Comparison of Oral Health Status in Asia: Results for Eight Emerging and Five High Income Countries or Regions and Implications

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Objective: *To review the burden of oral disease by investigating the current situation of oral health status in selected countries within the regions of South, East and South-East Asia, where the burden is spposed to be particularly high with a view to determining which countries are performing better than others and why.*
Methods: *The study is descriptive and observational in nature and the material is derived from existing databases. As this is a cross-sectional investigation, it offers evidence about relationships and influencing factors. If available, the longitudinal data is integrated.*
Results: *Amongst the emerging countries, the Chinese enjoy a relatively favourable dental health status and amongst the high income countries, the South Koreans exhibit the best dental health status by comparison. In contrast to the above-mentioned perception, caries levels are relatively low and occur in the early stages in most of the emerging Asian countries investigated, even though, for the most part, caries and periodontitis remain untreated. The hypothesis that, when countries climb the socioeconomic development ladder, caries levels increase and worsen if left untreated, leading to edentulousness, cannot be confirmed for most of the developing Asian countries under investigation. Probable reasons for this surprising finding are discussed and found to be in line with current knowledge in cariology. Interestingly, the high income Asian countries under investigation perform better than many Western European countries.*
Conclusion: *Under the specific circumstances prevailing in the Asian countries under investigation, a preventive and tooth preserving dental strategy for the entire population should offer emerging countries great opportunities to maintain a relatively low level of caries. Utilising a strategy of this ilk, these countries could achieve improved dental health across the population with comparatively low resources.*
Key words: *benefits from preventive dentistry, caries burden in Asia, dental care in emerging countries, performance of high income Asian countries*
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There are only a few cross-national studies that evaluate oral health status on a population basis and investigate both the efficacy and efficiency of oral care systems in affluent regions[1]. In the case of developing countries, such knowledge is almost totally lacking. In these countries, oral health policy, in particular, generally ranks very low on the government agenda, due to the fact that the main oral diseases – caries and periodontitis – is not life-threatening and financial resources for health care are extremely scarce. Consequently, dental care is almost exclusively financed by means of out-of-pocket payments[2,3]. Although some emerging Southeast Asian countries try to reduce their dependence on out-of-pocket payments in general health care[4], this is hardly true for oral care. Consequently, many households in low and middle income countries cannot afford to utilise dental services (if at all existent) or, in the case of severe oral problems, are driven into catastrophic expenditure

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(expenditure on dental care ≥ 40% of the household's capacity to pay), which means that up to 35% of households are forced to reduce their expenditure on basic necessities (food, housing, clothing and education)[5].

When looking at the regions of the world with the highest global burden of oral conditions, defined here as untreated caries (Decayed Teeth [DT] > 0), severe periodontitis (a Community Periodontal Index score of 4 or a clinical attachment loss of ≥ 6 mm or a gingival pocket depth ≥ 5 mm) and severe tooth loss (≤ 9 remaining permanent teeth), measured by means of Disability-Adjusted Life-Years (DALYs) and DALYs per capita, the regions of South, East and Southeast Asia stand out. East and South Asia are also the regions that, between 1990 and 2010, experienced the least favourable changes in per capita oral health needs[6]. In defining untreated caries as a DT > 0 instead of using the DMFT Index, Kassebaum et al[7] argue that only the DT component of the DMFT Index gives an appropriate description of the caries burden as treated teeth are no longer diseased. This point of view is comprehensible when considering the immediate treatment of caries. However, it neglects the life-long caries experience, which is important, as filling therapy implies an irreversible loss of hard tooth tissue[8].

This is the reason why this study has chosen to focus on selected emerging countries from populous Asian regions and to analyse the oral health status and the dental care conditions of these Asian populations, with the aim of determining which countries are performing better than others, and why. In this context, the hypothesis that "oral health status deteriorates in developing countries that have a rising standard of living and are undergoing nutrition transition" will be examined. This hypothesis posits that "dental caries, if not treated, will steadily progress over time and will finally lead to edentulism"[9]. A standardised model for predicting caries development in 6 to 18 year olds in third world countries is based on this assumption[10].

Materials and methods

The empirical data are taken from the World Health Organization's Global Oral Database (GODB)[11], from material collected by Songpaisan et al[12], who presents overviews of oral health and dental care delivery structures of Asian countries, as well as from current national oral health surveys conducted in various countries.

