweezers), sterilized gauze and plaque revelator. The presence of complete or partial dentures was also assessed.

The thermal practitioners who agreed to participate in the study were also instructed and advised on the need to carry out good oral hygiene (teeth and tongue), with a neutral-flavored toothpaste, as well as being advised to suspend the use of any antiseptic for the oral cavity (elixir). Furthermore, careful eating was advised, avoiding spicy, acidic and sugary foods at very extreme temperatures (hot/cold), to avoid interference with the results.

Statistical data analysis

A descriptive analysis was carried out, using absolute and relative frequencies for categorical variables, measures of central tendency (means, median) and dispersion (standard deviation, minimum and maximum) for continuous variables.

Subsequently, inferential analyzes was carried out with the aim of validating the research hypotheses. Parametric tests were used whenever the conditions of normality and homogeneity of variances are met. The Shapiro–Wilk test was used to test normality. To evaluate the effect of treatment, at different times and on the different variables studied, the parametric t-Student test for paired samples was used to compare the means of a variable with normal distribution for two independent samples. As a non-parametric alternative, the Wilcoxon test and McNemar test for paired samples was used, with the purpose of establishing statistical significance between the mean values of the variables. To assess the intensity and direction of the relationship between two variables, the correlation coefficient were determined. Dependencies between variables were analyzed using the r-Pearson or τ_b -Kendall correlation tests. All data were entered and processed using SPSS software (Statistical Package for the Social Sciences Inc., Chicago, Illinois, USA) version 27.0.

Results

Sample characterization

The sociodemographic data of the 90 patients equally distributed between the TW_TA experimental group ($n=45$) and the control group ($n=45$) are presented in Table 1.

The sample collected consists of 90 thermal practitioners distributed equally across the two groups: TW_TA and control. It is observed that globally 70% ($n=63$)

Table 1 Sample characterization - sociodemographic data

Variables		GROUPS				Total	
		TW_TA		Control			
		n	%	n	%	N	%
Gender	Male	13	28.9	14	31.1	27	30.0
	Female	32	71.1	31	68.9	63	70.0
	Total	45	100	45	100	90	100
Age	Until 45 y	11	24.4	9	20.0	20	22.2
	From 46 to 55 y	11	24.4	8	17.8	19	21.1
	From 56 to 65 y	4	8.9	12	26.7	16	17.8
	Over 65 y	19	42.2	16	35.6	35	38.9
	Total	45	100	45	100	90	100
	$X- \pm sX— \pm s$	57.13 ± 18.505		56.76 ± 16.079		56.94 ± 17.237	
Employment status	Self-employed	2	4.4	6	13.3	8	8.9
	Employee	20	44.4	12	26.7	32	35.6
	Retired	17	37.8	14	31.1	31	34.4
	Unemployed	1	2.2	3	6.7	4	4.4
	Student	1	2.2	2	4.4	3	3.3
	Domestic	4	8.9	8	17.8	12	13.3
	Total	45	100	45	100	90	100
Residence	Rural	17	37.8	18	40.0	35	38.9
	Urban	28	62.2	27	60.0	55	61.1
	Total	45	100	45	100	90	100

TW_TA thermal water from Termas de Amarante. Control—saline solution

Table 2 Average, standard deviation, minimum and maximum values of the DMFT Index

Group		Mean and standard deviation	Minimum and maximum
TW_TA	DMFT ($n=45$)	4.07 ± 2.389	0–11
	D ($n=2$)	1.00 ± 0.000	1–1
	M ($n=45$)	1.13 ± 2.237	0–10
	F ($n=45$)	2.87 ± 1.258	0–5
Control	DMFT ($n=45$)	4.71 ± 2.257	0–10
	D($n=5$)	0.80 ± 0.748	0–2
	M($n=32$)	2.53 ± 1.620	1–7
	F ($n=41$)	3.10 ± 1.511	1–9

TW_TA thermal water from Termas de Amarante. Control- saline solution DMFT-Decayed(D),missing(M) and flled(F) permanent

are women and that they are also the majority in each group. The two groups have a relatively close average age: 57.13 ± 18.505 and 56.76 ± 16.079 for TW_TA and Control, respectively.

Oral examination

According to the results of the statistics (Table 2), the average number of teeth that experienced dental caries, mainly indicate that the "filled" component is the most common among individuals, along with a high rate of missing teeth. Considering the significant lost of teeth, it is crucial to determine the number of participants that have undergone rehabilitation for edentulous spaces using the appropriate prosthesis.

