Changes in oral health and condition with age

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In recent years, there has been a dramatic shift in the overall oral health status of populations in the developed world: people are living longer and retaining more natural teeth into old age. While this can be viewed as a sign of improvement, this situation brings its own problems. The prevalence of caries, enamel erosion and chronic periodontal disease increases with age and, for the individual, the effects of these oral diseases also accumulate over time. New problems arise in consequence, for example the prevalence of dentine hypersensitivity increases as roots are exposed due to increasing gingival recession. Plaque control can become more difficult with increasingly complex restorations and calculus accumulates. There are also issues relevant to social confidence: tooth colour darkens with ageing, in terms of intrinsic colour and also extrinsic tooth stain, both of which can affect perception of overall loss of whiteness. In this overall context, the role of personal oral care products and daily oral hygiene routines becomes even more important. This review examines how oral health and condition of the mouth changes with age and describes the potential for modern day toothpastes to reduce unwanted effects that occur during the ageing process.

Key words: Ageing, caries, erosion, gingivitis, periodontitis, gingival recession, calculus, colour, tooth sensitivity, anti-age toothpaste, dentifrice, zinc citrate, vitamin E, potassium citrate

Introduction

The past several decades have seen a dramatic shift in dental healthcare in the developed world'. The improving oral health status of populations, such as people keeping more teeth for longer, has brought impressive benefits but at the same time, has created or raised awareness of other oral and dental health problems[2]. The focus has changed over time from the restoration and extraction of carious teeth, to the prevention of caries and the maintenance of periodontal health throughout life'. As dentition is kept for longer, other problems appear such as secondary caries around existing fillings, root caries due to gingival recession and exposed dentine, and sometimes an increased malodour due to reduced salivary flow associated with the increased medication typically taken by elderly people. Existing problems such as calculus, extrinsic stain and dentine hypersensitivity may also increase to being significant issues for these patients.

This review examines the effect ageing has on the overall health of the mouth and describes how modern day toothpastes can aid in managing these effects during the natural ageing process.

French Insight Study

As well as relevant literature citations, this review also contains data that were obtained from a study conducted to determine the dental health status in French Consumers, related to key demographic parameters including age, gender and level of education. The study was carried out in seven locations in France, including one metropolitan, two urban and four rural communities. Research International carried out the recruitment of the subjects for the study on behalf of Unilever Oral Care. The population was proportioned by age, gender and level of education at each location. About 880 subjects (roughly half male and half female), aged between 15-64 years old, were interviewed and then as-

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sessed by two dentists. Key parameters from this study are included in this report where relevant.

The effect of ageing on dental caries

A recent review [4] of the available epidemiological data from many countries clearly indicates that there is a marked increase in the prevalence of dental caries, challenging the historical consensus that dental caries prevalence was in decline [5]. This global increase is found in children and adults, primary and permanent teeth, and include coronal and root surfaces. While the causes of this increase are unclear and opinions differ, the remedy is well known and includes oral health educational programmes, an emphasis on twice daily tooth brushing with a fluoride toothpaste, a reduction of intake in sugary foods and regular dental check ups[4].

Dental caries can be observed early in life, and is reported to be the most common chronic childhood disease of children aged 5 to 17 years in the USA[4]. Caries in the permanent dentition can be found soon after the eruption of the first permanent molars, where it usually begins in the pits and fissures [6].