This includes eight low and middle income (emerging) countries, located in the three above-mentioned Asian regions, representing different stages of development. Five high income Asian countries function as a benchmark for the developing Asian countries. The countries included have also been chosen in a manner that allows comparisons between ethnic groups living in different neighbouring countries such as Malayans in Malaysia and Singapore or Chinese individuals in Mainland China, Hong Kong or Taiwan. Sweden has been chosen as the benchmark for the high income Asian countries, because its population currently enjoys the best oral health status in terms of affluent countries[1]. Only countries or regions with nationally representative samples have been selected. The participating countries or regions and their status are shown in Table 1.

Table 1 Participating Asian countries or regions and their development status 2012.

Asian regions[1]	Development level[2]		
	Lower middle income	Upper middle income	High income
Southeast Asia	Indonesia (ID) Sri Lanka (LK) Philippines (PH) Vietnam (VN)	Malaysia (MY) Thailand (TH)	Singapore (SG)
East Asia	–	Mainland of PR China (CN, China mainland)	Hong Kong (HKSAR, China) Taiwan (TW, China)
South Asia	India (IN)	–	–
Asia-Pacific	–	–	Japan (JP) South Korea (KR)

Note: 1, According to Global Burden of Disease Study (GBD) regions; 2, According to World Bank classification.
References source: [13,14]

This study focuses on natural dentition without considering prosthetic status, owing to the lack of reliable data and the fact that natural teeth are normally preferred over artificial teeth[15,16]. As dental decay and its related complications (tooth loss) cause the greatest threat to natural teeth and account for about 95% of the oral burden across the world[17], the measurement of dental status is conducted using the key tool for caries experience in dental epidemiology: the Decayed, Missing, Filled (DMF) index[18].

Contrary to the DALYS measurement concept, which was invented to help health policy and health research in prioritising health activities and which is characterised by a sophisticated construction using subjective estimates from international experts from around the world and the general public with regard to health severity[6,19]; the measurement concept used in this study involves proven objective morbidity indicators of 'incidence' (number of new disease cases during a certain time period divided by the population) and 'prevalence' (number of people in a population who have a disease at a given point divided by the population). Incidence rates measure the risk of a particular disease, whereas prevalence rates capture both incidence and duration of a particular disease[19].

The target population used for the comparison comprises of individuals aged from 5 to 74 years. In each country, therefore, well-established indicators for dental decay in the WHO reference classes: children (5 to 6 years), adolescents (12 years), adults (35 to 44 years) and seniors (65 to 74 years) are recorded and later combined into a composite indicator – the Dental Health Index (DHI) – that represents oral health status on a population basis. The detailed construction of this composite indicator is presented elsewhere[1]. This paper presents only a brief description of a DHI that is slightly modified, by adding the indicator for seniors – M-T (missing teeth) in 65- to 74-year-olds – to the formula, thereby boosting the sensitivity of the DHI.

As a means of depicting the dental health of children, adolescents, adults and seniors, the conventional, standardised WHO indicators for each age bracket are combined into an overall indicator taking the form of a single figure. Owing to the fact that improvements in the indices 'proportion of caries-free teeth in 5- to 6-year-olds' and 'edentulousness in 65- to 74-year-olds' are not rectified – a higher proportion of caries-free teeth indicates a positive change, whereas greater rates of edentulous seniors indicate a deterioration – these two indicators first have to be rendered compatible before being combined with the absolute DMFT values for adolescents and adults and missing teeth as well as edentulism in seniors. The rate of caries freedom in children and edentulism in seniors is therefore converted to a point system, which ensures that changes in both indicators affect the population-related DHI rectified and balanced[1]. In an analogous manner, the 'Index of missing teeth in 65- to 74-year-olds' is calculated using a ten-point scale (Table 2).

Table 2 Conversion of absolute M-T values into a ten point scale.

M-T 65/74 (absolute)	Index of M-T in 65/74 yr olds
0-2	1 point
2-4	2 points
4-6	3 points
6-8	4 points
8-10	5 points
10-12	6 points
12-14	7 points
14-16	8 points
16-18	9 points
18-20+	10 points

Healthy deciduous and healthy permanent teeth in adolescents form the indispensable basis for a long-lasting healthy dentition. Consequently, the dental health of children and adolescents should be weighted more heavily in the overall indicator than DMFT values for adults and missing teeth, as well as edentulism in seniors. As the single indicators for children and adolescents, both of which relate only to 1-year range age groups, are easier to improve than the indicators for adults and seniors, which relate to 10-year range groups, this is achieved by adding the points for the proportion of caries-free teeth, the absolute DMFT values for 12 and 35- to 44-year-olds, to the points for missing teeth and the proportion of edentulism among seniors, unweighted, and then dividing the sum by the number of included indicators (five in our case). The lower the DHI, the better the overall dental health status of the population. Expressed as a formula, the DHI is as follows:

DHI = (Caries-free Index 5/6 + DMFT 12 + DMFT 35/44 + Index of MT 65/74 + Edentulism Index 65/74) : 5

Table 3 Dental Health Index for Asian populations from countries or regions at different development levels 2003/2013, using Sweden as a worldwide benchmark.