Regarding the usage of removable prostheses, approximately ¼ of the population studied used a dental prosthesis (Table 3), with the higher percentage belonging to the control group (84.4%).

The periodontal health of the participants was also assessed by evaluating the presence of gingival bleeding (Table 4), the probing depth (Table 5) and the plaque index trough O'Leary index (Table 6), while simultaneously recording the differences at two time points, T0 and T14.

At the beginning of the study, 68.9% ($n=31$) of TW_TA individuals and 46.7% ($n=21$) of control group had presented gingival bleeding. After thermal treatment, the percentage of participants with gingival bleeding on the TW_TA group decreased to 40.0% ($n=18$) while the control group remained unaltered. Therefore, the effect of thermal treatment in reducing gingival bleeding is notorious, which was proved by the statistics using the McNemar test ($p=0.001$).

Probing depth is another parameter that needs to be considered. The depth of the probing was measured

Table 3 Characterization of prosthesis use by group

Prosthesis	Grup				Total	
	TW_TA		Control			
	n	%	n	%	n	%
Yes	29	64.4	38	84.4	67	74.4
No	16	35.6	7	15.6	23	25.6
Total	45	100	45	100	90	100

TW_TA thermal water from Termas de Amarante. Control—saline solution

Table 4 Characterization of gingival bleeding at assessment times T0 and T14 by group

Gum bleeding		Group				Total		X^2 (p)
		TW_TA		Control				
		n	%	n	%	n	%	
T0	Absent	14	31.1	24	53.3	38	42.2	4.555 (0.033)
	Present	31	68.9	21	46.7	52	57.8	
	Total	45	100	45	100	90	100	
T14	Absent	27	60.0	24	53.3	51	56.7	0.407 (0.523)
	Present	18	40.0	21	46.7	39	43.3	
	Total	45	100	45	100	90	100	

TW_TA thermal water from Termas de Amarante. Control- saline solution X^2 (p) Chi-square independence test statistics (proof value)

X2 (p) - use of Fisher's exact test

Table 5 Characterization of the presence of pockets at the initial moment (T0) and at the final moment (T14) in the evaluation by group

Periodontal pocket		Group				Total		X^2 (p)
		TW_TA		Control				
		n	%	n	%	N	%	
T0	Absent	24	53.3	33	73.3	57	63.3	10.952 (0.002)
	Pocket of 4-5 mm	21	46.7	8	17.8	29	32.2	
	Pocket > 5 mm	0	0.0	4	8.9	4	4.4	
	Total	45	100	45	100	90	100	
T14	Absent	34	75.6	33	73.3	67	74.4	4.202 (0.446)
	Pocket of 4-5 mm	11	24.4	8	17.8	19	21.1	
	Pocket > 5 mm	0	0.0	4	8.9	4	4.4	
	Total	45	100	45	100	90	100	

TW_TA thermal water from Termas de Amarante. Control- saline solution X^2 (p) – Statistics of the chi-square independence test (proof value)

Table 6 Characterization of the O'Leary index at the initial moment (T0) and at the final moment (T14) of evaluation by group

O'Leary index		Group				Total		X^2 (p)
		TW_TA		Control				
		n	%	N	%	n	%	
T0	Satisfactory ≤ 25%	41	91.1	42	93.3	83	92.2	2.212 (0.667)
	Irregular [26%-40%]	2	4.4	3	6.7	5	5.6	
	Unsatisfactory ≥ 41%	2	4.4	0	0,0	2	2.2	
	Total	45	100	45	100	90	100	
T14	Satisfactory ≤ 25%	45	100	45	100	90	100	Not applicable
	Total	45	100	45	100	90	100	

TW_TA thermal water from Termas de Amarante. Control- saline solution X^2 (p) – Statistics of the chi-square independence test (proof value)

from the free gingival margin to the bottom of the pocket. If the depth is greater than 3 mm its indicative of pathology by the presence of periodontal pockets. If the probing indicates a value below 3 mm, we can indicate the presence of a healthy gengiva with absence of periodontal disease. The results suggest that after 14 weeks, there is a reduction in the number of participants with periodontal pockets and none had pockets greater than 5 mm, which shows a beneficial effect of thermal water in reducing periodontal pockets. This clearly shows that that there was a visible effect of thermal treatment reducing periodontal pockets, which is statistically significant using the McNemar test ($p = 0.001$).