Many epidemiological studies around the world have focussed on children and it is clear that caries prevalence increases with age. There are many examples of this *vi%*amongst Brazilian children aged 0-5 years[7] and 5 and 12 years old ; Chinese children aged 3-5 years ; Mexican children aged 6-9 and 6-12 years[10*11]; United Kingdom children aged between 5 and 8 years and between 12 and 15 years; Children from the USA, aged 5-17 years old[4]. However, despite the focus here on caries in children, caries remains a major health issue that increases in magnitude throughout life. For instance, in an extensive National Oral Health Survey across India , it was found that the prevalence of dental caries, for both coronal and root surfaces, increased .with the subject's age. The prevalence was 51.9%, 53.8% and 63.1% in 5, 12 and 15-year-old children respectively. The prevalence increased to 80.2% and 85.0% in adults aged 35-44 and 65-74 years old respectively. The observation that the percentage of adults with experience of caries, restorations or missing teeth increased with their age has also been reported in other adult populations. For example, in Australia the mean number of coronal filled surfaces is reported[14] as 2.7% for 16-19 year-old subjects and increased to 6.3%, 20.1% and 33.8% for 20-34, 35-49 and 50-64 year-old subjects respectively Similar increases are reported[14] for a USA adult population, from 4.4% for 16-19 year-old subjects to 27.3% for 50-64 year-old subjects. In a Swedish epidemiological study of 987 subjects in 2003 [15], the number of individuals without caries and restorations decreased with age from, for example, 12% of the population at age 20 years to 0% at age 40 years. The corresponding decayed and filled teeth (DFT) increased from 5.9 at 20 years to 113 at 40 years and 17.0 at 60 years. Zhang *etaL^'*-conducted a systematic review of the oral health status of Chinese adults and found that the decayed/missing/ filled teeth (DMFT) index significantly increased with age. Rural subjects presented higher DMFT than urban which increased markedly for rural subjects over 45 years of age. In the UK Adult Dental Health Survey , the mean proportion of teeth which were filled but otherwise sound, increased with subject age from 9% in the 16-24 years age group to 39% by the age of 45-54 years. These studies demonstrate there is an overall increase in caries prevalence with age, however, the pattern and presentation of caries can also change with age. As already mentioned, children first develop coronal caries in pits and fissures, but in those countries with access to professional dental care, these primary lesions are typically already restored. Therefore secondary caries is the problem, particularly as the restorative cycle progresses with increasing complexity of restorations, and the concomitant increase in difficulty of maintaining good plaque control.

One caries problem generally found in older age-groups is that of root caries. Greater life expectancies combined with improvements in tooth retention have resulted in increased numbers of people who have retained their teeth into old age. This increase in number of teeth combined with the increase in gingival recession results in older persons with more root surfaces exposed to bacterial plaque accumulation and at greater risk to root caries[18]. For example, the mean Root Caries Index value in a Swedish population significantly increased with age from 14% to 16% and 22% in the 55, 65 and 7 5 year-olds, respectively[19].

In summary, older people are a group prone to active caries, a conclusion from Thompson[20], in a recent review of dental caries experience studies with at least three years of follow-up in older people (> 50 years). Importantly, the widespread perception that root surface caries is their only problem is erroneous: Thompson[2] found that while both coronal and root surface caries contributed to the observed increments, there was a consistent pattern whereby coronal caries made the greatest contribution to the overall increment. This finding supports his suggestion that clinical preventative measures for older people should clearly be directed at all caries. It is well established that regular brushing of the teeth with a toothpaste containing fluoride can reduce the incidence of dental caries[21]. Indeed, in a clinical study, fluoride toothpaste usage was found to be effective in preventing both coronal and root caries [22]

The effect of ageing on tooth wear and erosion

In the current era of improved dental awareness and self-care, many individuals retain their dentition for longer than ever before; and thus the dental tissues must withstand greater exposure to the physicochemical insults imposed by diet and oral hygiene practices which can lead to tooth surface loss or tooth wear[1]. Tooth wear is considered a multifactorial process that may encompass erosion (chemical action), attrition (tooth-to-tooth contact), and abrasion (physical wear, such as from tooth brushing), where erosion is considered the dominant factor[23,] . Dental erosion is commonly defined as the chemical dissolution of the dental hard tissues without bacterial involvement [25]. Erosion is generally caused by acids of either an intrinsic (e.g. stomach acid) or an extrinsic (e.g. dietary acids) nature giving rise to the dissolution of the hydroxyapatite component of dental hard tissues. In enamel, this results in a softened layer of tissue which if not re-hardened, for example by a remineralising agent such as saliva, may be lost due to further dissolution or physical insult[25]. Once the softened enamel layer is physically lost, it is not replaced and the result is ever decreasing enamel thickness. This can give the affected surface a smooth, glazed appearance[26] On anterior teeth, enamel may be thinned sufficiently for the edges to appear translucent and with further tissue loss there can be chipping of the incisal edges [2] which can ultimately lead to an unacceptable appearance of the teeth[27]. With the loss of enamel and subsequent exposure of dentine, there is a further risk of hypersensitivity[2] .

In a recent review[25], the main strategy for minimising tooth wear was described as education. This is because individual's tooth wear is asymptomatic in the early stages and therefore early detection and intervention by the dental health professional will be of the utmost importance. The review also stated that there is evidence that fluoride can provide some protection against erosion, and that the use of fluoride toothpastes and mouthrinses should therefore be encouraged.

