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DESIGN OF A MOBILE APPLICATION FOR ORAL HEALTH SUPPORT

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ABBREVIATIONS

French acronyms are kept as used in the original text; their meaning is given in English.

ADS	Anti-Discoloration System
AH	Hyaluronic acid (acide hyaluronique)
AINS	Non-steroidal anti-inflammatory drugs (NSAIDs)
ANI	French national inter-professional agreement (Accord National Interprofessionnel)
ARS	French Regional Health Agency (Agence Régionale de Santé)
ASPBD	French public oral-health stakeholders network (Acteurs de la Santé Publique Bucco-Dentaire)
CA	Revenue (chiffre d'affaires)
CE	European Conformity marking
CAO	DMF index — decayed, missing, filled teeth (Cariée Absente Obturée)
CETAF	French technical support and training centre (Centre Technique d'Appui et de Formations)
CHX	Chlorhexidine
CSPS	Calcium sodium phosphosilicate
DM	Medical devices (dispositifs médicaux)
DREES	French Directorate for Research, Studies, Evaluation and Statistics
EVA	Visual analogue scale (échelle visuelle analogique)
IA	Artificial intelligence
INSEE	French National Institute of Statistics and Economic Studies
HAS	French National Authority for Health (Haute Autorité de Santé)
Mds	Billions (milliards)
mm	Millimetre
N	Newton
ppm	Parts per million
OFMA	French observatory of analgesic medicines (Observatoire Français des Médicaments Antalgiques)
OMS	World Health Organization (WHO)
ONDPS	French national observatory of health-profession demographics
O-R	Oscillating-rotating
SHF	High-frequency sonic (sonique à haute fréquence)
SPF	Santé Publique France (French national public-health agency)
UE	European Union (EU)
UFSBD	French Union for Oral Health (Union Française pour la Santé Bucco-Dentaire)
USD	United States dollars

“Always looking towards the future
and listening to the past,
so as to speak to you in the present”

— Hector ORCESI

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INTRODUCTION

Digital technology is an integral part of contemporary society. Through the technological advances it enables, it is driving a transformation of every sector of activity. Healthcare, which is not exempt from this structural groundswell, is in turn undergoing a genuine revolution, and it is now difficult to imagine meeting the full demand for care without relying on these new tools. In parallel, the population's care needs are constantly increasing, particularly in the dental sector. Indeed, according to the French National Institute of Statistics and Economic Studies (INSEE), consumption of medical care and goods (hospital care, outpatient care, medicines, prostheses, consumables, etc.) reached 13.9 billion euros in France in 2021, compared with 10.8 billion in 2011 — a 28% increase in 10 years (1).

As a result, waiting times for an appointment with a practitioner are getting longer and longer, across all medical specialities. According to a study by the French Directorate for Research, Studies, Evaluation and Statistics (DREES) published in 2018, the average wait is 2 days for a general practitioner and can reach 52 days for an ophthalmologist. Dental surgeons, for their part, have an average waiting time of 21 days depending on the person's symptoms (2). The current care supply is under constant pressure and can no longer keep up with the growing demand for oral healthcare.

The thinking behind this work is to design, develop and model a digital application able to offer **oral health support**. The objective — far from it — is not to replace the consultation or the care provided by a dental surgeon, but to be a first point of contact for the population, in order to guide them appropriately and lead them to adopt **preventive measures**. The aim is to improve the prevention of oral diseases so as to respond as fully as possible to the growing demand for care. Given the complexity of use, this application is initially intended for **adults only**.

To carry out this work, three broad categories were defined, based on the oral symptoms experienced by the application's user:

- **asymptomatic**;
- **symptomatic without emergency criteria**, which can be managed initially with a therapeutic molecule found in over-the-counter oral hygiene products;
- **symptomatic in an emergency situation**.

To meet the needs of these three sub-populations, this work is organised into four main parts, so that the application can provide relevant assistance in oral hygiene and in the management of oral diseases.

First, the context of carious and periodontal disease will be set out, in order to understand their epidemiological and economic impact on society and the prevention strategies available.

In response, the second part will address the asymptomatic population, with the full set of oral hygiene measures recommended for maintaining oral health.

The third part is intended for symptomatic users — both for the management of minor symptoms of gingival inflammation, dentine hypersensitivity and benign lesions of the oral mucosa, and for painful symptoms of an emergency nature. A non-exhaustive but evidence-based review of the literature will present the molecules available for these symptoms and the existing emergency care pathways.

Finally, the fourth part will discuss digital developments applied to the field of health, in order to assess the potential of these new technologies. The regulations and legislation governing their use will be specified so as to define the good practices to be put in place. As a perspective, a presentation of a first prototype and its algorithmic organisation will be included, to better understand the application's potential.

1/ BACKGROUND: THE MAJOR ORAL DISEASES

1.1 Prevalence of carious disease

Carious disease is a chronic, multifactorial disease of bacterial aetiology, linked to the presence of cariogenic bacteria that adhere to and colonise tooth surfaces. These bacteria are contained within dental plaque, a complex of organic elements responsible for both carious and periodontal disease.

In 2015, the Global Burden of Disease article published in the *Journal of Dental Research* estimated that 2.5 billion people were affected by carious disease and that the prevalence of untreated cavitated caries was 34% among adults (3). In 2020, the World Health Organization (WHO) confirmed these figures, estimating 2.3 billion untreated dental caries on permanent teeth worldwide (4). The French National Authority for Health (HAS) has also estimated that 33 to 50% of adults in France have at least one carious lesion requiring treatment (5). These figures show that carious disease remains a genuinely major oral health problem worldwide.

To better understand the prevalence of this disease in France, the French Union for Oral Health (UFSBD) and the CETAF technical centre carried out a study in 2005 on adults living in metropolitan France. In this study, 2,114 participants aged 35 to 65 underwent an oral examination in one of the participating centres between September 2002 and June 2003. The objective was to establish a diagnosis of oral health situations. Regarding carious disease, out of 32 teeth (6):

- 15.3 teeth were healthy;
- 6.7 had at least one filling;
- 1.4 were carious;
- 4.6 teeth had been extracted (not counting third molars).

More recently, the study by Dr DECUP et al. confirmed these results, with a prevalence of around 33% for carious disease (7).

The scale of carious disease is beyond doubt; the application's objective is to promote a set of good practices in order to prevent this disease.

1.2 Prevalence of periodontal disease

Periodontal disease is a bacterial dysbiosis responsible for inflammation of the tooth's supporting tissues. Gingivitis is a superficial, reversible condition of the gums which, according to the HAS, affects more than 80% of adults (8). Periodontitis, for its part, is defined as deep, irreversible damage to the periodontal tissues resulting in attachment loss. It can lead to tooth loss, which has a negative impact on quality of life, nutrition, speech and self-esteem, as well as consequences for other diseases such as diabetes (9).

In 2003, the WHO estimated that severe periodontitis affects 5 to 15% of the world's population (10). These figures were corroborated by a second report published in 2020: it concerned 267 million people worldwide, particularly the elderly (4). These results are consistent with those of Chapple et al., published in the *Journal of Clinical Periodontology* in 2015, which estimated that severe periodontitis affected more than 11% of adults (11). Furthermore, periodontitis is considered the sixth most prevalent disease in the world according to the Global Burden of Disease (12). It is therefore a common, irreversible disease that represents a considerable public health burden.

To better understand the prevalence of this disease in France, the study carried out by the UFSBD and CETAF reported the following findings on gingival health (6):

- 51.7% of participants had inflammation extending to 12.5% of sites (6 examination sites per tooth);
- 17.4% had spontaneous bleeding on a very small number of sites (1.7%);
- 82.2% had periodontitis (attachment loss > 2 millimetres (mm)), of which 5% at a severe stage;
- 70.2% had gingival inflammation.

These results correlate with the study by Bourgeois et al., published in 2007 and carried out on 2,144 adults aged 35 to 64. A probing depth ≥ 2 mm was present in 82.2% of the population, and 46.7% had attachment loss ≥ 5 mm (13).

The prevalence of periodontal disease is unequivocal; the application's objective is to provide a set of recommendations to improve and optimise periodontal health.

1.3 Socio-economic impact

In addition to having a considerable impact on the general health and social well-being of those affected, the costs associated with preventing and treating oral diseases are substantial for both individuals and health systems. In 2015, the direct costs of oral conditions amounted to 357 billion US dollars (USD) worldwide, and indirect costs such as sick leave to 188 billion USD, according to the WHO. In the same year, 90 billion euros were spent on treating oral conditions in the European Union, making it the third-largest expenditure item for non-communicable diseases, behind diabetes and cardiovascular disease (4). The management of these oral diseases represents 5% of the health budget in European countries (14). For France, the WHO estimated direct costs at 11.1 billion euros and indirect costs at 6.3 billion euros in 2016 (15). The socio-economic impact of oral diseases weighs on health systems as a whole.

Moreover, people on low incomes are more vulnerable because of their limited access to quality care and a healthy diet. This can lead to social exclusion and stigmatisation for those affected, with a negative impact on their personal and professional lives.

In 2006, the French “Health and Social Protection” survey showed that 14% of the population of metropolitan France had postponed medical care for financial reasons over the previous 12

months. Dental care and prostheses were the types of care most often postponed (33.5% and 36% respectively). The lack of complementary health insurance was the main reason for this postponement: 32% of people without cover reported forgoing care, compared with 19% of beneficiaries of the complementary universal health cover (CMU-C) and 13% of those with private complementary insurance (5).

In response, the French National Inter-professional Agreement (ANI) law was passed in 2013, requiring employers to offer complementary health insurance and to cover 50% of its cost (16). However, in 2019, the CMU covered 8.6% of the 64 million French people with complementary health insurance (95% of the population), an increase of 31% in 10 years. The ANI law did not improve precarious situations; above all, it increased the number of group contracts, which now cover 90% of employees, at the expense of individual contracts (17).

These figures once again expose the over-representation of the most disadvantaged socio-professional categories when it comes to forgoing care.

It is therefore important to put effective prevention strategies in place to minimise the economic and social costs associated with managing oral diseases. Oral hygiene products constitute an essential therapeutic arsenal for preventing the development of oral diseases. They are the first step in their management, making it possible to maintain good-quality hygiene.