On the other hand, chi-square test of independence revealed a significant association between the presence of periodontal pockets and the group at the beginning of the study (X2 = 10.952, $p = 0.002$). However, by the end of the thermal period, this condition was no longer significant (X2 = 4.202, $p = 0.446$). This suggests a positive improvement in periodontal health within the TW_TA group.

The plaque index was accessed through O'Leary index and the results are presented in Table 6.

The results clearly show that all participants benefited from plaque reduction after the thermal treatment, with a visible reduction of the index for both groups.

Quality of life—clinical assessment

In addition to evaluating oral health, the study aimed to evaluate quality of life using questions from the SNOT-20 naso-sinus impairment test questionnaire, which assessed symptoms related to OMD and the participant's perception of their health. The questionnaire was administered at both T0 and T14. For symptoms associated with OMD, responses were measured on a 4-point scale:"absent", "few times", "often" and "always". Table 7 presents the response at T0 and T14.

Overall, symptoms associated with OMD were reported by most participants as to being "absent" in both groups following thermal treatment. To compare between groups and across time points, the global average of symptoms was calculated from nine items for each

Table 7 Results of symptoms by group

Symptoms	Time point	Group	Absent n (%)	Few Times	Often	Ever
1.Orofacial pain	T (0)	TW_TA	13 (28.9)	19(42.2)	12(26.7)	1 (2.2)
		Control	23(51.1)	14(31.sssss1)	7 (15.6)	1 (2.2)
	T (14)	TW_TA	29 (64.4)	15(33.3)	1 (2.2)	0 (0.0)
		Control	32 (71.1)	12(26.7)	1 (2.2)	0 (0.0)
2. Feeling of pressure inside the face	T (0)	TW_TA	25 (55.6)	16(35.6)	4 (8.9)	0 (0.0)
		Control	29 (64.6)	16(35.6)	0 (0.0)	0 (0.0)
	T (14)	TW_TA	38 (84.4)	7 (15.6)	0 (0.0)	0 (0.0)
		Control	43 (95.6)	2 (4.4)	0 (0.0)	0 (0.0)
3. Pain on palpation or local percussion	T (0)	TW_TA	22 (48.9)	16(35.6)	6 (13.3)	1 (2.2)
		Control	22 (48.9)	16(35.6)	6 (13.3)	1 (2.2)
	T (14)	TW_TA	33 (73.3)	12(26.7)	0 (0.0)	0 (0.0)
		Control	38 (84.4)	7 (15.6)	0 (0.0)	0 (0.0)
4.Localized facial edema	T(0)	TW_TA	29 (64.4)	14(31.1)	1 (2.2)	1 (2.2)
		Control	32 (71.1)	10(22.2)	3 (6.7)	0 (0.0)
	T(14)	TW_TA	42 (93.3)	3 (6.7)	0 (0.0)	0 (0.0)
		Control	42 (93.3)	2 (4.4)	1 (2.2)	0 (0.0)
5. Partial or total inability to feed	T(0)	TW_TA	38 (84.4)	7 (15.6)	0 (0.0)	0 (0.0)
		Control	38 (84.4)	6 (13.3)	1 (2.2)	0 (0.0)
	T(14)	TW_TA	41 (91.1)	4 (8.9)	0 (0.0)	0 (0.0)
		Control	45(100.0)	0 (0.0)	0 (0.0)	0 (0.0)
6. Bad breath	T(0)	TW_TA	20 (44.4)	13(58.9)	12(26.7)	0 (0.0)
		Control	21 (46.7)	13(28.9)	10(22.2)	1 (2.2)
	T(14)	TW_TA	33 (73.3)	10(22.2)	2 (4.4)	0 (0.0)
		Control	35 (77.8)	9 (20.0)	1 (2.2)	0 (0.0)
7. Headaches	T(0)	TW_TA	14 (31.1)	16(35.6)	12(26.7)	3 (6.7)
		Control	17 (37.8)	13(28.9)	15(33.3)	0 (0.0)
	T(14)	TW_TA	28 (62.0)	16(35.6)	1 (2.2)	0 (0.0)
		Control	31 (68.9)	13(28.9)	1 (2.2)	0 (0.0)
8. Earache	T(0)	TW_TA	35 (77.8)	8 (17.8)	2 (4.4)	0 (0.0)
		Control	34 (75.5)	10 (22.2)	1 (2.2)	0 (0.0)
	T(14)	TW_TA	41 (91.1)	4 (8.9)	0 (0.0)	0 (0.0)
		Control	43 (95.6)	2 (4.4)	0 (0.0)	0 (0.0)
9.Frequent fever episodes	T(0)	TW_TA	41 (91.1)	4 (8.9)	0 (0.0)	0 (0.0)
		Control	40 (88.9)	4 (8.9)	1 (2.2)	0 (0.0)
	T(14)	TW_TA	45(100.0)	0 (0.0)	0 (0.0)	0 (0.0)
		Control	45(100.0)	0 (0.0)	0 (0.0)	0 (0.0)