The increase in erosion has been demonstrated in children and young people. For example, in-a UK study[29] with 1,308 children aged 12 years at baseline and then re-examined two years later, it was found' that the prevalence of deep enamel lesions increased from 4.9% to 13.1%. Similarly, in a review of data from UK dental surveys of young people it was also concluded that erosion increased with age of children and adolescents over time[30] In another study[31] with groups of subjects aged 10-13 years old and 15-16 years old from the Netherlands, the percentage of subjects with visible smooth wear was 3% in the younger group and 30% in the older group.

In terms of the prevalence of tooth wear in adults, a recent systematic review concluded that the predicted percentage of adults presenting with severe tooth wear increases from 3% at the age of 20 years to 17% at the age of 70 years and that increasing levels of tooth wear are significantly associated with age[32]. Similarly, Bartlett and Dugmore concluded in their recent review that literature evidence demonstrates that normal levels of erosion and wear are age dependant. Further, in another recent review[34] of non-carious cervical tooth surface loss it was concluded that the older the population becomes the greater percentage of lesions are found, the greater the number of lesions per individual occur and that the lesions become larger.

In a study with groups of subjects aged 26-30 years old and 46-50 years old in Switzerland, the prevalence and severity of erosion was greater in the older age group . For example, erosion with involvement of dentine was observed in 7.7% and 13.2% of the younger and older aged groups respectively. A sub-set of the original groups was re-examined six years later and it was found that there was a distinct progression of erosion on facial and occlusal surfaces and wedge-shaped defects[36]. The increase in the defects was more marked in the older group.

The effect of ageing on gingivitis

Chronic marginal gingivitis is defined as the 'non-specific, reversible inflammatory response to dental plaque involving the gingival margins' [37]. If adequate oral hygiene is restored and professional cleaning undertaken as necessary, gingivitis usually resolves and the tissues become clinically healthy again. In this way, Lang *et al?* *commented that gingivitis may be perceived as the protective host response against bacterial challenge. However, their review of long-term longitudinal data clearly demonstrated the importance of gingivitis: teeth with consistently non-inflamed gingivae had a 50 year-survival rate of 99.5%, while those with consistently inflamed gingivae had 70% more attachment loss and a 50 year-survival rate of only 63.4%. Based on these data, they concluded that persistent gingival inflammation is a clinically significant risk factor for periodontal attachment loss and tooth loss[38].

Factors that enhance plaque retention or impede plaque removal such as crowded or crooked teeth, crowns and other restorations are predisposing factors for gingivitis and the persistence of this inflammation may develop into chronic periodontitis. There is a correlation between gingival bleeding and age that could be in part due to the accumulation o f these impediments to plaque control[39]. Plaque control at the gingival margin can also be complicated by restorations and gingival recession: Robinson[40] found that patients over 60 years of age required more frequent oral prophylaxis for the maintenance of gingival health than individuals under 25 years old. This finding was interpreted to be largely due to the increased incidence of exposed root surface in older individuals which allows more rapid plaque accumulation and calculus formation than enamel surfaces.

Data from experimental gingivitis studies also indicate a change in the inflammatory response of gingivae to plaque with age. Robinson[40] showed that elderly individuals develop more rapid and severe gingivitis than young individuals following the abstention of oral hygiene. Likewise, Fransson *etal?* [x] found that while 65-

80 year-old subjects formed similar amounts of plaque as subjects 20-25 years of age during a 3-week period of abstention from oral hygiene, they developed more gingivitis. This age-related increase in gingivitis was seen in clinical assessments, gingival crevicular fluid volume and also morphometric analysis of histological samples: more inflammatory cells were also found in lesions of older individuals. Similar findings have also been reported by Tsalikis eZö/*[2] who compared experimental gingivitis in 20-22 year-olds with that in 61-65 year-olds. In this study, clinical signs of gingivitis and gingival crevicular volume were more pronounced in the older group. Gingival crevicular fluid levels of the pro-inflammatory cytokine interleukin-1 beta at day 21 of no oral hygiene were also significantly higher in the older group, whereas they remained low for the younger adults. In contrast to Fransson *etal**\ within this particular study, the plaque accumulation during the experimental period was also significantly higher in the older age group.