The market for oral hygiene products is growing steadily. Worldwide, it was worth approximately 35 billion USD in 2016 and is forecast to reach 44.5 billion USD in 2024 — a 27% increase in 8 years (18).

In France, the market was estimated at 925 million euros for 307 million units sold in 2020. It was divided into three categories: toothpaste (55.3% of revenue), toothbrushes (27%), and the remainder comprising mouthwash, gels, etc. (17.7%) (19).

The socio-economic impact of oral diseases is considerable; the application seeks to reduce their incidence in order to lower the associated costs.

1.4 Prevention

Although progress has been made in oral treatments, the incidence of untreated oral diseases persists and continues to grow worldwide, rising from 2.5 billion in 1990 to 3.5 billion in 2015 (14). The WHO considers that these risks can be reduced by implementing preventive measures at the level of entire populations (20). Prevention brings together all the hygiene-maintenance methods conducive to preventing the development of oral diseases. The WHO defines oral health as the absence of mouth or facial pain, oral or pharyngeal cancer, oral infection or lesion, periodontal disease, tooth loosening and loss, and other diseases and disorders (21).

According to the FDI World Dental Federation, the concept of oral health is multi-faceted, including the ability to speak, smile, smell, taste, touch, chew, swallow and express emotions through facial expressions with confidence, without pain, without discomfort and without disease of the craniofacial complex (22).

The main diseases affecting oral health are carious and periodontal disease. Almost the entire world population will face at least one of them during their lifetime, as the studies cited above have shown. This is why it is essential to prevent them proactively.

The French law of 9 August 2004 on public health policy distinguishes between two levels of approach to health problems: the individual level and the collective level.

The individual approach concerns the spontaneous behaviour of users and health professionals, in both care and prevention; the benefit is obtained by the individual.

The collective approach, for its part, takes into account the physical, social, economic and cultural determinants of a population's state of health, and aims to correct the shortcomings of the actors involved through regulation; the benefit is obtained by the population as a whole (23).

In order to add a collective approach to the application, it was relevant to study the behaviour of the French population in terms of oral health.

In 2016, Santé Publique France (SPF) reported that among 15-75 year-olds, 71.1% brush their teeth twice a day, 25.1% once a day and 3.8% less often. They also highlighted the marked socio-cultural gradient in brushing compliance. The lack of hygiene within the population and/or ineffective brushing was demonstrated by the SPF study (24).

Their results are consistent with those of the UFSBD/CETAF study, which also showed that 87.2% of adults had dental plaque on 30.3% of sites. In addition, 20.0% of participants showed a quantity of plaque sufficient to be visible to the naked eye during the clinical examination, though on a very limited number of sites (2%) (6).

In conclusion, all of these elements set out the challenges of oral disease prevention. The WHO defined them at its 16th assembly in May 2007 for all Member States (25):

- integrate oral health prevention into policies for the prevention of chronic non-communicable diseases;
- integrate oral health prevention into primary care and make preventive actions available to disadvantaged populations;
- develop fluoridation programmes;
- develop oral health promotion programmes for pre-school and school-age children;
- plan the training of dental personnel (dental assistants, dental hygienists, nurses) able to carry out preventive procedures and promote oral health;
- ensure oral health surveillance within the overall health-monitoring system;
- support research on oral health and encourage the international sharing of data from the evaluation of prevention programmes.

As part of a preventive approach combining collective and individual dimensions, the application seeks, at the collective level, to support the care of the entire population in pursuit of better oral health. At the individual level, it aims to adapt to the user's current situation and to lead them to put in place the preventive measures needed to achieve good-quality oral health.

2/ THE ASYMPTOMATIC POPULATION: HOW CAN THEIR ORAL HYGIENE BE IMPROVED?

2.1 Choosing a toothbrush

2.1.1 Manual toothbrush and brushing technique

The toothbrush is the best means of maintaining oral hygiene and optimal plaque control. To define the characteristics of a good-quality toothbrush to recommend within the application, the criteria defined at the European Workshop on Plaque Control were selected (26):

- a handle size suited to the user's age and dexterity;
- a head size suited to the mouth;
- nylon or polyester bristles with rounded tips and a diameter of at most 20/100 of a millimetre;
- bristle softness compliant with ISO standard 22254 (27).

Toothbrush quality involves several characteristics. Bristle retention is measured by the minimum force required to pull a single tuft of filaments out of the brush head. This minimum tuft-removal force must not be less than 15 Newtons (N) according to ISO standard 20126 (28).

Wear is also an important parameter: a study published in 2019 measured the effects of wear on plaque scores for toothbrushes after 3 months of use. The results showed that the quality of plaque control was inversely proportional to brush wear (29).

Regarding bristle softness, a study published in 2021 examined dentine abrasion in contact with bristles as a function of the force applied and bristle hardness. The results showed their proportional impact on dentine abrasion, which justifies the use of soft bristles on a daily basis (30).

To ensure good-quality plaque control and avoid any iatrogenic behaviour, the application recommends the Workshop criteria (26) for manual toothbrushes: a handle size suited to dexterity and age, a head size suited to the mouth, and soft bristles. In addition, the French national health insurance website (ameli.fr) recommends changing the brush every 3 months (31).

Brushing quality also correlates with the brushing method used. It plays a crucial role in removing dental plaque, so it deserves attention.

In 2017, a meta-analysis was carried out on two randomised clinical trials in which the test group used the modified Bass technique and the control group used the horizontal technique. The modified Bass technique consists of positioning the toothbrush at the tooth/gum junction at a 45° angle towards the root. A small-amplitude, antero-posterior horizontal movement is performed on the outer and then the inner surfaces, applying very light pressure (32). The

occlusal and posterior surfaces must also be brushed with an antero-posterior movement and sufficient pressure to reach the bottom of the fissures. The meta-analysis showed that the modified Bass technique provides significantly better control of dental plaque than the horizontal brushing technique (33). However, this technique requires gentleness with the gums, and it is delicate and complex for the majority of the population to perform despite its superior brushing quality.

In 2019, a systematic review was carried out to identify and assess the quality of the evidence on the effectiveness of manual tooth-brushing techniques in the existing literature. Thirteen articles were included in the final review, and the results showed great variability between studies, preventing any definitive conclusion on the ideal brushing technique (34).

There are not yet enough studies on manual brushing methods and plaque removal to reach a consensus.

In order to offer a method suited to everyone, the French health insurance website (ameli.fr) highlights the roll technique. It consists of placing the brush at the tooth/gum junction, tilting it 45° towards the root, then performing a rolling movement from the gum towards the tooth. This movement must be performed in this direction only, lifting off dental plaque and food debris. To brush the lingual surface of the mandibular incisors more easily, the brush should be positioned vertically, finishing with the occlusal surfaces (31). It is the most accessible method, providing good-quality plaque control while protecting against iatrogenic behaviour. It also recommends a brushing time of at least 2 minutes, with all teeth brushed thoroughly.

However, a study by Williams et al., published in 2004 in the *Journal of Periodontology*, showed improved plaque reduction for 3 minutes of brushing with either a manual or an electric toothbrush. The randomised clinical trial assessed the plaque index after 1 and 3 minutes of brushing in the two groups of 40 participants; the results showed a significant improvement of around 50% after 3 minutes of brushing (35).

As for frequency, food debris and dental plaque should be removed after every meal — that is, 3 brushings a day (morning, midday and evening). Nevertheless, it is sometimes complicated to brush one's teeth at work, so the HAS recommends at least 2 brushings a day (5). Moreover, evening brushing is all the more important because salivary flow slows during sleep, reducing saliva's protective actions (36).

To improve oral hygiene methods in the asymptomatic population, the application is designed to include the modified Bass technique and the roll technique as the preferred manual brushing methods, with a minimum brushing time of 2 minutes, extendable to 3 minutes.

2.1.2 Electric toothbrush and brushing technique

Electric toothbrushes are part of the population's therapeutic arsenal for minimising the presence of dental plaque.

A study carried out in 2018 compared the performance of an oscillating-rotating (O-R) electric toothbrush for reducing dental plaque and gingivitis against a manual toothbrush. It was

conducted as a randomised, double-blind trial. The clinical examinations assessed the plaque index, the gingival index and bleeding on probing in patients with plaque and/or mild to moderate gingivitis. Both brushes showed a statistically significant reduction in the plaque index and the gingival index. After 5 weeks, the number of bleeding sites was reduced by 52.2% for the O-R toothbrush and by 23.6% for the manual toothbrush, a statistically significant difference. The O-R brush achieved significantly greater reductions in the plaque index, the gingival index and the number of sites bleeding on probing than the manual brush (37).

The O-R electric toothbrush therefore provides optimised plaque reduction and periodontal health compared with a manual toothbrush.

There is also another electric toothbrush system, the high-frequency sonic (SHF) toothbrush. A meta-analysis published in 2021 compared the effectiveness of the O-R electric toothbrush with the SHF toothbrush in removing dental plaque and gingival inflammation. The systems were assessed over 4 weeks on the following parameters: plaque index, sites bleeding on probing, and gingival index scores. The results showed that in 54% of the comparisons there was a significant difference in favour of the O-R for the plaque, bleeding-on-probing and gingival indices (38).

In conclusion, for better control of dental plaque and better gingival health, choosing an O-R electric toothbrush appears preferable to an SHF system.

Regarding the brushing technique for O-R brushes, Oral-B®, the market leader, recommends positioning the toothbrush at 45° to the root and applying light pressure for 2 seconds to guide the head over each tooth surface (outer, occlusal and inner). Pressure sensors exist that can help the user find the ideal pressure and avoid iatrogenic behaviour. In addition, the minimum 2 minutes of brushing must be respected, and the brush head should be changed every 3 months, as with manual toothbrushes (39).

With a view to maintaining hygiene in the asymptomatic population, the application includes a second option in its toothbrush guidance: an O-R system electric toothbrush.

2.2 Interdental hygiene

2.2.1 Sizes of interdental spaces

To complete the preventive support offered to the asymptomatic population, it was necessary to consider interdental hygiene aids such as dental floss and interdental brushes. These complementary tools help remove food deposits and dental plaque from the inaccessible areas between the teeth, which contributes to preventing carious and periodontal disease. Interdental hygiene is therefore essential, and to address it properly the different sizes of these interdental spaces must be taken into account.