TW_TA thermal water from Termas de Amarante. Control- saline solution $\bar{X}$ – median; Z (p) – Mann–Whitney statistical test (proof value)

individual at two assessment moments. This value ranges from a minimum of 1 to a maximum of 4, with higher values indicating more severe symptoms. The results are shown in Table 8.

When comparing the two groups (TW_TA and Control), it is evident that the absence of symptoms increased in the TW_TA group from T0 to T14. This reduction in symptoms, particularly those related to pain, is more pronounced in the TW_TA group compared to the control group.

The initial symptom averages were 1.57 ± 0.332 for the TW_TA group and 1.49 ± 0.355 for the control group. After the thermal treatment, these values decreased to 1.18 ± 0.200 and 1.12 ± 0.165, respectively. The significance of the treatment effect on the improvement of symptoms and their evolution at the two sampled moments was assessed with a mixed repeated measures ANOVA.

Because the assumption of normality for symptom distributions was not met, the homogeneity of

Table 8 Results of global symptoms at the initial moment (T0) and at the final moment (T14) by group

Symptoms	Group		Test homogeneity of variances[a]	Greenhouse–Geisser test[b]	Test between moments	Test Levene[c]	Teste between groups
T0	TW_TA	1.57 ± 0.332	$F = 1.143$ ($p = 0.330$)	$F = 0.087$ ($p = 0.768$)	$F = 200.728$ ($p = 0.000$) $\eta^2 = 0.695$	$F = 0{,}993$ ($p = 0.322$)	$F = 1.646$ ($p = 0.203$)
	Control	1.49 ± 0.355					
T14	TW_TA	1.18 ± 0,200				$F = 3{,}424$ ($p = 0.068$)	
	Control	1.12 ± 0.165					

TW_TA thermal water from Termas de Amarante. Control- saline solution – Mean ± standard deviation

[a] M Box test

[b] This test was used for the interaction because sphericity was not verified

[c] verification of variance homogeneity at each moment; η2 – measure of effect

the covariance matrix was confirmed by Box's M test (F = 1.143, $p = 0.330$). Since sphericity was not assured, the Greenhouse–Geisser method was applied, revealing that the interaction between treatment and group was not statistically significant (F = 0.087, $p = 0.768$).

There was a significant overall reduction in symptoms (F = 200.728, $p < 0.001$), indicating a strong impact from the thermal treatment ($\eta^2 = 0.695$). However, the differences between the two groups were not statistically significant (F = 1.646, $p = 0.203$).

Discussion

Studies that confirm the benefits of thermal treatment in oral heath are scarce or practically non-existent. Thus, for most of the results there is still no evidence provided by other authors to compare with the results obtained in this study, which means that that there is a need for future investigations.

However, and regarding the hypothesis that thermal treatment with TW_TA has beneficial effects in the oral health of the participants, our study show interesting results with the reduction of several parameters associated with periodontal diseases and with the increased of quality of life related to OMD.. Overall, treatment with oral irrigations carried out in *Termas de Amarante*, for 14 days, with themal water, resulted in a significant improvement in the evaluated parameters, such as gingival bleeding, periodontal pockets and plaque index. Liu et al. highlighted the clinical benefits of oral irrigation in periodontal diseases, suggesting that this therapeutic effect is underlying a negative modulation of pro-inflammatory CF interleukins [22]. This can be attributed to the minerals present, such as sulfur and sodium, which have antibacterial,antiseptic anti-inflammatory [6], antioxidant and desensitizing action. Sulfuric waters have a positive effect on mucous membranes, relieving pain, reducing the intensity and duration of exacerbations and preventing the progression to chronicity [28, 29]. Like other aqueous solutions, sulfuric waters, which activate oxidation–reduction processes, will remove secretions, eliminating potential irritants and allergens, including bacteria and other microorganisms [28, 29]. They are natural stimulants of cellular trophism and have a regulatory action on body secretions. In the future, further investigations in this area may help to understand this relationship in reducing the levels of pro-inflammatory cytokines, gingival bleeding, periodontal pockets and plaque indexes. The improvement in periodontal health might have been also associated to a reduction in chronic stress. In this context, environmental changes—like the calming influence of the thermal setting—could contribute to stress reduction, potentially relieving periodontal inflammation [30]. However, due to the short intervention period of 14 days, we consider it unlikely that stress reduction significantly impacted the decrease in bleeding on probing and the other periodontal parameters. Instead, we believe the observed benefits are more directly related to the properties of the thermal water itself.