Regarding the natural history of gingival inflammation, a review by Anerud *etal**[3] discussed the fact that changes from 'healthy gingiva' to a 'chronic gingivitis' take place early in life and that both the number of individuals with gingivitis as well as the degree of severity within individuals increase through the teens and early twenties. However, the progress of the disease does depend on the socio-economic status of the individuals. In the Norwegian population studied, there was no general increase in prevalence and severity of gingivitis up to 40 years of age. In comparison, a similar study in Sri-Lanka showed quite severe forms of gingivitis already by the age of 20 and then a steady increase in mean gingivitis levels through the twenties and early thirties so that at 40 years of age more than 97% of sites bled on probing. Whilst this study appears to highlight two extremes of the condition, it is clear that it is rare for individuals to maintain the gingival health that is seen in early adulthood and the tendency is that gingivitis worsens with age.

The effect of ageing on periodontitis

Gingivitis and periodontitis are considered to bea continuum of the same inflammatory disease[44]. Chronic adult periodontitis differs from chronic marginal gingivitis in that there is also loss of attachment between the root surface, the gingivae and the alveolar bone and bone loss itself may occur. The loss of attachment is accompanied by apical migration of the junctional epithelium. This is evident clinically by either a pathologically deepened gingival crevice, termed a periodontal pocket, or gingival recession (see below) or indeed a combination of these two, depending largely upon the anatomical situation.

Chronic adult periodontitis is the most common form of periodontitis affecting the general population and is the major cause of tooth loss after the age of 25[37] Albandar *etal**[3] found from their studies that the prevalence of periodontitis and the prevalence and extent of attachment loss increase considerably with age. Destructive periodontitis and attachment loss were consistently more prevalent in males than females and more prevalent in blacks and Mexican American than whites [45].

Interestingly however, results from a study by Abdel-latif and Burt showed that oral hygiene was the most important predictor for periodontitis and that the effect of age on the progression of periodontitis could therefore be considered negkgible when good oral hygiene is maintained. That said, research on the epidemiology of periodontal disease suggests that the disease in older adults is probably not due to greater susceptibility but is instead the result of cumulative disease progression over time [47]. In the UK for example, 85% of the population 65 years of age and over had some attachment loss of 4mm or more compared with just 14% in the 16-24 age group '. Likewise in the US, the proportion of adults with at least one site with loss of 2mm or more was 86.4% for the 45-54 age group compared with 37.3% for the 1 8-24 age group[48]

As mentioned above, periodontitis and gingivitis are considered to be part of the same inflammatory continuum and the consensus of opinion is that prevention of gingivitis prevents periodontitis [44]. Furthermore, gingivitis is now recognised to be a signification risk factor for periodontal attachment loss and tooth loss[38]. Therefore controlling gingival inflammation at an earlier stage would lead to a reduction in the more serious form of the disease that becomes more prevalent in older adults.

The effect of ageing on gingival recession

Gingival recession is a condition where the gingival margin recedes from its normal attachment at the crown margin with the root to go further apically down the tooth root. The gingival margin then lies against the root surface of the teeth and the root is thus exposed. In affected persons, recession can cause increased sensitivity of teeth and may even lead to loss of vitality of the affected teeth. In their studies, Albandar and Kingman [39] reported that there was a significant increase in prevalence, extent and severity of gingival recession with age, a fact that has also been reported by other authors [49,5°].

A number of factors have been shown to be important for gingival recession, including gender, malpositioned teeth and tobacco consumption .Joshipura *et al**[9] found subjects who brush with excess vigour are likely to have root surface exposure as a result of the trauma due to brushing. However, gingival recession is thought to occur primarily as a consequence of periodontal diseases and whilst over-use or aggressive manipulation of mechanical oral hygiene aids such as toothbrushes or floss are common causative factors, anatomical and other factors may also be involved. Joshipura *etal.* also reported that subjects with poor oral hygiene were more likely to have root surface exposure and this was attributed to periodontal disease. Lang *et al*[3*] stated that it has been convincingly demonstrated that development of periodontitis only occurs in areas of long-standing gingivitis. It can therefore be concluded that good control of gingivitis in its early stages will also aid in reducing gingival recession.