Level status	Country or region/ Survey year	Caries free at age 5/6		DMF-T 12	DMF-T 35/44	M-T 65/74		Edentulism 65/74		DHI7	Rank
		%	Index (1)	(2)	(3)	abs.	Index (4)	%	Index (5)	(6)	
Lower middle-income	IN, 2003/5	17	8.3	1.3	3.5	10.0[6]	6	6.5	0.7	3.96	2
	ID, 2007	< 7	9.3	0.9	4.5	17.0	9	23.6[1]	2.4	5.22	6
	PH, 2011	12	8.8	3.3	12.9	21.0	10	> 30[3]	3.0	9.80	8
	LK, 2002/3	35	6.5	0.9	8.4	15.2	8	21.8	2.2	5.20	5
	VN, 2001	16	8.4	1.9	4.7	6.6[4]	4	16.4[2]	1.6	4.64	4
Upper middle-income	CN, 2005	34	6.6	0.5	3.9	9.6	5	6.8	0.7	3.34	1
	MY, 2007	25	7.5	1.1	10.7	22.1	10	39.0	3.9	6.64	7
	TH, 2012	22	7.8	1.3	6.0	13.9	7	8.2	0.8	4.58	3
High income	JP, 2011	58	4.2	1.4	12.3	9.1	5	6.9	0.7	4.72	4
	HK, 2011	49	5.1	0.4	6.9	12.7	7	5.6	0.6	4.00	3
	SG, 2005/11	51	4.9	0.6	7.4	8.8[6]	5	17.7	1.8	3.94	2
	KR, 2012	38	6.2	1.8	5.5	5.8[5]	3	5.9	0.6	3.42	1
	TW, 2004/13	21	7.9	2,5	7.3	13.7	7	11.7	1.2	5.18	5
Benchmark	SE, 2011/13	78	2.2	0.8	9.7	5.5	3	9.9	1.0	3.34	-

Note: 1, 65+; 2, South Vietnam, > 60 years; 3, Estimation after Ortiguero; 4, 45+; 5, 55+; 6, Manipal, South India; 7, DHI (6) = [(1) +(2) + (3) + (4) + (5)]/5.
References source: [9,11,12,20-24]

For the most part, disability through oral diseases is caused by untreated caries, severe periodontitis and severe tooth loss, where untreated caries predominates below age 35 and decreases in higher age brackets. Severe periodontitis predominates between the ages of 35 and 59 years of age and severe tooth loss is predominant in seniors over the age of 60[6]. In addition to the robust worldwide GODB database for DMFT values, this index simultaneously registers caries and tooth loss and, indirectly, periodontitis – as the disease, in its severe form, also causes tooth loss in higher age groups.

The study is descriptive and observational in nature and the material is derived from existing databases. As a cross-sectional investigation, it provides evidence of relationships and influencing factors. If available, longitudinal data was integrated. As it is not an experimental study, conclusions regarding cause and effect are limited.

Results

The new DHI Index, that has proven to be valid for comparing oral health in affluent countries[1], is applied here, in an expanded version, to the eight selected emerging Asian countries that are at differing stages of development. The five high income countries are analysed separately because caries treatment in affluent countries is quite different from developing countries where the F-component is usually low and the D-component is relatively high. This is why the DMFT index should be applied only to countries that are at a similar development stage, in order to avoid distorted results. At a later stage, we will return to this phenomenon and analyse it in detail.

For emerging countries or regions

Interestingly, with DHIs of 3.34 and 3.96, the two largest Asian countries, China closely followed by India, enjoy a comparatively favourable dental health status among the Asian developing states under investigation (Table 3). Their dental status is about twice as good as that of the Malay and Filipino populations, who rank lowest on this scale. The two countries with the most and the least favourable dental status are both at different development stages (i.e. the upper middle and lower middle income), indicating that the link between a rising standard of living and dental status is weaker than is often argued in the literature.