Our results suggest that thermal treatment with *Termas de Amarante* has a beneficial effect on the perception of the severity of the main symptoms associated with OMD, since overall, there was a positive evolution of the parameters evaluated in both groups. However, it was the TW_TA group that had the greatest reduction in the frequency of pain. In the TW_TA group, pain occurs "rarely" in 35.5% ($n = 16$) of the individuals and in the control group in 28.9% ($n = 23$). Xerostomia and recurrent oral ulcerations (recurrent aphthae) were considered, based on complaints and clinical evidence of dry mouth, the most prevalent pathologies causing pain. According to the literature, recurrent oral ulceration (recurrent aphtha) is one of the main pathologies that affects the oral mucosa of Portuguese people, 10 to 25% [31] Skrinjar et al. [19] observed that the thermal water-based spray (Buccotherm®) promoted a significant reduction in symptoms associated with dry mouth, 2 weeks after thermal treatment. Although all the agents

tested in this study (Xeros® and marshmallow root) showed a beneficial effect in relieving this symptomatology, the beneficial action of the thermal water spray (Buccotherm®) was superior [14].

The results indicate that the thermal treatment at Termas de Amarante effectively reduces pain-related symptoms, supporting the hypothesis that crenotherapy and oral irrigations, over a 14-day period, have a prompt effect in clearing debris, irritants, allergens, and bacteria from the mucous membranes [32]. Cuttler et al. have reported the decrease in IL-1β levels in patients subjected to oral irrigations and careful daily oral hygiene, accompanied by a tendency for increased levels of the anti-inflammatory cytokine IL-10, which may help to explain the improvements in "Pain on palpation" or local percussion" at the end of treatment [33].

However, it is important to highlight that pain is defined as an unpleasant multidimensional experience, which involves an emotional and sensorial component of the person suffering from it, with great variability in the perception and expression of pain, in the face of the same painful stimulation [34]. Furthermore, even though the Visual Analogue Scale (VAS) is a well-accepted and sensitive assessment parameter for pain perception, patients do not always understand how to use the VAS, which increases the subjectivity of this test [34]. Chronic pain (in the mouth and tongue), being one of the symptoms that frequently associated to OMD, is a challenge for dentists, as it can predispose the person to great suffering and disability. The literature presents convincing evidence that good oral hygiene, combined with regular medical monitoring and/or the use of antimicrobial agents, can combat, reduce or even eliminate OMD [21].

Significant improvement in OMD symptoms, combined with decreased medication use and fewer visits to the Family Doctor and/or Dentist, suggests that thermal treatment contributes to better overall health and oral well-being. Consequently, the numerous benefits and existing scientific evidence support the recommendation of thermal therapy when appropriately prescribed [35]. The literature provides strong t evidence that good oral hygiene practices, regular medica check-ups and the use of antimicrobial agents can combat, reduce or even eliminate OMD. The challenge, however, lies in patient motivation and the communication skills of oral health professionals. Thermal facilities have proven to be effective environments for enhancing communication and motivation in this regard [16]. To ensure the preservation of natural teeth throughout life, it is essential to explore all techniques available to combat OMD. In recent years, several European countries have seen a growing trend toward sharing the costs of thermal treatments [36] Italy, with over 340 active spas, is one of the most advanced nations in this field, where thermal establishments form a significant network from both a health and economic perspective [36]. In Portugal, renowned for its rich thermal heritage stretching from north to south, and home to the world's first thermal hospital, Rainha D. Leonor Hospital in Caldas da Rainha, this issue has been addressed in a limited manner. The situation became more pronounced when, in August 2011, the Government suspended reimbursement for thermal treatments for users of the National Health Service (SNS). This decision highlighted the absence of a coordinated policy to integrate thermal medicine into the SNS, despite its potential as a key component in health care, the promotion of healthy lifestyles, and disease prevention—two key objectives of the National Health Plan (PNS). The anti-inflammatory properties of Portuguese TW have already been demonstrated, supporting their therapeutic use in the treatment of inflammation-related diseases and promoting their putative application in cosmetic products and medical devices [6].