The effect of ageing on oral soft tissues

Whilst age-related changes in the oral mucosa remain open to interpretation, it has been reported for many years that clinically the aged oral mucosa is often smoother and dryer. Shklar[51] found distinct differences between oral mucosa of young individuals and the oral mucosa of elderly persons, including epithelial and connective tissue atrophy, van der Velden [52] reported research findings suggesting that the degree of periodontal breakdown increases with age, that with increasing age inflammation of the periodontium tends to develop more rapidly and that in the process of ageing the peridontium shows a slower rate of wound healing. More recently, Karube *etal*[33] studied gingival microstructure according to a number of conditions. No difference was found according to underlying disease, medications or the presence or absence of dentures but changes were noted in the microstructure of the gingiva according to age. Likewise, Vandana and Savitha [54] examined the thickness of gingiva in association with a number-of parameters including age in a group of Indians with an age range of 16-3&years. They found that the younger age group had significantly thicker gingiva than that of the older age group.

Despite the findings of Karube *et al,*[53] reported above, many authors believe that changes in the oral mucosa may be a reflection of associated systemic disease and/ or medication rather than intrinsic age related changes. For instance, saliva is known to play an essential role in the maintenance of oral health. Many older adults take medications many of which are associated with decreased saliva, dry mouth and xerostomia [47], which in turn can have an effect of overall dental health. Niessen and Fedele [47] also reported that oral and pharyngeal cancers increase with age which again can impact the overall health of the oral mucosa. This Ending was also reported in a review of the area by Napier and Speight[55], stating that older patients, particularly females were more at risk than younger patients at developing potentially malignant oral disorders.

The effect of ageing on oral microbiology

Whist the mouth of a new born baby is usually sterile [37], from the first feeding onwards it is regularly inoculated with microorganisms. The pioneer species are the first to colonise such as *Steptococcus. salivarius,S. mitis* and 5*. *oralis.* After this, the eruption of teeth has a significant ecological impact on the oral environment and its resident microflora with the acquisition of some genera such as 5. *sanguinis and* X *mutans* occurring optimally at certain ages [56*58]. Puberty causes an increase in spirochaetes and black-pigmented anaerobes, possibly due to hormones entering the gingival crevice and acting as a novel nutrient source. Eventually, a climax community is reached [59], the resident oral microflora remaining relatively stable and coexisting in reasonable harmony with the host[37] This stability is termed microbial homeostasis and is due to a dynamic balance among the resident flora through numerous inter-bacterial and host-bacterial interactions. Some life experiences, such as pregnancy may lead to a temporary change in the balance but it is not until later in life that some variations in the oral microflora are seen [37]. These variations can be attributed to both direct and indirect effects of ageing. Significantly higher proportions and isolation frequencies of lactobacilli and staphylococci (mainly *5*. aureus) in* saEvawere found in healthy subjects aged 70 or over while yeasts were isolated more often and in higher numbers from saliva in those aged 80 or over. In fact, the incidence of oral candidosis is more common in the elderly due to a number of factors including denture wearing, physiological changes to the oral mucosa, malnutrition and to trac element deficiencies [37]

The effect of ageing on oral malodour

Malodour in children is relatively rare, even though they may harbour some of the "malodour' causing organisms. However, oral malodour is relatively common in the adult population. In young adults, it is the metaboEsm of bacteria located on the tongue that accounts for the majority of malodorous compounds found in mouth air. High odour subjects generally have a higher total bacterial load on the tongue, and higher numbers of Gram-negative anaerobes, with higher proteolytic activity, producing volatile sulphur compounds [37] As a person ages, it is beEeved that periodontal disease takes on a more important role in malodour . Indeed, in the older population, oral malodour production may be direcdy related to the patient's periodontal condition as the production of disagreeable odours occurs more rapidly in patients with periodontal disease. In addition, medications commonly taken in the aged population can induce xerostomia, which can lead to an increase in malodour in this population[61], due in part, to the creation of a suitable environment for associated microorganisms [62]

The effect of ageing on calculus formation

Calculus or tartar is the term used to describe calcified dental plaque. It consists of intxa-and extracellular deposits of mineral, as well as protein and carbohydrate. Mineral growth can occur around any bacterium; areas of mineral growth can then coalesce to form calculus, which may become covered by an unmineralised layer of bacteria. Calculus can occur both supragingivally (especially near the salivary ducts) and sub-gingivally, where it may act as an additional retentive area for plaque accumulation, thereby exacerbating periodontal disease.

Over 80% of adults have calculus, either as supragingival and/ or subgingival calculus. In populations with regular oral hygiene and access to professional care, supragingival calculus is first observed in early teen years[63]. If it is not removed, the levels will obviously increase dramatically with time. The French Insight study *(Table*shown that the prevalence of supragingival calculus increases with age. In addition, subgingival calculus has also been shown to increase in prevalence and severity with age[39]. Once formed, professional scaling is required to remove calculus.