An assessment of the single indicators shows all emerging countries possessing a high potential for improving freedom from caries in early childhood. Only in China and Sri Lanka are one-third of deciduous teeth caries-free. In all other countries, this value is ≤ 25%, indicating that all emerging countries still fall short of the global WHO goal for the year 2000, targeting a caries prevalence in 5- to 6-year-olds, which is less than 50%. However, the DMFT values for 12-year-olds are more favourable (0.5 to 1.9) except for Filipino adolescents (3.3), which matches the poorer values for caries relief among pre-schoolers in the Philippines. Apart from the Philippines, all developing countries surpass the WHO goal for the year 2000 of a DMFT for 12-year-olds of ≤ 3. An important observation is that the severity of caries is higher in primary dentition (dmtf: 3.1 to 9.8)[11,12] than in permanent teeth (DMFT: 0.5 to 3.3), where the disease is mostly limited to the occlusal and buccal/lingual surfaces[25].

Figure 1 illustrates that caries lesion progression in the 12 to 18 age bracket, in developing Asian countries in which the relevant data were available and where almost no filling therapy has taken place, is in fact much lower than predicted by the third-world model posited by Yee and Sheiham[10].

The pronounced overestimation of caries progression in the Yee/Sheiham model in comparison with real values is due to the model assumption (which is based on the traditional restorative treatment approach) that caries, if not restoratively treated, steadily progresses. This assumption is no longer tenable because modern cariology has discovered that caries and periodontitis does not progress continuously but discontinuously, with alternating phases of active, stagnating and inactive periods[26]. In addition, some form of preventive, group-oriented interventions in children have been and continue to be practised in all countries.

According to WHO's categorisation of caries levels[27], the burden of dental decay in adults is either 'very low' (DMFT < 5.0) or 'low' (DMFT: 5.0 to 8.9) in most countries – again with the exception of the Philippines and Malaysia, where caries levels are 'moderate' (DMFT: 9.0 to 13.9).

In Vietnam, Mainland China and India the number of missing teeth in seniors is relatively low, with the people of Malaysia and the Philippines suffering from severe tooth loss. With rates below 10%, edentulism in seniors is low in India, Mainland China and Thailand. The bulk of countries facing complete tooth loss ranged from 16% to almost 40%. The situation, again, is most severe in Malaysia and the Philippines.

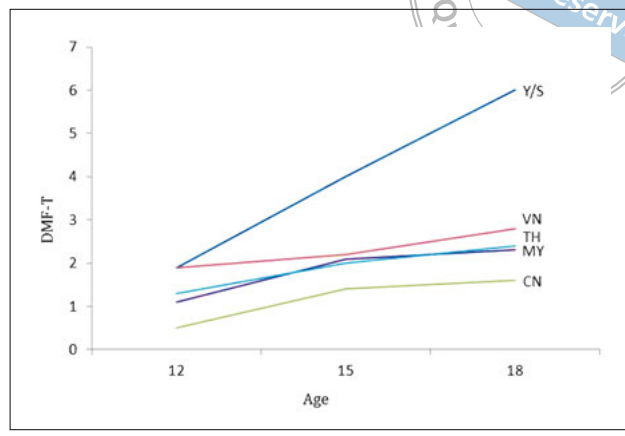

Fig 1 Caries development in the prognosis model of Yee/Sheiham (Y/S) vs the reality in Asian developing countries in 2010. Reference source: [10,12]

Additional longitudinal data from Indonesia, Sri Lanka and Malaysia show that caries trends in adolescents and adults have been on the decline for the past decade, while they remain rather stable in Vietnam[12].

For high income countries or regions

A comparison amongst the high income Asian states (Table 3) reveals that the populations of South Korea, Singapore and Hong Kong have a slightly more advanced dental status than Japanese citizens. However, compared with the worldwide benchmark country, Sweden, they rank lower. A more detailed country analysis shows that only Taiwan and South Korea are still short of the WHO goal for 2000 (caries-free 5 to 6 year olds ≥ 50%). The WHO goal for 12-year-olds is being attained by all high income Asian states. The two city states (Hong Kong China and Singapore) even exhibit 'very low' caries prevalence in adolescents (DMFT < 1.2), whereas Japan, South Korea and Taiwan China fall into the 'low' WHO category (DMFT: 1.2 to 2.6), indicating potential for improvement. Remarkably, the level of caries experience in adults (mean DMFT: 5.5 to 12.3) in all of the developed Asian countries is significantly lower than in many affluent Western European countries such as Denmark, France, Switzerland, the United Kingdom, the Netherlands and Finland (mean DMFT: 13.5 to 17.4)[1], where most caries levels must be classified as 'high' (DMFT ≥14). However, among seniors, relatively high figures in the area of missing teeth are found in Hong Kong China and Taiwan China and edentulism is comparatively elevated in Singapore.

Table 4 Ranking of Asian populations according to DHI and adults aged 35/44 according to their DMF-T and FS-T, independent of the development status.