This research showed that 14 days of treatment with thermal water from *Termas de Amarante* has a positive effect on the periodontal status, and in lightening the OMD symptoms. All beneficial effects occurred in the short term (after the 14-day thermal treatment).

These promising results indicate that treatment with thermal water from *Termas de Amarante* may be part of the therapeutic arsenal available to Dentists in the treatment of OMD. Nevertheless, further studies will be needed to expand these conclusions, namely monitoring the temporal evolution of the results, including assessments at 3 and 6 months after completion of the thermal treatment.

The medical and scientific communities, including those in hydrology, face a significant challenge in promoting longevity, which is often accompanied by an increase in chronic organic diseases, such as rheumatic and respiratory conditions. These two conditions are among the primary reason for spa visits in Portugal [12]. The literature shows a strong correlation between these conditions with oral health [37, 38]. As kife expectancy increases, improving quality of life becomes crucial, and strategies for heathy aging should be prioritized.. Given the socioeconomic impact of this trend, it is important to raise awareness among both healthcare professionals and the general public about natural therapies like thermal water, which have been used for thousands of years with minimal side effects. Thermal establishments provide an ideal setting for patient education and the adoption of healthy habits, particularly concerning oral hygiene and diet. Patients who use these services tend to be more health-conscious and may be more open to incorporating thermal water into their healthcare regimen.

In the future, it would be interesting to evaluate oral microbiome changes before and after thermal treatment and asses the inflammatory profile using saliva or dental plaque samples as well as salivary pH monitoring along treatment. Additionally, future studies should include groups of thermalist categorized by specific conditions, such as those with periodontal disease, OMD and oral pathologies related to dental prostheses, among others. Another approach would be to compare these results with similar studies conducted in other spa facilities, focusing on different reasons for visiting the spa (such as rheumatic and respiratory diseases) and associated systemic conditions (e.g., hypertension, diabetes, regular medication, and lifestyle), using the same variables as this study. A comparison between these findings would provide valuable insights. Additionally, further research is needed to examine the factors that influence the oral health and their relationship with psychosocial and clinical aspects, with the aim of improving patient treatment. It is also important to evaluate the benefits and costs of conventional treatments versus thermal treatments in the short, medium, and long term. More comprehensive methodologies should be employed, involving a broader range of inclusion criteria and longer study periods, to assess the socioeconomic impact of thermal therapies in oral health.

Conclusions

This study provides valuable insights into the effects of thermal water treatment on oral health and overall quality of life in a population of thermal practitioners. This work showed that thermal water promoted significant improvements in oral health parameters, namely a reduction in gingival bleeding and a reduction of the plaque levels. Quality of life related to OMD also improved after thermal treatment. While the interaction between treatment and control groups was not statistically significant, there was a clear overall reduction in symptoms, indicating the beneficial effects of thermal treatment. Further research with targeted groups is recommended to explore these benefits in more detail that could enhance oral health practices in Portugal by fully leveraging the potential of thermal waters.

Data availability

The data used to generate and support the findings of this study are available from the corresponding author upon request.

Abbreviations

OMD	Oral mucosa diseases
TW	Thermal waters
DNA	Deoxyribonucleic acid
TNF	Tumor necrosis factor
SNS	National Health Service
TA	*Termas de Amarante*
DGEG	*Direção-Geral de Energia e Geologia*
DMFT	Index or decayed, missing, and filled teeth
WHO	World Health Organization
VAS	Visual Analogue Scale
IPC	Pro-inflammatory cytokines
OHI	Oral hygiene instructions

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Authors' contributions

SL, SM, APG, MJC, NV and JFF were responsible for the conceptualization and design of the project. SM, PC and PL were responsible for the data collection. SM, SL, APG, PC and NV were responsible for the statistical analysis and contributions to the various analytical approaches and interpretations of data. APG, MJC, PL and JFF drafted the main manuscript and made major contributions to the revising of the manuscript. All authors read and approved the final manuscript submitted.

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Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The research was approved by the Health Ethics Committee of the Universidade Católica Portuguesa (Approval report number 205). Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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