The space between teeth in adults has no defined diameter and changes over time, which makes it difficult to determine the best interdental hygiene aid. In 2015, a randomised cross-sectional study assessed the distribution of the diameter of, and access to, interdental spaces in a young adult population free of periodontal disease. Of the 2,408 interdental spaces examined, 92.3%

were accessible to interdental brushes. However, 80.6% of sites required smaller-diameter interdental brushes (0.6 to 0.7 mm). Anterior sites required smaller interdental brushes (55.8% of 0.6 mm brushes) than posterior sites (26.1% of 0.6 mm brushes). The analyses showed a significant association between site location and bleeding risk: the difficulty of accessing posterior sites doubles this risk (40). Even though the study has selection biases, small diameters are preferable in the absence of periodontal disease, given the size of the interdental space.

To better understand the value of matching the interdental hygiene aid to the clinical situation, a systematic review published in 2020, comprising 27 studies, assessed the most effective interdental hygiene aids for plaque removal according to interdental space sizes. The results showed that intermediate and large brushes (≥ 0.8 mm) have the highest level of evidence of effectiveness for people with type II embrasures (papilla covering > 50% of the embrasure) or type III embrasures (papilla covering < 50% of the embrasure). Dental floss and small-diameter brushes (0.6 to 0.7 mm) are the alternatives for people with closed type I embrasures (papilla completely filling the embrasure) (41).

2.2.2 Interdental brushes

A Cochrane meta-analysis published in 2019 on interdental hygiene aids assessed the effects of using interdental brushes in addition to brushing, compared with brushing alone, on plaque control. Seven studies, with a total of 354 participants, were included. After 1 month, there was a 0.95-point reduction in the mean plaque index on a 0-5 scale — an additional 32% reduction in dental plaque. Interdental brushes proved their effectiveness and complementarity in plaque control. In addition, the reduction of gingivitis was also assessed using an index on a 0-4 scale covering the criteria of gingival inflammation (bleeding, colour, etc.). After 1 month, the results showed a reduction in this index for the test group — an average 34% reduction in gingival inflammation (42) compared with brushing without any interdental hygiene aid.

Interdental brushes are essential to maintaining hygiene and are recommended to users, with emphasis on their method of use, which consists — with a diameter suited to the space — of “rubbing without forcing or floating”, to allow optimal, non-iatrogenic brushing.

2.2.3 Dental floss

Since not all interdental spaces are accessible to brushes, dental floss is an interdental hygiene aid that provides access to closed embrasures. The 2019 Cochrane meta-analysis on interdental hygiene aids compared the use of interdental brushes and dental floss as adjuncts to brushing. The results showed no statistically significant difference in plaque control or gingival inflammation (42).

However, a lack of data and numerous biases were noted, preventing a precise conclusion. Nevertheless, dental floss has not been shown to be less effective than interdental brushes at removing plaque. Moreover, it removes trapped food and thus reduces the development of proximal caries at the contact point. It therefore contributes, in a manner complementary to the toothbrush, to maintaining dental and periodontal health.

Where interdental spaces are closed, dental floss must be used as the interdental hygiene aid.

With a view to maintaining good-quality oral hygiene, the application proposes two interdental hygiene aids:

- dental floss in the case of a closed embrasure;
- interdental brushes when the space is sufficient for them to pass through.

2.3 Fluoride toothpaste

Fluoride plays a major role in preventing carious disease. A Cochrane systematic review published by the *Faculty Dental Journal* in 2014 showed a 24% reduction in the DMF (decayed, missing, filled) index with the use of a fluoride toothpaste compared with a placebo (43). These results were confirmed by the Cochrane meta-analysis published in 2019, which compared the effects of a fluoride toothpaste with a fluoride-free toothpaste. After 3 years, the use of a toothpaste containing 1,000 or 1,100 ppm of fluoride reduced the DMF index by −0.53 compared with a fluoride-free toothpaste in adults (44).

Fluoride is present in our environment and its ingestion in small quantities is common throughout the world; at high doses, however, it can be dangerous. The American Dental Association recommends not exceeding 120 mg of fluoride (264 mg of sodium fluoride) per intake (45). However, the fluoride doses associated with daily brushing at a concentration of 1,450 ppm present no risk, except in the case of deliberate ingestion of too large a quantity of toothpaste.

It is therefore necessary to follow the UFSBD recommendations (46):

- brush the teeth with toothpaste at least twice a day, with a fluoride concentration of 1,450 ppm for an adult;
- spit out excess toothpaste without rinsing after brushing.

In summary, for the asymptomatic category, the application proposes three axes:

- choose between a soft manual toothbrush and an O-R electric toothbrush, with an appropriate brushing technique;
- use interdental hygiene aids — interdental brushes are advised, except in the case of a closed embrasure where dental floss is preferable;
- recall the benefits of using a toothpaste with a fluoride concentration of 1,450 ppm.

3/ THE SYMPTOMATIC POPULATION: HOW SHOULD THEY BE ADVISED AND GUIDED?

3.1 Symptomatic population without emergency

Faced with the waiting times for a consultation with a dental surgeon, the application aims to offer a form of management while awaiting the appointment. A non-exhaustive list of molecules with therapeutic purpose was drawn up to define the oral care products that can be suggested for a specific set of symptoms.

Three types of symptoms emerge that can initially be managed with over-the-counter products:

- dentine hypersensitivity;
- gingival inflammation;
- benign lesions involving healing of the oral mucosa.

Analysing the molecules contained in these products made it possible to assess their effectiveness on the targeted symptoms. A summary table of the specific products selected, with their trade name, molecule and minimum age of use, is presented in Appendices 1, 2 and 3.

3.1.1 Dentine hypersensitivity

3.1.1.1 Aetiology

Dentine hypersensitivity is a recurring condition within the population: according to the FDI, its frequency ranges from 3 to 57%, owing to the diversity of the populations studied (47). People with periodontitis tend to have a higher prevalence, linked to root exposure caused by the destruction of periodontal tissues. Likewise for wear lesions, erosion and any other conditions causing enamel loss: exposure of the dentine causes hypersensitivity (48).

In addition, a growing number of young adults have presented with this condition in recent years, owing to iatrogenic factors such as acid-rich diets, aggressive brushing, lifestyle habits and the inappropriate use of whitening agents (47).

Management strategies depend on the severity of the symptoms and range from the topical application of a desensitising molecule to endodontic treatment. Management must however be staged, allowing more conservative strategies to prevail before considering invasive dental interventions, in keeping with the therapeutic gradient: Kérourédan et al., in their *Actualités Pharmaceutiques* article published in November 2020 on treatments for dentine hypersensitivity, define this gradient as a progressive approach starting from the aetiology and non-invasive ambulatory treatments, such as desensitising molecules, and ending with invasive treatments (49).

With an approach based on recommending oral hygiene products, the application therefore positions itself on the first step of the therapeutic gradient (50).

3.1.1.2 Molecules with therapeutic purpose

In order to select the most appropriate products for inclusion in the application, a literature review of the molecules effective against dentine hypersensitivity was carried out on PubMed/MEDLINE, the Cochrane Library and Google Scholar®. These molecules act by occluding the dentinal tubules, preventing fluid movement within them, which is the source of the analgesic action. Three randomised controlled clinical trials and 2 meta-analyses led to the selection of the most effective molecules, in order to define a non-exhaustive list of the desensitising toothpastes (Appendix 1) available on the French market.

The first randomised clinical study, published in 1986, compared the effectiveness of a toothpaste based on nicomethanol fluorhydrate (fluorinol) with a desensitising toothpaste containing 5% potassium nitrate and 0.9% sodium monofluorophosphate. The results showed that pain scores steadily decreased over 4 weeks for both toothpastes. After 1 week, the reduction in hypersensitivity was significantly greater for the toothpaste with 5% potassium nitrate and 0.9% sodium monofluorophosphate. However, after 4 weeks, the reduction was significantly greater for fluorinol (51). This study showed effectiveness for both toothpastes, but above all demonstrated the superiority of fluorinol as a long-term desensitising molecule.

In 2001, the second study compared a toothpaste containing potassium nitrate, stannous fluoride and sodium fluoride (toothpaste A) with, on the one hand, a toothpaste containing potassium chloride and sodium fluoride (toothpaste B) and, on the other, a fluoride toothpaste (toothpaste C). After 8 weeks, the group using toothpaste A showed significantly higher tolerance in the tactile and air-jet tests compared with toothpaste C. Toothpaste A also showed significantly better results in both tests than toothpaste B (52). These results showed that potassium nitrate, stannous fluoride and sodium fluoride have genuine effectiveness against dentine hypersensitivity.

The third, published in 2001, compared the effectiveness of fluorinol toothpastes versus those based on calcium sodium phosphosilicate (CSPS) on pain, using a visual analogue scale (VAS) with tactile, air-jet and cold-water tests. CSPS is a bioglass that reacts with saliva to create a protective hydroxyapatite layer on the tooth, thereby blocking the dentinal tubules. Both groups showed a statistically significant reduction in dentine sensitivity compared with baseline. After 3 weeks, the VAS scores for the tactile tests were considerably lower in the fluorinol group (53). This study once again demonstrated the superiority of fluorinol in treating dentine hypersensitivity.

The first meta-analysis, published in 2019, compared arginine and CSPS as contained in the Pro-Argin® (arginine) and NovaMin® (CSPS) technologies. Three studies were included in the meta-analysis, with 302 participants. They showed no statistically significant difference between the two molecules in terms of reducing hypersensitivity immediately after 4 weeks of use (54). In summary, toothpastes containing arginine or CSPS showed equivalent effectiveness in reducing dentine hypersensitivity.

In 2020, the second meta-analysis included 125 randomised controlled trials with 12,541 patients to compare the desensitising molecules used in toothpastes. The following molecules showed substantial benefits compared with fluoride:

- CSPS was the most beneficial for all 3 stimuli, with high to moderate certainty;
- stannous fluoride was beneficial for the tactile and air stimuli, with high to moderate certainty;
- arginine was beneficial for the air stimulus.