Country	DHI Rank	DMF-T	DMF-T Rank	FS-T$	FS-T Rank
CN	1	3.9	2	24.4	4
KR	2	5.5	5	26.5	1
SG	3	7.4	9	25.9	3
IN	4	3.5	1	n.a.#	n.a.#
HK	5	6.9	7	23.4	9
TH	6	6.0	6	23.6	5
VN	7	4.7	4	23.6	7
JP	8	12.3	12	26.4	2
TW	9	7.3	8	> 23.5*	8
LK	10	8.4	10	20.1	10
ID	11	4.5	3	23.6	6
MY	12	10.7	11	n.a.#	n.a.#
PH	13	12.9	13	15.3	11

Note: $, FS-T, Base: 28 teeth; *, Estimation; #, n.a. = not available
Source: references [11,12] and Table 3.

At first glance, all DHI values from Asia's high income countries are worse than the DHI for China, the leader of our emerging country group. How can this phenomenon be explained? To solve this issue requires looking at the above-mentioned problem that occurs when the dental status of populations, measured by means of the DHI or by the DMFT index in relation to middle-aged adults, is applied to countries at differing stages of development. To illustrate this, the lower income countries and the high income Asian countries have been classified according to their DHI rank and their ranking according to the DMFT in adults aged 35 to 44 years old, keeping in mind that the DMFT index provides information on caries and treatment, and to a lesser extent on the health of a person's dentition[28]. These rankings were then compared with a country's ranking according to the FS-T index (Filled and Sound Teeth), which represents the number of functional (sound and restored) natural teeth. Table 4 indicates how a country's ranking changes with different underlying indices.

In most cases, classifying the ranking according to DHI or DMFT in adults aged 35 to 44 years old leads to similar results, which is not surprising because the DHI index also relies to a great extent on DMFT values. In both indices, Mainland China ranks very high and some lower income countries rank ahead of the high income regions of Japan and Taiwan. These results are hardly understandable because, in all lower income countries, treatment needs are often unmet (see the low Care Indices in Table 5) and therefore neither of the indices paint a realistic picture of the population's dental health when compared to high income countries, where the Care Index usually lies between 80% and over 90%. Consequently, when evaluating the oral health status of a population from countries at differing stages of development, it is necessary to use the FS-T index of middle-aged adults to make sure that curative treatment is valued positively and not negatively. When using this indicator, the high income countries of South Korea, Japan and Singapore rank first. Interestingly, in this ranking, Mainland China also does well coming in fourth, even before Hong Kong and Taiwan (Table 4).

However, as our approach focuses on the dental status of the entire population, the FS-T index of adults alone does not meet the foremost requirements, which is why, using the DHI index both socioeconomic country types must be analysed separately. Only in this way can comparable and realistic findings be attained that can ensure meaningful conclusions for both country types are found.

Possible advancements

The greatest potential for improvement exists in the area of caries freedom in deciduous teeth where values of

Table 5 DHI Rank, Care Index (F/D+F) x 100) for 35-44 year old Asians from different countries or regions, sugar intake/capita/yr, fluoride (F) exposure and existence of preventive programs in 2003 to 2012.

State level	State	DHI Rank	Care Index (in %)	Sugar intake/yr[1] (kg)	Fluoride exposure and preventive programs (% of population covered)
Lower middle income	IN	2	n.a.	20.5	F in ground water <1.0 mg/l: 85%; 1.0-1.5mg/l:7%. No systemic fluoridation because of strong opposition against fluorides; school dental programs in cities, non at village level; wide-reaching network of public health delivery system
	ID	5	0.05	24.3	F-toothpaste: 90%; School dental programs: toothbrushing with F-paste, fissure sealants
	PH	8	0.06	24.0	30% (pupils only); program for pre-schoolers and school program since 2005; tooth brushing is main means of controlling caries;
	LK	6	14	33.9	F in ground water (1 mg/l): 15%; school dental clinics for 3-13 yr olds at regional level
	VN	4	11	15.2	Water fluoridation: 30%; F-tooth paste: 90%; 50% of pupils get regular dental care at school: dental education, fluoride mouth rinsing, tooth brushing, clinical examinations, fissure sealants; pilot program for salt fluoridation
Upper middle income	CN	1	19	11.7	F- tooth paste: 30-40%; topical F-application for pre-schoolers, fissure sealing for school-agers in some Central and Western regions
	MY	7	n.a.	51.8	Water fluoridation (0.5 ppm): 78%; F- tooth paste: 90%; widespread comprehensive school dental service, mobile dental clinics, fissure sealants, oral goals (2020) for 6 to 16 yr olds
	TH	3	47	41.2	F- tooth paste: 95%; periodontal examination for pregnant women; care for pre-schoolers: tooth brushing, dental check-ups, school health surveillance, fluoridated milk for 4-12 yr olds
High income	JP	4	92	17.2	F-toothpaste: 95%; School health system: topical F-application: 1-14 yr olds: 38%; annual examinations, fluoride mouth rinse in most schools
	HK	1	80	24.9	Water fluoridation (0.5 ppm):100%; School dental service: regular check-ups, dental education, preventive treatment, fissure sealants
	SG	3	84	55.5	Water fluoridation (0.5 ppm): 100 %; 185 school dental clinics: free preventive and curative care, health promotion and education; topical F-application and fissure sealants; 25 mobile dental clinics for secondary schools; caries risk screening for primary pupils
	KR	2	85	24.4	Water fluoridation: 6.4%; F- tooth paste: 90%: at school: tooth brushing, regular examinations, dental education, fluoride mouth rinsing, topical F-application for pupils < 14 yrs with high risk, fissure sealants for molars, school dental unit chair in primary schools
	TW	5	57	26.0	Topical F-application (preschoolers): 33%; F-mouth-wash (pupils): 98%; fissure sealants for high risk pupils