The effect of ageing on tooth colour and stain formation

The colour of the teeth is determined by the combined effects of their intrinsic colour, which is influenced by light scattering and absorption within enamel and dentine, and the presence of extrinsic stains that may form on the tooth surface[64'66]

It is well documented that as people age their intrinsic tooth colour has a significant tendency to become darker and more yellow, as determined in a number of study populations [67'73]. In the vast array of genetically determined tooth colourations, all teeth appear to darken over the course of time [74].

The impact of subject age on tooth colour is believed to be due to a number of factors. As the dental pulp ages it shrinks and leaves secondary dentine in its wake[74]. At the same time, it is hypothesised that pigments and ions of an amorphous organic and inorganic nature permeate and deposit at the enamel-dentine junction, causing the overall dentine chroma to become more saturated[74]. Due to normal tooth wear processes, the enamel thickness can decrease and the dentine colour will begin to have a greater influence on the overall tooth colour. The impact on reduced enamel thickness giving rise to increased tooth yellowness has been confirmed with *in vitro* experiments[75]. The net result of these processes is an overall progressive darkening and yellowing of the teeth with age.

With respect to extrinsic stains, these can also be affected by the general wear, tear and disease of teeth and their supporting tissues that occurs throughout life and that can lead directly or indirectly to tooth discolouration[64]. Thermal expansion and contraction forces exaggerated by normal tooth flexure can give rise to the creation of cracking and crazing within the enamel surface, which can become more pronounced with time[74]. Physical trauma can result in the formation of enamel cracks or the bulk loss of enamel, both of which can allow the internalisation of extrinsic stains. In addition, the exposure of dentine through enamel wear or gingival recession can also increase the uptake of staining chromogens into the tooth[64].

Extrinsic stain was assessed in the French Insight Study. Staining was scored on the buccal surfaces of the upper and lower incisors. The worst code was recorded for the 8 test teeth. Each code was given a numerical score as shown in *Table 2* and the compound stain index=Intensity*Area calculated. *Figure 1* shows the mean stain index (I* A) for each age group and *Table 3* shows the percentage increase in extrinsic stain with each age group.

Control of extrinsic stain is possible with the regular use of a toothpaste[76,77]. Toothpastes typically contain an abrasive system in order to help reduce or prevent extrinsic stains from forming since a low or non-abrasive paste is unable to prevent extrinsic stains. The toothpaste may contain other ingredients to augment its cleaning performance, such as surfactants and calcium chelators[78]. The removal of extrinsic stain can be accomplished using whitening toothpastes, which are typically formulated to have an enhanced cleaning performance[76,7 , 9]. Interestingly, the removal of existing extrinsic stain had a significant impact on the overall improvement of tooth colour, as clinically measured and perceived by subjects who had used a whitening toothpaste for four weeks[77].

The effect of ageing on tooth sensitivity

As discussed by Addy[80], the adopted definition for dentine hypersensitivity states ‘dentine hypersensitivity is characterised by short, sharp pain arising from exposed dentine in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or disease’. It is a common oral health problem affecting one or more teeth of many adult individuals. Addy[80] commented that hypersensitivity increases with age, with a peak between 30-40 years. In our own studies, hypersensitivity was seen to increase up to and beyond 60 years of age *(Table 4).* The primary cause of exposed dentine is thought to be gingival recession[81] but changing diet may also be a factor. Increased consumption of acidic foods and drinks can lead to enamel erosion, a factor which in turn leads to increased dentine exposure. Hypersensitivity is also set to rise in the general population as caries and periodontal disease prevention results in improved oral health status and functionality of the dentition .