In conclusion, fluorinol has the best long-term effectiveness against hypersensitivity. It is contained in the Dents sensibles® toothpaste by ELGYDIUM®, and also in other dosage forms such as the SENSILEAVE® gel and the sensibilité® mouthwash of the ELUDAY® sub-brand. Stannous fluoride, for its part, is contained in the Sensibilité & Gencive® range by SENSODYNE®, the Sensitive plus soin complet® toothpaste by ELMEX® and the Soin complet® toothpaste by MERIDOL®. CSPS is contained in the Répare & Protège® range of SENSODYNE® toothpastes. Arginine is present in the Sensitive® range by ELMEX® via the Pro-Argin technology, and in the Total® toothpaste by Colgate®.

For dentine hypersensitivity, the application proposes three therapeutic axes:

- the SENSILEAVE® gel by ELGYDIUM®, with the action of fluorinol, the molecule showing the best results;
- a desensitising toothpaste from those listed in Appendix 1;
- the full set of recommendations on toothbrushes and interdental hygiene aids, to limit iatrogenic risks and ensure good-quality plaque control.

3.1.2 Gingival inflammation

3.1.2.1 Aetiology

Plaque-related periodontal diseases are caused by a bacterial dysbiosis responsible for inflammation of the periodontal tissues. The bacterial origin is linked to the presence of bacteria within dental plaque. This presence triggers an innate immune response, expressed as an inflammatory reaction. Chronic inflammation can cause attachment loss and lead to the destruction of periodontal tissues, which may result in the loss of the tooth itself.

Gingival bleeding and gum pain are the first warning symptoms of gingival inflammation. The Chicago classification, established during the 2017 World Workshop, defines gingival health as the absence of erythema, oedema and patient-reported symptoms, bleeding on probing < 10% and a probing depth ≤ 3 mm (55). Based on this classification, patient-reported gingival bleeding is a pathognomonic sign of gingival inflammation.

A study published in 2021, carried out on 408 adults, assessed patients' ability to accurately report gingival bleeding during brushing. Haemoglobin levels in saliva/toothpaste were analysed and compared with a full-mouth periodontal examination. The results showed that the 37.1% of subjects who had reported gingival bleeding had significantly higher haemoglobin levels than

those who had not. The total quantity of haemoglobin in the saliva/toothpaste was positively correlated with the number of bleeding sites and the severity of gingival inflammation. Conversely, the absence of self-reported bleeding on brushing together with low haemoglobin levels were reliable predictive indicators (between 93% and 98%) of periodontal health (56).

Bleeding on brushing is therefore a symptom perceptible to everyone, and it is used to define the population suffering from gingival inflammation within the application. Note that it may be accompanied by painful sensations.

3.1.2.2 Molecules with therapeutic purpose

The application's objective is to recommend the oral hygiene products suited to treating gingival inflammation. The assessment of this inflammation is standardised by the Silness and Löe gingival index (1967) (57), which uses both a visual assessment of inflammation and an assessment of bleeding on probing. Each site is scored on an increasing scale from 0 to 3, and an average score can be calculated for each tooth assessed.

The Quigley-Hein plaque index modified by Turesky et al. (1970) assesses the quantity of disclosed plaque on unrestored tooth surfaces on a scale of 0 to 5 (58). There is also the Silness and Löe plaque index (1964), measured at the marginal gingiva with a probe, with scores from 0 to 3 (59).

Gingival inflammation can be reduced by antiseptic molecules thanks to their bacteriostatic and/or bactericidal effects. To this end, chlorhexidine (CHX) is a broad-spectrum antiseptic frequently used in oral healthcare. It increases the permeability of the bacterial membrane, causing cell lysis. Its bacteriostatic activity is achieved by disrupting bacterial DNA replication, thereby halting proliferation. At a higher dose, CHX becomes bactericidal, destroying bacterial cells entirely. In addition, it is positively charged and binds to bacterial anions, thereby neutralising plaque adhesion to tooth surfaces (60).

A first meta-analysis, published in 2012, measured the effectiveness of CHX mouthwash on gingival inflammation using the gingival index (1967). Seven studies were included, and a 0.32 reduction in the index was observed compared with the control group (61).

A second meta-analysis, carried out in 2017, confirmed these results. Ten clinical trials comprising 805 participants with a gingival index (1967) of approximately 1 were included. After 6 weeks of using the CHX mouthwash solution, the index was reduced by 0.21 compared with placebo. These results show the action of CHX in reducing the gingival index and therefore inflammation. The evaluations also covered the reduction of dental plaque, with 12 clinical trials and 950 participants. After 6 weeks, the Quigley-Hein index modified by Turesky et al. (1970) was 1.45 lower for the test group, indicating a strong reduction in plaque. These results were confirmed by the 0.58 reduction in the Silness and Löe plaque index (1964) (62). In the long term, the results on plaque reduction and gingival inflammation were similar.

To study the optimal dosage, a randomised double-blind clinical trial carried out in 2017 compared the effectiveness of different CHX concentrations (0.06%, 0.12% and 0.2%) in

mouthwash solutions. The results showed no statistically significant difference in the Silness and Löe gingival index (1967) or the Quigley-Hein plaque index modified by Turesky et al. across the 3 concentrations. However, the 0.2% CHX mouthwash gave slightly better, significant results on the Silness and Löe plaque index (1967) compared with the other two concentrations. The effects on plaque of the 0.12% and 0.06% concentrations, as measured by the Silness and Löe plaque index, were not statistically different from each other, but each was significantly effective compared with baseline (63).

These results confirmed the effectiveness of all 3 concentrations on gingival inflammation, with a slight advantage on plaque for the 0.2% concentration. This superiority was obtained with a dosage of two 1-minute rinses per day — which also guarantees the best compliance, since no midday use at a workplace is required.

In 2022, a systematic review published the most effective CHX protocols for limiting its side effects. Sixty-seven articles were selected, including 13 on the side effects associated with CHX. After 21 days of use, some participants reported altered taste, numbness, slight pain in the tongue or mouth, xerostomia and tooth staining. Although altered taste and numbness were significantly more frequent with the 0.12% and 0.2% concentrations, no serious adverse effects were reported. Tooth staining was the adverse effect most often reported by patients (64). However, an anti-discoloration system (ADS) exists which demonstrated effectiveness against CHX-related staining in a mouthwash in a clinical trial by Varoni et al. in 2017 (65). The CURASEPT® brand uses the ADS system for its range of CHX mouthwashes with concentrations of 0.05%, 0.1% and 0.2% CHX.

To ensure maximum effectiveness and safety for the user, it is essential to follow the recommendations of the health authorities.

Regarding the dosage of a 0.12% CHX mouthwash solution, the HAS recommendations advise a dose of approximately 12 ml of undiluted mouthwash per use, for 1 minute, for the PAROEX® pharmaceutical speciality. It recommends 2 to 3 rinses per day, with a treatment duration of up to 14 days without adverse effects (66). The average duration of prescribed mouthwash treatments is between 6 and 10 days for 59% of prescriptions (67). Nevertheless, the French National Agency for Medicines and Health Products Safety (ANSM) recommends consulting a dental surgeon before extending a CHX treatment beyond 14 days of use, or after 5 days without improvement of symptoms (68).

Regarding the ELUDRIL® range at 0.12% CHX, the instructions for use advise against swallowing the mouthwash, as local adverse effects such as irritation and a burning sensation may occur. This mouthwash solution contains alcohol and is therefore not recommended for people in withdrawal or for pregnant women. Moreover, in the event of massive ingestion and major systemic absorption, neurological, hepatic and digestive disorders may occur (69). In addition, the ANSM recommendations indicate a lack of data for pregnant and breastfeeding women (68). In the event of pregnancy or breastfeeding, a consultation with a dental surgeon is therefore necessary before using CHX, all the more so given the existence of alcohol-based

solutions (66). For 0.2% CHX solutions such as ELUDRIL Perio®, which is alcohol-free, the dose per use is 10 ml for 1 minute, twice a day, and the usual treatment duration is 7 days (70).

CHX is also available in other dosage forms, such as oral gels (ELUGEL®, PARODIUM®, etc.), which have a localised action, unlike mouthwash. Several commercial forms of CHX-based products exist, and a non-exhaustive list is available in Appendix 2.

A meta-analysis published in 2014 compared CHX gels and toothpastes with CHX mouthwash. The only study in which both groups had proper oral hygiene conditions (twice-daily brushing) showed no statistically significant difference (71). CHX toothpastes have thus not shown results in their favour. In summary, the gel is a dosage form that can be applied topically and locally to mucosa affected by gingival inflammation. It therefore complements the range of CHX products by allowing the area to be treated to be targeted, unlike mouthwash, which acts on the entire oral cavity.

In the treatment of gingival inflammation, CHX is an integral part of the therapeutic arsenal proposed by the application. A CHX gel is recommended for localised bleeding, and a mouthwash when the inflammation is generalised. The treatment duration is 1 week, with a frequency of 3 applications or 1-minute rinses per day — except for mouthwashes at a 0.2% concentration, where 2 rinses a day are sufficient.

To complete the therapies against gingival inflammation, sodium bicarbonate — by virtue of its basic character — neutralises the acidity produced by the bacterial complex of dental plaque, and is therefore included in the application. It thus reduces gingival inflammation. In addition, the abrasive effect of sodium bicarbonate beads improves the mechanical removal of dental plaque during brushing.

A randomised clinical trial published in 2017 compared the effects of brushing for 6 weeks with a 67% sodium bicarbonate toothpaste against a bicarbonate-free toothpaste. The 148 participants had to have at least 20 measurable teeth, gingivitis, a positive response to bleeding on brushing and at least 20 sites bleeding on probing. The modified gingival index (1986) used in this study is measured on a scale ranging from no inflammation to severe inflammation (72). After 6 weeks, in the test group compared with the control group, the number of sites bleeding on probing decreased significantly, as did the values of the modified gingival index and the bleeding index (73).

A study published in 2018 compared the effectiveness and tolerance of twice-daily brushing with toothpastes containing 67% sodium bicarbonate against a placebo over 6 months. The results showed that sodium bicarbonate produced statistically significant improvements in the modified gingival index (1986) and the number of bleeding sites compared with placebo. Very good tolerance was also observed in the study, with no side effects recorded over the 6 months. The short-term results also favoured a reduction in gingival inflammation with the use of the sodium bicarbonate toothpaste (74).

Toothpaste with 67% sodium bicarbonate has demonstrated its effectiveness in improving gingival health and reducing bleeding.