Note: 1, WHO guideline for children and adults: yearly intake of free sugars: < 10-15 kg/capita
References source: [11,12,20,29-31]

over 50% should be targeted. In this regard, the best rates (about 80%) worldwide are found in affluent countries such as Sweden and Denmark. In Asia, countries or regions like Japan, Singapore and Hong Kong prove that the levels of caries freedom in deciduous teeth between 50% and 60% are realistic. Except for Filipino adolescents, caries prevalence in 12-year-olds leaves only minor room for progress. Despite high caries prevalence and severity in deciduous teeth, with almost no treatment of it in the emerging countries, the prevalence of dental decay in permanent teeth falls nevertheless and is either in the 'very low' or 'low' severity category. The

programs designed to enhance the oral health of preschoolers and school children are successful in most of the emerging countries, while programs for toddlers are rare (Table 5). It is only in the Philippines that there is a general lack of programmes initiated by public health bodies[12]. Literature on preventive dental care and on the efficacy of public dental programs in Sri Lanka is also very sparse.

Given the low caries burden among adults in most of the emerging countries, again with the exception of Malaysia, the Philippines and Sri Lanka, a further decrease in DMFT values cannot be expected. On the contrary, as these countries climb the socioeconomic ladder, dental services and access to dental facilities will improve, with the consequence that the F-component of the DMFT index will increase. This fact can be observed by comparing the Care Index of 35/44 year olds from lower income and high income Asian countries (Table 5). The Care Index for adults is significantly higher in the more affluent Asian countries, which means that the F-T component in these countries is much more distinct, for example, the Chinese Mainland DMFT level of 3.9 is lower than the DMFT levels for Hong Kong (6.9) and Taiwan (7.3). The same is true when we compare the DF-T values in the high income state of Singapore (6.3) with those of its lower income neighbour Malaysia (4.3) (see Tables 3 and 6).

In the affluent Swedish population, the DF-T value for middle-aged adults (8.9)[9] lies significantly above those of the high income Asian countries or regions of South Korea (4.7), Hong Kong (3.5) and Singapore (6.3). Although the Swedish DF-T value also includes initial lesions[9], the Swedish Care Index of 81% is clearly lower than that of Japan (92%) and is at the same level as Hong Kong, South Korea and Singapore. This means that many lesions have been treated non-invasively, indicating the strong preventive treatment approach that is practised in all Swedish age brackets. The very high Care Index in Japan might indicate over-treatment and suggests room for improvement in the area of prevention.

A substantial amount of potential for improvement lies in reducing tooth loss in adults above the age of 35 and in diminishing edentulism in seniors. This is particularly urgent in the Philippines and Malaysia, where tooth loss in adults is already extremely frequent (Table 6) and continues into an advanced age. In these two countries, tooth loss in the elderly is severe – a condition that seriously impairs oral functioning and chewing ability.