Delivery of anti-ageing benefits from a Toothpaste

As seen from all the data reviewed above, increasing age is accompanied by increase in oral problems. Oral

Table 1 Percentage increase in calculus with age. Results from the French Insight Study

Clinical Parameter	Age						
	15-16	17-21	22-30	31-40	41-50	51-60	61-64
Calculus	39	69	81	84	88	85	98

Table 2 Numerical scores for coding used to assess extrinsic stain in the French Insight Study

Code	Category	Diagnostic Criteria	Score	
N	None	No Stain	1	
L	Low intensity	Yellow tan-light stain	2	Intensity
M	Medium intensity	Medium brown - medium stain	3	
H	High intensity	Dark brown or black - heavy stain	4	
L	Small area of stain	Stain up to one third of region	2	Area
M	Medium area of stain	Stain up to two thirds of region	3	
H	Large area of stain	More than two thirds of region	4	

Table 3 Percentage increase in stain with age. Results from the French Insight Study

Clinical Parameter	Age						
	15-16	17-21	22-30	31-40	41-50	51-60	61-64
Stain	17	17	18	27	26	23	25

Table 4 Percentage increase in tooth hypersensitivity with age. Results from the French Insight Study

Clinical Parameter	Age						
	15-16	17-21	22-30	31-40	41-50	51-60	61-64
Hypersensitivity	3	1	18	28	33	30	46

y = 0.4154X + 4.6743

Figure 1. Mean stain index for each age group in subjects with extrinsic stain (n=189) from the French Insight Study

disease and damage is generally progressive and, over time, the effects accumulate and are exacerbated. Also, the changing anatomy due to loss of soft and hard tissue allows new problems to emerge, such as root caries and dentine hypersensitivity. At the same time, throughout developed countries at least, patient expectations of long-term oral health and aesthetics generally appear to be increasing.

More adults than ever before are retaining more of their natural teeth for longer and the need for effective prevention practices becomes even more important. As discussed by Albandar and Kingman [39] this will not only improve the level of oral health of the population but could also produce great cost savings for health providers.

Self-performed oral hygiene through tooth brushing has long been the cornerstone of oral prevention. This mechanical approach to plaque removal is a practice now embedded in the developed world, even though it is generally practiced less frequently than the 'twice daily'dental professional recommendation and the levels of dental plaque in populations remain relatively high[82]. While the commonly achieved efficacy of cleaning by tooth brushing itself may not be ideal, the process has key importance as a means of deEvering topical agents to help protect and maintain the dentition.

The widespread usage of fluoride toothpastes in particular has been attributed as the single most important factor responsible for reducing caries [83] and there is also evidence that fluoride provides some protection against dental erosion [84,85]. The inclusion of stable, available fluoride is therefore generally accepted to be of fundamental importance for toothpaste. However, it is clear that fluoride alone is insufficient to address the problems facing the ageing patient; a multi-functional formulation is needed.

In the mouth, fluoride has complex interactions with calcium that are key for remineraEsation of early caries lesions and for caries inhibition [86,87] Increased levels of calcium in the mouth are associated with a reduction in DMFT (decayed, missing and filled teeth) [88,89]. The presence of calcium also affects the overall balance of re- and demmeraksation processes that occur in enamel erosion - addition of calcium to acidic beverages has been shown to reduce their erosive potential significandy [90,9!].

Toothpaste can also be formulated to provide calcium' for added benefit and several examples have been reported previously. The addition of calcium glycerophosphate to a sodium monofluorophosphate (SMFP) toothpaste showed increased dekvery of calcium to plaque [92] with enhanced protection from enamel demineraksation [3] compared to placebo. Calcium benefits are also evident from calcium carbonate-based SMFP formulations, which have been shown to reduce the pH drop of plaque foUowing a sucrose challenge *in vivo*** and to reduce enamel demineraksation and enhance remineralisation *in situ** .More recendy, studies showing that a new toothpaste containing micro-calcium delivered elevated levels of calcium to the mouth and promoted enhanced remineraUsation of demineralised enamel lesions [97]. Similar findings have also been reported for the use of hydroxyapatite in toothpaste formulations [98]. Taken together, these findings support a hypothesis that the provision of an effective source of calcium from a fluoride toothpaste will help to protect against the increasing dental caries and erosion that occurs with age.

With respect to gum health, as discussed above, persistent gingivitis is a significant risk factor for loss of attachment and tooth loss, both of which increase with age. Preventing gingival inflammation will therefore help to prevent periodontitis and associated gingival recession. Modulation of the host inflammatory response via redox status is one potential approach[99]: anti-oxidant deficiency in the oral cavity is associated with poor gum condition [10°]. Several toothpastes on the market contain micronutrients such as vitamin E, which has both anti-oxidant and anti-inflammatory effects[99,] and could potentially be beneficial for gingival health if dekvered to the relevant site of action. While some products have shown delivery of vitamin E to the gingival tissues [102] and penetration into viable gingival tissue layers[103], there is limited information on other products.