Regarding usage advice, the PARODONTAX® brand, which offers a wide range of toothpastes containing sodium bicarbonate, recommends brushing 2 to 3 times a day. However, the sodium bicarbonate beads contained in the toothpastes have an abrasive effect and can damage enamel if the conditions of use are not respected (75). Despite an absence of data on the subject, long-term use could cause abrasion phenomena. Furthermore, masking bleeding reduces the chances of alerting the individual to the presence of more severe periodontal disease. Finally, if the basic character of sodium bicarbonate disturbs the oral osmotic balance, this can lead to alkalosis, hypocalcaemia, etc., which can result in cell lysis (76).

In the short-term treatment of gingival inflammation, sodium bicarbonate is an integral part of the support proposed by the application in response to this symptom. It is advised to use a toothpaste containing sodium bicarbonate until the bleeding disappears, with a brushing frequency of 2 to 3 times a day.

In addition to proposing these two molecules, it is essential to keep plaque levels as low as possible in order to reduce the bacterial load and prevent gingival inflammation. Brushing and interdental hygiene aids have proven their effectiveness in reducing plaque and gingival inflammation, as detailed in section 2.2.2. They are therefore an integral part of the therapeutic proposal for gingival inflammation.

In the treatment of gingival inflammation, the application proposes:

in the short term:

- a gel or mouthwash containing CHX, depending on the extent of the inflammation;
- a toothpaste containing sodium bicarbonate;

in the long term:

- an interdental hygiene aid, together with the full set of recommendations for maintaining good-quality brushing.

3.1.3 Benign lesions of the oral mucosa

3.1.3.1 Aetiology

Benign lesions of the oral mucosa are common conditions that can be located on the tongue, the floor of the mouth, the gums, the inner surface of the cheeks and lips, the palate and the soft palate. Although they are generally not serious, these lesions can cause painful sensations and interfere with eating. There are various aetiologies for benign lesions of the oral mucosa, notably cuts, mouth ulcers (aphthae), burns, etc. (77).

Cuts are traumatic lesions. They can be caused by hard, sharp objects such as food, kitchen utensils, dental appliances or accidental contact with the teeth. Cuts cause a sensation of pain and bleeding. In most cases, these lesions heal on their own within a few days to a week.

Mouth ulcers are ulcerations that generally form on the tongue, cheeks or lips. The exact aetiology of aphthosis is not known, but several factors are implicated, such as stress, fatigue,

food allergies, vitamin deficiencies and viral or bacterial infections. They are generally painful and can cause discomfort when chewing, speaking and swallowing. In most cases, these lesions heal on their own within one to two weeks. However, recurrent aphthous stomatitis is a condition in which ulcers recur more frequently. It causes real difficulty eating, and therapies must be put in place to relieve the patient. The same applies to giant aphthae, whose larger diameter and accentuated symptoms also require therapy.

Burns are lesions caused by exposure of the oral mucosa to thermal agents such as hot food and drinks, cigarettes or irritant chemicals. Burns can cause pain, inflammation, blisters and a loss of sensitivity in the affected area. In most cases, these lesions heal on their own within a few days to a week.

Other types of benign oral mucosal lesions exist, such as mucoceles, epidermoid cysts, hyperplastic lesions, fibromas, papillomas, etc.

Once they have appeared in the mouth, and given their benign nature, only the symptoms related to mucosal healing can be targeted by the recommended products.

3.1.3.2 Molecules with therapeutic purpose

The wound-healing process is influenced by many factors, including chronic diseases, metabolic disorders and risk behaviours. To improve this process, many molecules have been developed to promote healing. The use of products composed of hyaluronic acid (HA) offers an interesting therapeutic proposal for benign lesions of the oral mucosa. It creates a protective barrier and accelerates the healing process at the lesion site. It also has an analgesic effect, making the healing process easier to bear.

In 2017, a randomised double-blind clinical trial measured the impact of 2 different HA concentrations on reducing discomfort and on the healing speed of palatal donor-site wounds after an epithelial-connective tissue graft harvest. Thirty-six patients were randomly divided into three groups. After palatal graft harvesting, topical applications of gels containing 0.2% and 0.8% HA were used in test groups 1 and 2 respectively, while control group 3 received a placebo. The results showed that the test groups experienced significantly less pain than the control group on days 3 and 7. The mean VAS score for burning sensation was significantly higher in the control group than in test groups 1 and 2. After 21 days, complete visual healing was achieved for all patients in the two test groups, whereas it was only achieved on day 42 in the control group (78). HA confirmed its effectiveness in the healing process following trauma from an epithelial-connective graft harvest.

In 2019, a retrospective study assessed the effectiveness of an HA-based mouthwash and gel on minor recurrent aphthous stomatitis. After 7 days, the average reduction in size was highly significant for both groups. However, the gel group showed a significantly faster improvement in lesion size than the mouthwash group. The results also showed a reduction in pain for both groups, with no statistically significant difference. After 7 days, complete visual healing of the lesion was achieved in more than 50% of cases in both groups (79). The gel dosage form

demonstrated its superiority in reducing lesion size and painful sensations in the healing of an ulcer, compared with a mouthwash.

In 2023, a randomised double-blind clinical trial carried out a histological analysis of the effects of a 0.8% HA gel on the early healing of gingival tissues. Biopsies were taken 24 hours after the raising of a full-thickness flap, and the test group received a 2-minute topical application of HA gel at the end of the procedure. The results showed that 24 hours after surgery, the early healing score was significantly higher in the test group. The histological sections also showed improved extracellular matrix remodelling and collagen maturation. However, the growth of new vessels, assessed by microvascular density, was not improved by the gel application (80). These results demonstrated HA's capacity to stimulate the gingival healing process.

HA in oral gel form is offered by the following brands: Cooper® with its HYALUGEL® product, GUM® with the AftaClear® gel, and GENGIGEL®. A non-exhaustive list of gels containing HA is available in Appendix 3. Manufacturers recommend 3 to 5 topical applications per day with clean hands.

Gingival healing can be subject to infections linked to the exposure of the underlying tissues. To prevent this risk, antiseptic gels are commonly used to protect the lesion while healing takes place. The antiseptic effects of CHX and its action on inflammation were set out in the previous section.

A randomised clinical trial published in 2020 compared the effectiveness of HA and CHX mouthwashes in treating minor recurrent aphthosis. Thirty-four participants were included in the study. They had to use 10 ml of mouthwash for 30 seconds, 3 times a day. Pain scores were assessed with a VAS and lesion sizes were measured. After 3 and 7 days, pain scores were lower in the group treated with the HA gel — a statistically significant difference. However, the results showed no significant difference between the two study groups with regard to lesion size (81).

HA and CHX are two molecules with a positive impact on gingival healing. In addition, CHX's antiseptic effect limits the risk of infection during gingival healing.

With a view to supporting the healing process, the application proposes topical applications of a gel composed of HA or CHX until the lesion disappears.

To conclude on the symptomatic population without emergency, the application aims to respond immediately to these 3 types of symptoms:

For dentine hypersensitivity:

- the SENSILEAVE® gel by ELGYDIUM®, with the action of fluorinol, the molecule showing the best results;
- a desensitising toothpaste from those listed in Appendix 1;
- the full set of recommendations on toothbrushes and interdental hygiene aids, to limit iatrogenic behaviour and guarantee optimal plaque control.

For gingival inflammation:

- a gel or mouthwash containing CHX, to be used at most 2 or 3 times a day for 1 week;
- a toothpaste containing sodium bicarbonate until the bleeding disappears;
- an interdental hygiene aid, together with the full set of recommendations for maintaining good-quality brushing.

For benign lesions of the oral mucosa:

- a gel composed of HA or CHX, to be used until the lesion disappears.

In all cases, the user is encouraged to consult a dental surgeon to clarify their specific care needs.

3.2 Population in an emergency situation

3.2.1 Dental emergency and self-medication

A dental emergency is accompanied by intense pain and, even though it is rarely life-threatening, it can have long-term consequences for the dentition. Dental emergencies can be classified into three categories: infectious, haemorrhagic and traumatic (82).

For all these conditions, an intense pain syndrome is often the warning signal, and the usual reflex is self-medication to reduce the pain. An observational, cross-sectional study published in 2016 assessed patients' behaviour in these dental emergency situations. The results showed that 85% of patients had taken a medicine before going to the emergency department; of these, fewer than 10% had consulted a health professional before self-medicating. The most commonly used medicines were non-steroidal anti-inflammatory drugs (61%), antibiotics (34%) and glucocorticoids (2%) — the latter potentially dangerous or useless for treating a dental emergency (83). This study showed that more than 75% of new emergency patients had already taken medicines without having seen a health professional.

Another study, on the links between beliefs about medicines and self-medication with analgesics for managing dental pain, was conducted in Kuala Lumpur in 2017. Self-medication with analgesics was observed in 29.4% of participants, and 95.6% had a pain syndrome justifying analgesic use (84). The data collected were confirmed by a study published by Simon et al., which concluded that the prevalence of self-medication was approximately 30% (85).

These various studies showed that self-medication is practised by people in dental emergency situations and can affect up to 85% of patients attending a dental emergency department (83).

Self-medication is, moreover, an increasingly frequent phenomenon, particularly for treating dental pain. An American study published in 2005 showed that the medicines most consumed in self-medication were NSAIDs (38%) and paracetamol (33%) (86). However, taking medicines without the advice of a health professional can prove dangerous because of the possibility of side effects and drug interactions. For example, the ANSM states that taking NSAIDs during certain infections can mask symptoms such as fever or pain, leading to delayed care and an increased risk of serious infectious complications linked to altered immune system behaviour (87). The

HAS recommends using paracetamol rather than NSAIDs in the event of pain and/or fever, particularly in a context of infection (88).

3.2.2 Paracetamol

For treating the pain syndrome associated with a dental emergency, the molecule of choice is therefore paracetamol. It was discovered in 1878, marketed 50 years later, and has a very solid clinical track record (89). According to the French observatory of analgesic medicines (OFMA), in 2018 more than one in two French people received at least one reimbursed prescription for a paracetamol-only pharmaceutical speciality (90). Although these medicines are effective and safe when used correctly, they can also present risks if used inappropriately.