In the other countries, apart from China, the yearly increment in tooth loss, between the age brackets of 35 to 44 and 65 to 74, is also fairly high (0.34 M-T to 0.47 M-T) and needs to be addressed. As this process will

Table 6 Missing teeth (M-T) and the annual increase in tooth loss among adults from different Asian countries in 2013, using Sweden as the world benchmark.

level status	Country or region	M-T in adult age brackets		Δ M-T /yr
		35/44	65/74	
Lower middle income	IN	n.a.	10.9[5]	n.a.
	ID	2.9	17.0[2]	0.47
	PH	9.6	21.0	0.38
	LK	4.9	15.2	0.34
	VN	2.1	6.6[1]	0.45
Upper middle income	CN	2.3	9.6	0.24
	MY	6.4	22.1	0.52
	TH	3.7	13.9[2]	0.34
High income	JP	0.7	9.1	0.28
	HK	3.4	12.7	0.31
	SG	1.1	8.8[3]	0.26
	KR	0.8	5.8[4]	0.17
	TW	3.4	13.7	0.34
Benchmark	SE	0.8	5.5	0.16

Note: 1, 45+; 2, 65+; 3, 55+; 4, 60+; 5, Manipal, South India.
References source: [9,11,12,20], own calculations.

occur over generations, as tooth loss at a young age cannot be reversed at an advanced age, health authorities should start as early as possible to create a framework in which it is easier for individuals to avoid tooth loss. The Swedish and South Korean data show that good results can be achieved by providing a relevant framework.

Despite an overall low level of caries burden in the emerging Asian countries under review, a high proportion of households could face catastrophic dental health expenditure (CDHE), whether this is the case can be understoood from Table 7.

Between 7% and 14% of households with dental expenses of greater then 0 in these Asian countries were affected. Although these rates are relevant, they fall well below the extreme rates of 25% to 35% found in some developing states of Africa, Eastern Europe and South America[5]. Table 7 also illustrates that neither a country's development stage or its DHI have an influence on the number of households negatively affected by CDHE.

In Asia's high income countries or regions, the populations of the three tiger states of South Korea, Singapore and Hong Kong lead the ranking, ahead of Japan and Taiwan. Only Sweden performs better (Table 3). One might have expected Japan to lead the ranking, given that it has had well-developed social insurance and a sophisticated oral delivery system for a long time. The three tiger states were able to create proper oral systems and a well-functioning oral care infrastructure with the aid of corresponding health policies, within a very short time period[32-34].

Although China's DHI is better than that of the high income Asian states, it can be assumed that the populations of the latter countries can boast a better dental status. As already mentioned above, in China, unlike in the high income countries, oral diseases predominantly remain untreated, which is why the FS-T index must be adhered too. Table 8 illustrates this for seniors as well. The ranking levels in both age brackets are widely in accordance. Remarkably, middle-aged Mainland Chinese individuals have more functional teeth than Hong Kong and Taiwanese subjects. Mainland Chinese seniors have 2.5 more functional teeth than in Hong Kong. As this study refers exclusively to natural dentition, it ignores prosthodontic provision, which is particularly important in seniors when less than 20 functional teeth are present, therefore chewing ability is affected. Despite the lack of representative data on prosthetic restoration in patients, there is evidence that seniors in Hong Kong have their missing teeth replaced more often (Table 8). Overall, this indicates that dental status and dental provision in Hong Kong is more elevated than in Mainland China.

Table 7 Context between Country Status, DHI and CDHE in % of those countries with Dental Health Expenditure (DHE) > 0 in the period 2003 to 2012.

Country status	Country	DHI	CDHE (%)
Lower middle income	IN	3.94	8.7
	VN	4.64	14.2
	PH	9.80	11.9
Upper middle income	CN	3.34	13.3
	MY	6.64	7.2

Reference source: [5]

Discussion

Cross-national research depends on the accuracy of health outcome data and comparable survey time points. For many countries, current surveys existed. If this was not the case, the closest available survey data were chosen. Only for a few cases did figures have to be estimat-

Table 8 Adult dental status ranking in high income Asian countries or regions according to FS-T index and prosthodontic status in comparison with Mainland China.

Country or region	FS-T 35/44	Rank	FS-T 65/74	Rank	Replaced teeth (%) in 65/74 yr olds
JP	26.4	2	17.9	3	68.9
HK	23.4	6	13.0	6	63.2
SG	25.9	3	18.3	2	N.a.
KR	26.5	1	21.5	1	57.5#
TW	>23.5	5	16.8	4	50.7*
CN	24.4	4	15.5	5	30.6$

Note: $, Mean value for 60-69 and ≥ 70; *, 40-64 year olds; #, Elderly using social welfare centres
References source: [11,21,35-38], own calculations

ed. Caution needs to be exercised regarding the validity of the survey data for India – a vast country with widely differing living conditions and over 70% of the population living in rural areas. The pooled data, originating from only seven Indian states out of 29 and exhibiting wide variation[39], might not withstand close scrutiny. These aforementioned limitations often occur in transnational, cross-sectional studies. The author believes that the datasets are reliable and draw a realistic picture of the population's current oral health status in emerging and high income Asian countries or regions.