The more traditional approach in using a toothpaste to prevent gingivitis has been to use specific antimicrobial agents. Triclosan and zinc are the anti-microbial agents most commonly found in toothpastes and both have clinically proven anti-gingivitis efficacy . The efficacy of a triclosan copolymer system has been researched extensively [105 107]. Likewise, zinc salts are widely used in toothpastes and mouthrinses and there is a large body of evidence demonstrating it also to be an efficacious antimicrobial agent *in* vzvo,with both anti-plaque and anti-gingivitis efficacy [105]. The chnical efficacy of a 2% zinc citrate formulation in a six month study has previously been demonstrated to reduce plaque and gingivitis [108] and more recently, the antimicrobial efficacy of a 1% zinc citrate formulation has been reported .

The zinc ion also has additional benefits that are of relevance to the ageing patient. Zinc is well established as an effective anti-malodour agent for the mouth[11 '] and together with pyrophosphates and polyphosphonates zinc has been shown to be effective at restricting the formation of calculus by slowing crystal growth and reducing coalescence [112*114] This in turn can lead to a reduction in extrinsic stain caused by the formation of calculus and retention of coloured molecules within the calcified material. This is in addition to the stain removal effects of toothpaste which are most commonly provided by an abrasive system[78].

Regarding abrasivity, it is clear that this is a fundamental requirement for effective cleaning from a toothpaste, since without abrasives, stain accumulates[11] . However, in an ageing population where root dentine is more likely to be exposed by gingival recession, the potential for abrasive formulations to cause unacceptable dentine wear must be considered. The Relative Dentine Abrasion (RDA) value is commonly used to describe the abrasivity of toothpastes, but this requires appropriate interpretation.

RDA is an *in vitro* measure on dentine specimens and it has been shown that dentine wear *in vitro* increases linearly with increasing RDA [116]. However the normal situation in the mouth is different, where dental pellicle, saliva flow and fluoride would be expected to confer a protective effect. This has been seen with pellicle coated specimens *in situ,* where dentine wear rates are significantly reduced compared to water control with no pellicle. The protective effect is such that no significant difference on *in situ* dentine wear has been found between toothpastes over the RDA range of 90 to 204 [1] .This finding remains true in the long-term: with *in situ wear* protocols, there is no significant difference in dentine wear for toothpastes having RDA 90 to 204 after 24 weeks[118].

Furthermore, *in situ* wear rates are not linear with time and extrapolation of latter dentine wear rates *in situ* would give approx 450 microns of dentine wear in 80 years, twice daily brushing[119] Pickles eZ a//™state: "The data presented here suggest that whilst *in vitro* tests [i.e. RDA] have value in understanding differences in abrasivity between products (for example, for formulation optimisation), they cannot be used to predict *in vivo* effects". Addy and Hunter [2] state: "evidence from *in situ* and *in vivo* suggests that brushing with a toothbrush and toothpaste produces limited dentine wear in a life time of use, and virtually no wear to enamel". This provides necessary reassurance that the high performance silica cleaning systems generally present in modern toothpastes for stain removal[79] are suitable and do not pose any undue risk to the mature dentition.

Dentine hypersensitivity can be difficult to resolve and two broad approaches are commonly used in toothpastes. First, to interrupt the neural response to pain stimuli and second to occlude open tubules to block the hydrodynamic mechanism. The vast majority of de-sensitising toothpastes contain a potassium salt to 'numb' the pain. Potassium nitrate, potassium chloride and potassium citrate are used interchangeably in many countries at a concentration providing 2% potassium ion, which is the densensitising active ingredient[81] For tubule blocking strontium chlorid 10% has been present in marketed toothpaste for many years and more recently the efficacy of a formulation containing arginine, calcium carbonate and fluoride has been discussed . However, there is a lack of comparative studies and so far there is no evidence to show superiority of newer technologies over older, tried and tested ingredients.

Summary

The challenge for anti-ageing oral care products is to provide relevant multi-efficacy in an appealing format that will be used by individuals to help prevent the deterioration in oral health that can occur with increasing age. It is clear that appropriate technologies exist to address the problems, but most of these seem to appear individually in products focused on single benefits, for example gum health, anti-erosion or anti-sensitivity. Bringing the relevant ingredients together in a single formulation whilst retaining their activity would be greatly beneficial for home care, reinforcing the increasingly important focus on dental prevention.

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