A study carried out in 2015 assessed the proportion of paracetamol overdoses recorded in a dental emergency department. Data on paracetamol overdose cases linked to dental pain were collected retrospectively over a 24-month period. The results show 116 admissions for unintentional paracetamol overdose, with 48 cases (41%) linked to dental pain (91). These results proved that many iatrogenic behaviours exist in the presence of a pain syndrome linked to a dental emergency.

The risks of overdose are frequent; respecting the dose and frequency when taking paracetamol is a necessity. The HAS transparency committee recommends, for DAFALGAN 1000 mg®, composed solely of paracetamol (88):

- take the lowest dose, for the shortest time possible;
- respect the maximum dose per intake and the maximum daily dose;
- respect the minimum interval between intakes and the recommended treatment duration (3 days for fever, 5 days for pain, in the absence of a prescription);
- regarding dosage, for an adult or a child > 50 kg, the dose per intake should be 1,000 mg, intakes must be at least 4 hours apart, with a maximum of 4 g/24 h.

The high level of self-medication underlines the importance of running awareness campaigns on the proper use of medicines. Since 15 January 2020, the ANSM has decided that these medicines should be placed behind the counter only, in order to strengthen the pharmacist's advisory role towards people who wish to use them without a prescription (92). It also announced that warning messages about the risk of overdose for the liver are now displayed on boxes of medicines containing paracetamol (90).

With the aim of relieving the user in an emergency situation, the application provides recommendations on taking 1,000 mg of paracetamol, including the dosage, the maximum treatment duration, the dose per intake and per day, and the intervals to respect between two intakes. In addition, a warning about adverse effects and contraindications (allergies, etc.) is also available, to raise the population's awareness of the risks of self-medication. Furthermore, users are encouraged to read the package leaflet, providing access to complete documentation on paracetamol.

3.2.3 Guiding a dental emergency

3.2.3.1 Public services and facilities

Having covered analgesics and self-medication, this work aims to develop the guidance of users in emergency situations. Dental emergencies can be managed within a public facility or in the private sector.

As far as emergencies are concerned, French public services are increasingly overloaded. Indeed, the DREES estimated that attendance at hospital emergency departments has increased by around 3.6% each year since 1996, rising from 10.1 million to 21.1 million in 2018 (93). In 2016, the French Court of Auditors estimated that French hospitals received more than 21.2 million emergency patients (94). In 2013, dental emergencies represented a non-negligible share of these patients, estimated at 2.8%, i.e. around 600,000 patients (95). They weigh on the health system through their specific management, with only 20 public odontology departments within university hospitals able to handle a dental emergency across French territory (a map is available in Appendix 4).

Health authorities' growing awareness led the dental emergency unit of Clermont-Ferrand University Hospital to develop a patient-triage questionnaire in 2015. It made it possible to determine a time frame for care by examining the symptoms reported by the patient. This study was conducted on 300 patients, and its results showed that the tool determined a time frame for 92% of patients. It facilitated the regulation of the dental unit's activity and avoided overloading the department by scheduling appointments for patients who were not in an emergency situation (96). However, the limited availability of dental surgeons remains an obstacle to booking appointments that quickly; as a reminder, the average waiting time is 21 days (2).

The Normandy Regional Health Agency (ARS) is running an experiment integrating dental surgeons into the SAMU (emergency medical dispatch service). This new system, which is gradually being rolled out in various regions, allows more effective management of patients with dental emergencies while relieving the SAMU's workload. The aim of this experiment is to demonstrate the effectiveness of dedicated dental emergency management by improving the relevance of dispatch decisions and of the care received. The experiment began in 2021 and will last 2 years; the results are not yet available, but the introduction of such a measure has shown the importance of improving dental emergency management for the French health system (97).

For the management of dental emergencies by public services, the application directs users to two services:

- a telephone service to the SAMU, so that a health professional can perform high-quality triage;
- a location service for the nearest public dental emergency department.

3.2.3.2 Private services and facilities

To meet the needs of users in an emergency situation, strong emphasis is placed on the private sector's capacity to address this issue as well. Indeed, the majority of practitioners (79%) work in

private practice according to the French national observatory of health-profession demographics (ONDPS) (98). These figures are corroborated by the French Dental Council (ONCD), with nearly 82.70% in private practice in 2023 (99).

Decree No. 2004-802 on the public health code governing out-of-hours care enabled the ONCD to set up an on-call dental surgeon service operating on Sundays and public holidays, from 9 a.m. to 6 p.m. (100). The number of professionals on duty is organised at departmental level to guarantee continuity of care. In the event of a dental emergency, it is possible to contact the SAMU to obtain the address of the nearest on-call dental surgeon, or to go directly to the ONCD website. The website also provides the list of registered dental surgeons by town, postcode and department, but does not provide their contact details. After identifying a practitioner, the patient must look up their contact information in order to reach their practice. This entire process via the ONCD website represents an obstacle to booking an appointment.

To simplify appointment booking, online medical appointment platforms have grown strongly in recent years and, according to the government, more than 70% of French people have already used them (101). The French leader is Doctolib®, with more than 42.2 million patients in 2020. In total, 96.6 million appointments were booked online via this platform, representing 34% of all scheduled appointments. Moreover, a majority of the appointments booked (54%) are made outside practice opening hours (102). The platform's accessibility is an essential advantage, offering a new dimension in access to care.

To quickly guide users in an emergency situation towards a consultation, the application provides a link to:

- the website of the French Dental Council (ONCD);
- the Doctolib® website.

4/ MOBILE APPLICATIONS: HOW CAN THEY BE USED IN ORAL HEALTH?

4.1 The rise of health applications

In France, mobile devices are dominant: 95% of the population owns a mobile phone, of whom 77% have a smartphone. Young people are particularly keen users, with 94% of 15-29 year-olds equipped, compared with only 36% of the oldest (75 and over) (103). The equipment rate is higher among people with higher levels of education and in urban areas. In addition, 52% of smartphone users use their devices to search for health information (104).

The development of smartphones has been accompanied by an explosion in the number of mobile applications. In 2020, more than 350,000 health-related applications were available on the App Store® or Google Play Store®, according to the HAS (104). The digital health industry, through our smartphones and mobile applications, is booming. They represent an essential gateway to care thanks to their connectivity, their fit with expectations and their degree of adoption by the population.

With the aim of guaranteeing maximum coverage and accessibility, the application will be made available as a mobile application.

4.2 Advantages, drawbacks and limitations

Mobile applications in the health field offer many advantages, particularly in terms of disseminating prevention messages. They represent an unrivalled channel for distributing medical information; around 72% of doctors access drug information from their smartphones (105). They also make health information easier to access — for example, 66% of French people have already consulted or received medical results online (101). In addition, they have enabled the development of teleconsultations, with French general practitioners carrying out more than 13.5 million of them in 2020 (106).

However, drawbacks to the development of digital health remain. Applications may contain inaccurate information or be poorly designed, which can harm users' health. During the Covid-19 pandemic, Facebook® allowed the spread of false information or “fake news” — for example, the supposed benefits of a medicine without scientific evidence. Between May 2019 and May 2020, this false information was viewed more than 3.8 billion times by users of the social network (107). Applications can also pose confidentiality and security problems for users, particularly in the event of data theft or hacking. In 2020, 27 French hospitals fell victim to cyber-attacks, health data having become potential targets (101). From this standpoint, the General Data Protection Regulation (GDPR), the European legislation aimed at strengthening the protection of individuals' personal data within the EU, plays an essential role in protecting health data, a rapidly developing sector. It imposes restrictions and obligations to guarantee respect for privacy and the protection of individuals' rights in the collection, processing and use of data.

Furthermore, access to some applications may require payment, which can be an obstacle for the most disadvantaged populations.

Finally, the limitations of health applications include barriers affecting people who do not have access to a smartphone or who are not comfortable with technology, such as the elderly. On Doctolib®, there is a correlation between age and online appointment booking, with 24% of patients aged 25 to 34, 18% aged 45 to 54 and 10% over 65 (102). Moreover, applications do not replace consultations with a health professional, since they currently do not allow clinical and complementary examinations to be carried out. They may not be available in every language, or may not be suited to the specific management of complex and rare conditions.

The application developed here will not require a paid subscription, so that as many people as possible can access it — even though the incompressible costs of oral hygiene products remain a barrier for some.

The added value of the bibliographic work in the preceding parts makes it possible to present evidence-based information concerning:

- hygiene and the maintenance of optimal oral prophylaxis;
- the oral hygiene products available to specifically treat dentine hypersensitivity, gingival inflammation or benign lesions of the oral mucosa. It also provides information on managing dental emergencies.

However, the absence of clinical and complementary examinations prevents a positive diagnosis from being made and restricts the application's fields of use. In addition, keeping the data up to date will be an essential challenge in maintaining the level of information offered by the application.

4.3 Legal framework

The law and regulations concerning medical devices are governed by Regulation 2017/745 of the European Parliament and of the Council, established on 5 April 2017. It classifies health software as active medical devices (MDs) by virtue of their autonomous operation. The regulation allows a medical device to obtain the European Conformity (CE) marking and authorises its marketing (108).

Software programs are medical devices in their own right and must be designed to guarantee repeatability, reliability and performance with regard to their intended use. They must be designed and developed with risk management and safety built in with respect to the information delivered. Product verification and validation requires a clear description of the software's design and development process.

Decree No. 2019-856, issued on 20 August 2019 by the French Ministry of Health, governs the certification procedure for prescription-support software. It accredits the HAS as the reference authority for verifying compliance with good practice rules (109). The HAS ensures that software incorporates the medical recommendations and opinions in force. This certification procedure

contributes to improving prescribing practices for medicines, medical devices and cosmetics. It guarantees software compliance with minimum requirements in terms of safety, conformity and prescribing efficiency.

The application is intended to provide support with information that may lead to decisions for therapeutic purposes. For this type of software, EU Regulation 2017/745 on medical devices assigns class IIa.

4.4 Proposal of an application model for oral health support

The organisational structure of the application is available in Appendix 5. As described above, the population has been divided into 3 broad categories according to symptoms:

- asymptomatic;
- symptomatic, non-urgent, initially treatable with a therapeutic molecule available in oral hygiene products;
- in an emergency situation.

In keeping with this structure, the home page of the application prototype presents the user with the different symptom categories. Then, for each of them, the various support options are presented (Figure 1). For the sake of accessibility to the general public, all medical terms and expressions have been popularised and simplified within the application to make them easier to understand.

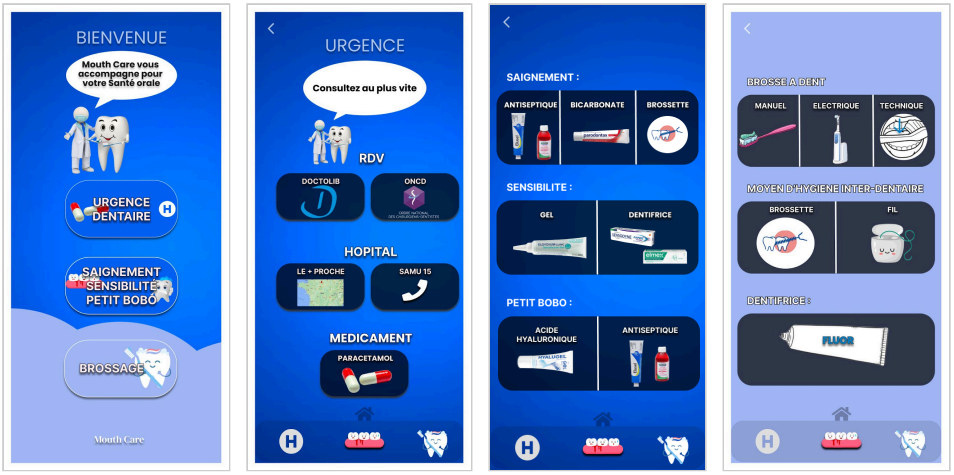


Figure 1: Application model — home.

WELCOME = presentation of the 3 population categories · EMERGENCY = Doctolib and ONCD websites for appointment booking, location service for the nearest dental emergency department, telephone service to SAMU-15, paracetamol recommendations · BLEEDING / SENSITIVITY / MINOR SORE = products presented according to symptoms · BRUSHING = presentation of oral hygiene topics

For the asymptomatic category, the oral hygiene topics presented are the toothbrush, interdental hygiene aids and toothpaste (Figure 2).

Regarding the toothbrush, the quality of the bristles, its size and the characteristics needed for optimal brushing are presented. The user can then explore either the 2 manual brushing

techniques or the O-R electric toothbrush. With these 3 pages, the user will have covered the essential information about toothbrushes.

The application will then encourage the user to consult the interdental hygiene aids. The objective is to raise the population's awareness of interdental hygiene in order to reduce the risk of developing oral diseases. Despite the absence of evidence in the literature that the interdental brush is superior to dental floss, its larger contact surface could make it more relevant for interdental use, particularly in a periodontal context. One page presents the 2 interdental hygiene aids and highlights the use of the interdental brush.

The final topic focuses on toothpastes and underlines the importance of using a toothpaste with a fluoride concentration of 1,450 ppm. It is also essential to explain to the user that respecting the minimum 2 minutes of brushing also allows the fluoride to penetrate the tooth better and thus strengthen it more effectively. Finally, the no-rinsing advice recommended by the UFSBD (46) is also presented on the toothpaste page.

Figure 2: Application model — asymptomatic category.

TOOTHBRUSH = criteria to follow, replacement interval, link to manual or electric brushing technique · TECHNIQUE = shared BASS/ROLL characteristics, steps to follow, brushing-time reminder · ELECTRIC = highlighted advantages, brushing technique, duration · INTERDENTAL HYGIENE = presentation of floss and interdental brush, the brush highlighted by stars · TOOTHPASTE = fluoride recommendations

For the symptomatic, non-urgent category, the user selects the type of symptom experienced from dental sensitivity, gingival bleeding and the presence of an oral mucosal lesion.

For each category, the appropriate oral hygiene products are presented with their molecule and dosage form. For each product, the dosage and method of administration are highlighted so that the user follows them (Figure 3). A non-exhaustive list of products is available for each molecule, to give examples available on the French market. Any contraindications are also shown.

Access to the page dedicated to the 3 topics of the asymptomatic category is provided. Since every set of symptoms requires hygiene to be maintained, the objective here is to lead the user to consult them.

Figure 3: Application model — symptomatic, non-urgent category.

SENSITIVITY 1 = presentation of the SENSILEAVE® gel, usage advice · SENSITIVITY 2 = presentation of several desensitising toothpastes, usage advice · BLEEDING 1 = presentation of gels and mouthwashes containing CHX, usage advice · BLEEDING 2 = presentation of several toothpastes containing sodium bicarbonate, usage advice · LESION = healing gel recommendations

For the emergency category, the page offers the ONCD and Doctolib® websites to help the user book an appointment if they have no regular practitioner or if theirs cannot see them urgently.

For the ONCD, the list of dental surgeons near the user is accessible; however, their surname, first name and postal address are the only data available for contacting them and obtaining an appointment.

On Doctolib®, the speciality searched is “dental surgeon”, the location selected is “around me”, and the availability option is set to 3 days. Together, these criteria allow the user to view the various possible appointments.

In addition, a map of dental emergency departments within public hospitals is available to ensure the user can be taken care of.

A summary of the indications, dosage, method of administration and contraindications of a 1,000 mg paracetamol tablet is also available, together with encouragement to read the package leaflet, in order to inform the user about taking the medicine.

To complete the picture, a telephone service to the SAMU 15 number is offered, and it is recalled that the SAMU can indicate the nearest on-call dental surgeon, available on Sundays and public holidays. Finally, it is explained that a health professional can advise the user on their decision regarding their emergency (Figure 4).

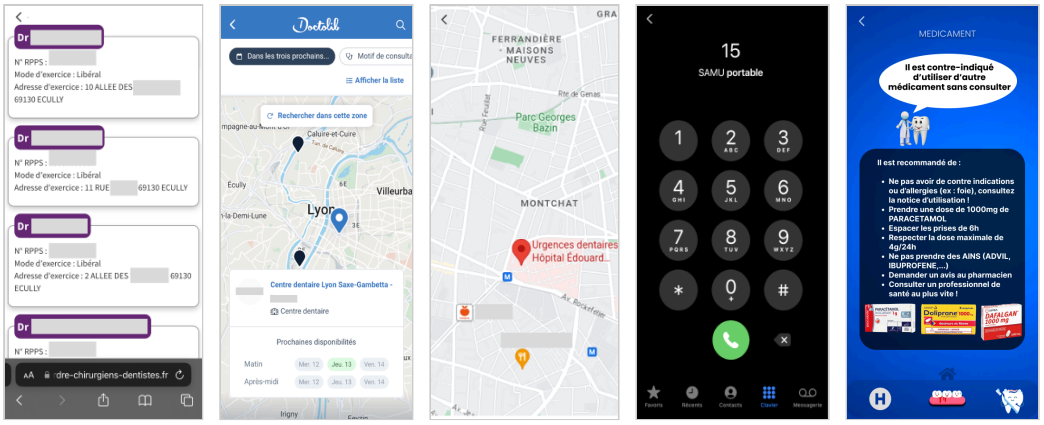


Figure 4: Application model — emergency category.

ONCD = list of nearby dental surgeons from the ONCD website · DOCTOLIB = user's location with available appointments in the next 3 days nearby · SAMU-15 = telephone service to SAMU-15 · MAP = dental emergency department in the nearest university hospital · MEDICATION = usage advice for a 1,000 mg paracetamol tablet

CONCLUSION

Technological advances in the field of oral health have undeniably contributed to improving the quality of care provided to the population. Digital technologies and artificial intelligence (AI) have paved the way for more accurate diagnoses, more effective treatments, faster care and better disease prevention. However, the demand for oral healthcare is closely correlated with exponential population growth. The United Nations (UN) estimates that the world population will reach 9.7 billion in 2050 (110). Adding the shortage of health professionals, health systems need new digital technologies to meet the growing demand for care.

Oral health applications are a rapidly expanding field, with multiple players highlighting specialised or general strengths. For example, a new application, Oralnum®, specialising in dental appointment booking, was created in 2018. As for the application presented in this work, it aims to be a first step towards earlier management of oral diseases, by providing advice and guidance according to symptoms. It can also be seen as a complementary tool, providing personalised assistance and supporting users in improving their oral health. It is therefore conceivable that the proposed application will develop further, for example by incorporating patient follow-up features or the estimation of risk factors for dental diseases, particularly carious and periodontal disease. Furthermore, all the data will need to be checked frequently and updated as necessary to guarantee information consistent with scientific evidence.

Nevertheless, it should be emphasised that the integration of these new technologies into oral health practice must not be seen as a panacea. They can certainly help improve care and treatment quality, but they cannot replace the human relationship and empathy of a health professional. At present, it seems impossible to substitute the caregiver's role — and would it even be desirable to replace it entirely?

It is therefore important that oral health professionals continue to incorporate digital technologies and AI into their practice, while preserving their essential role as caregivers. They must strive to maintain a holistic, personalised approach for each patient, taking care to integrate these tools responsibly. Indeed, it is worth remembering that the development of digital health technologies requires ethical and regulatory reflection, in order to guarantee their use with respect for the rights of patients and health professionals. It is therefore important to pursue research into evaluating the effectiveness and safety of digital health applications, to better regulate their use and prevent any form of abuse.

In conclusion, digital technologies and AI appear to be promising tools in the world of healthcare; they open up interesting perspectives in the field of odontology. It seems essential to continue integrating them in order to meet the full demand for care and to perfect the treatments available. Their challenges and opportunities represent a new challenge for the 21st century, where science and technology come together to reinvent the provision of care. It is in this spirit that the application developed as part of this doctoral work seeks to position itself.

APPENDICES

Appendix 1: Summary table of oral hygiene products containing a desensitising molecule

Dosage form	Trade name	Active ingredient	Min. age
Gel	ELGYDIUM Clinic Sensileave®	fluorinol	18
Toothpaste	ARTHRODONT Protect dent & gencive®	fluorinol	10
Toothpaste	SIGNAL Integral 8 Expert sensibilité®	sodium fluoride	12
Toothpaste	SENSODYNE Sensibilité & gencive extras fresh®	stannous fluoride + sodium fluoride	12
Toothpaste	SENSODYNE Sensibilité & gencive blancheur®	stannous fluoride + sodium fluoride	12
Toothpaste	SENSODYNE Sensibilité & gencive®	stannous fluoride + sodium fluoride	12
Toothpaste	SENSODYNE Action sensibilité®	potassium nitrate + sodium fluoride	12
Toothpaste	SENSODYNE Action rapide blancheur®	sodium fluoride	12
Toothpaste	SENSODYNE Action rapide®	sodium fluoride	12
Toothpaste	SENSODYNE Répare & Protège Original®	CSPS + sodium fluoride	12
Toothpaste	SENSODYNE Répare & Protège Blancheur®	CSPS + sodium fluoride	12
Toothpaste	SENSODYNE Répare & Protège Extra fresh®	CSPS + sodium fluoride	12
Toothpaste	MERIDOL Soin complet®	stannous fluoride + sodium fluoride	12
Toothpaste	MERIDOL Protection gencive & haleine fraiche®	stannous fluoride	12
Toothpaste	MERIDOL Protection gencive & Blancheur®	stannous fluoride	12
Toothpaste	MERIDOL Protection gencive®	stannous fluoride	12
Toothpaste	GUM Sensi Vital +®	potassium nitrate	7
Toothpaste	ELGYDIUM Dents sensibles®	fluorinol + CHX	12
Toothpaste	COLGATE Total®	arginine + sodium fluoride	12
Toothpaste	ELMEX Sensitive plus soin complet®	stannous fluoride	12
Toothpaste	ELMEX Sensitive Professional®	arginine	12
Toothpaste	ELMEX Sensitive Professional blancheur®	arginine	12
Toothpaste	ELMEX Sensitive Professional Répare & Prévient®	arginine	12
Mouthwash	GUM Sensi Vital +®	potassium nitrate	12
Mouthwash	ELUDAY sensibilité®	fluorinol	12

Appendix 2: Summary table of oral hygiene products containing a molecule acting on gingival inflammation

Dosage form	Trade name	Active ingredient	Min. age
Mouthwash	CURASEPT ADS® 205	0.05% CHX	6
Mouthwash	PREXIDINE®	0.12% CHX	6

Dosage form	Trade name	Active ingredient	Min. age
Mouthwash	PAROGENCYL Soin intensif gencive®	0.12% CHX	6
Mouthwash	PAROGENCYL Gum action®	0.12% CHX	6
Mouthwash	CHLORHEXIDINE Mylan®	0.12% CHX	6
Mouthwash	CHLORHEXIDINE Biogaran®	0.12% CHX	6
Mouthwash	CURASEPT ADS® 212	0.12% CHX	6
Mouthwash	GUM PAROEX 0.12%®	0.12% CHX	12
Mouthwash	GUM GINGIDEX 0.12%®	0.12% CHX	18
Mouthwash	CHLORHEXIDINE Arrow®	0.12% CHX	6
Mouthwash	CURASEPT ADS® 220	0.2% CHX	6
Mouthwash	ELUDRIL Gé®	0.12% CHX	6
Mouthwash	ELUDRIL Pro®	0.12% CHX	6
Mouthwash	ELUDRIL Classic®	0.12% CHX	6
Mouthwash	ELUDRILPerio®	0.2% CHX	6
Mouthwash	PAROEX 0.12%®	0.12% CHX	6
Toothpaste	PARODONTAX Original	sodium bicarbonate	12
Toothpaste	PARODONTAX Gel Fluor	sodium bicarbonate	12
Toothpaste	PARODONTAX Fraîcheur Intense	sodium bicarbonate	12
Toothpaste	PARODONTAX Complete Protection Fraicheur Intense	sodium bicarbonate	12
Toothpaste	PARODONTAX Blancheur	sodium bicarbonate	12
Toothpaste	ELGYDIUM Blancheur	sodium bicarbonate	12
Toothpaste	GIFRER BICARE Plus Dentifrice	sodium bicarbonate	12
Toothpaste	SIGNAL Integral 8 Nature Bicarbonate	sodium bicarbonate	12
Toothpaste	SANOGYL Blancheur	sodium bicarbonate	12
Toothpaste	SANOGYL Soin global	sodium bicarbonate	12
Gel	PARODIUM®	CHX	6
Gel	CURASEPT ADS®	CHX	6
Gel	ELUGEL	CHX	6

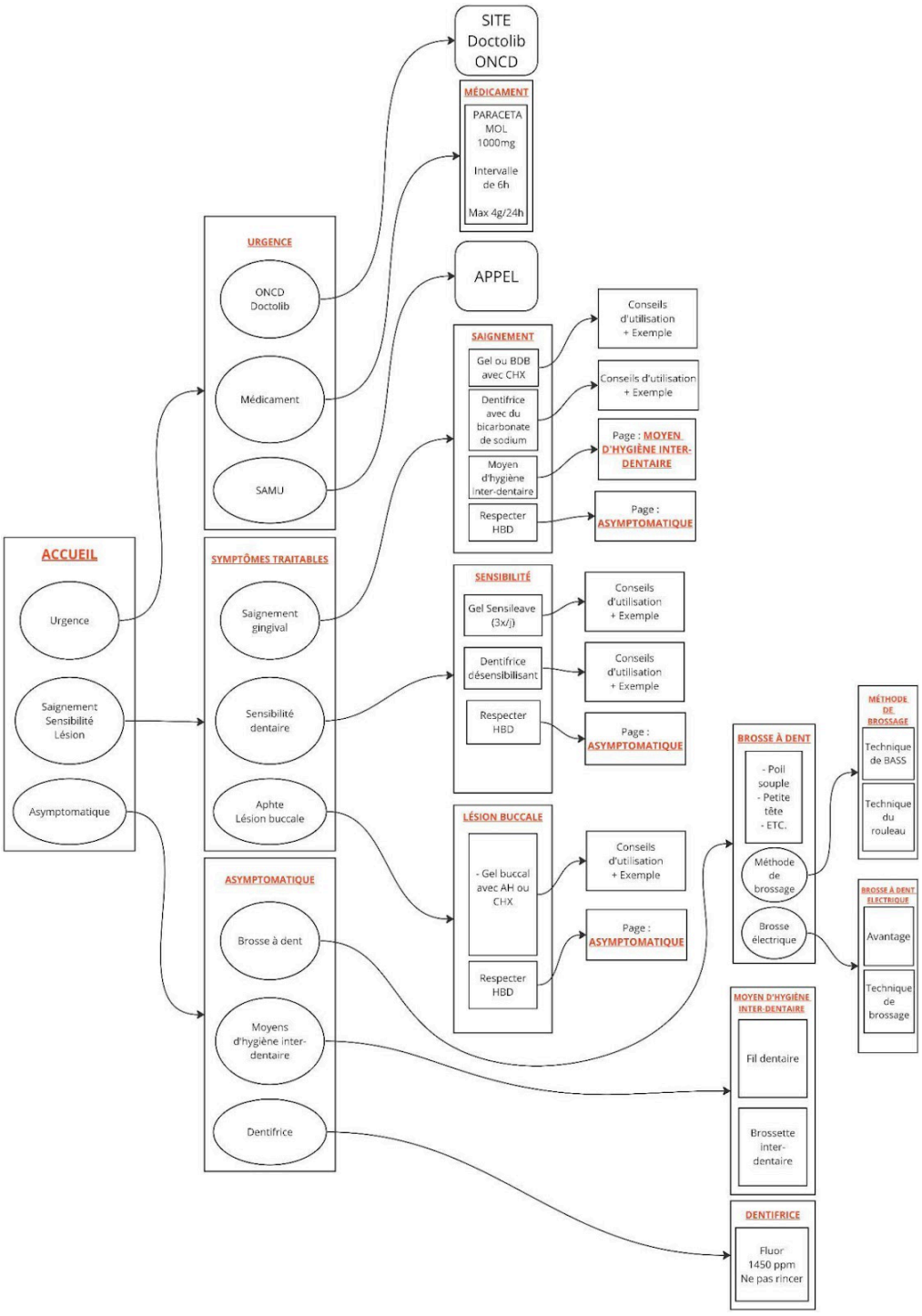
Appendix 3: Summary table of oral gels containing HA

Dosage form	Trade name	Active ingredient	Min. age
Gel	HYALUGEL®	HA	2
Gel	HYALUGEL Forte®	HA (0.8%)	2
Gel	GUM AftaClear®	HA	2
Gel	GENGIGEL®	HA	2
Gel	GENGIGEL Forte®	HA	2
Gel	Bloxaphte®	HA	2

Dosage form	Trade name	Active ingredient	Min. age
Gel	Synthol Oral®	HA	2

Appendix 4: Map of dental emergency departments in metropolitan France (Google Maps®)

Appendix 5: Flowchart of the application model



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Design of a mobile application for oral health support

Abstract

Digital technology, an integral part of our contemporary society, has transformed every sector of activity. Healthcare, not exempt from this structural groundswell, is in turn undergoing a genuine revolution, and it is now difficult to imagine meeting the full demand for care without relying on new digital tools. In parallel, the population's care needs are constantly increasing, particularly in the dental sector.

The aim of this work is to design, develop and model a digital application able to offer oral health support. The fundamental objective of this application is to be a first point of contact for users, encouraging them to adopt preventive measures and guiding them as effectively as possible.

The first part of this work sets out the context of carious and periodontal disease, in order to understand their epidemiological and economic impact on society and the prevention strategies available. The second part covers the full set of oral hygiene measures recommended for maintaining oral health. The third part presents the various minor symptoms the user may face, such as gingival inflammation, dentine hypersensitivity and benign lesions of the oral mucosa, as well as painful symptoms of an emergency nature. A non-exhaustive but evidence-based review of the literature presents marketed products available for these symptoms and the existing emergency care pathways. Finally, the fourth part discusses the possibilities of digital technology applied to the field of health, while also recalling the regulations and legislation governing this use in order to define the good practices to be put in place. As a perspective, a presentation of a first prototype and its algorithmic organisation are included, to better understand the potential of the proposed future application.

In conclusion, this proposal contributes to the implementation of an innovative digital solution for personalised oral health support, combining knowledge of oral hygiene with the technological and digital advances that open up very interesting perspectives in odontology. These opportunities represent a new challenge for the 21st century, where science and technology come together to reinvent healthcare.

Keywords

Application, Digital, Smartphone, Prevention, Oral hygiene, Personalised support, Dental emergency, Dentine hypersensitivity, Gingival inflammation, Benign lesion, Brushing, Interdental hygiene, Toothpaste

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