The main result of this study is that, even with rising standards of living or regardless of a country's development stage, caries levels, caries severity and lesion progression are relatively low in most of the investigated Asian countries or regions and certainly not as rampant, as was the case in many European countries 60 years ago or, as conventional wisdom would suggest, owing to the lack of treatment of oral disease in the emerging countries. Therefore, the hypothesis that when countries climb the socioeconomic ladder of development, caries increases and, if the disease remains untreated, the process inevitably progresses and finally leads to edentulousness, cannot be confirmed for most of the investigated developing countries. These findings are unexpected, but do not contradict current cariology, as the caries process does not progress continuously but can arrest and stagnate or be self-limited and, in addition, the pathological factors causing caries might be too weak to keep the caries process running[26,40,41]. This means that, in these countries, the prospects for a preventive dental approach for the whole population should be particularly favourable. Such a strategy could be achieved with comparatively fewer resources than would be required by a restorative approach[25,42]. The form that such a preventive dental system in a developing country could take has recently been described for China[43].

When trying to determine why some countries perform better than others, China's leading position among the emerging countries is surprising owing to the high level of accumulated treatment needs, extremely poor attitudes to oral health, the lack of knowledge and the inauspicious oral hygiene habits (even among dental students), the lack of dental delivery structures in rural areas as well as the paucity of public financing[44-49]. One explanation might be that levels of dental decay are particularly low and occur in the early stages[20,50], and lesion progression in Chinese adults and the elderly is rather slow. Otherwise, caries severity and tooth loss should be much higher than they are at present. Although gingival bleeding and calculus are widespread, periodontal breakdown is also low and does not cause major tooth loss[20]. In contrast to our presumption of slow lesion progression, Luan et al[51] found remarkable levels of lesion progression between 1984 and 1994 and a significant increase in new lesions with age.

This raises the question of why, given noteworthy lesion progression which mostly remains untreated, Chinese subjects still face a low caries increment, a low periodontal breakdown and a relatively minor increment in tooth loss/capita with age (0.24 M-T/year). In all other emerging Asian countries, yearly tooth loss is much more pronounced (between 0.38 and 0.52 M-T; Table 6).

As sugars are the key dietary aetiological cause of dental decay[52,53], the relationship between sugar intake/capita/year and DHI in China, India and the Philippines (the latter representing the country with the least favourable oral health conditions) is shown in Table 5. For evaluation purposes, the WHO threshold of 15 kg/capita/year has been used as epidemiological studies have found that reducing free sugars to < 15 kg/capita/year causes less dental decay compared with a sugar intake of >15 kg/capita/year[53]. With a current yearly sugar intake/capita of 11.7 kg, 20.5 kg and 24.0 kg, respectively, dental health status in China is comparatively higher than in India and much more so than in the Philippines, confirming the validity of the benchmark used in the evaluation.

The classical Chinese diet is considered to be healthy[54] and both the nutrition status and dietary habits have improved significantly over time. The Chinese diet has become more protein-rich[55] and the relatively high intake of sea food, which is rich in fluoride[56], helps to prevent dental decay[57]. Thus, the healthy and low cariogenic Chinese diet consisting of fruits, instead of sweet desserts, and fewer snacks in between meals[58], corresponds with the frequent intake of green tea, with its anti-cariogenic activity, to reduce the incidence and severity of caries[59] and to help inhibit periodontal disease[60-62]. These factors, taken together, seem to be the reason why China, under the current circumstances, performs fairly well.

Interestingly despite the high rank occupied by India, oral health awareness is widely lacking, dental structures are very rudimentary and oral health behaviour is poor[39]. Dental care is predominantly privatised and community programs are extremely rare. Although the dental workforce in India with 25,000 graduates each year from 289 dental schools (mostly private) is large, clinicians are concentrated in urban cities (75%) meaning that the vast majority of people in India do not have access to basic dental care[63] or fail to make use of it[64]. The Indian budg-

et allocates practically no money to the dental health sector. There is no organisational system for developing, monitoring and planning dental care structures. Studies on the dental status of adults living in the rural areas of India and their particular treatment needs, revealed that the 'decayed' component contributes to more than half of the DMFT score. In the majority of cases, one-surface fillings were needed and about 40% of the adults needed extractions[65,66]. Bearing these structures and conditions in mind, it comes as a surprise that the Indian population can boast such low caries levels.

In contrast to Chinese food, the typical Indian diet is rather cariogenic due to its richness in carbohydrates like white rice, potato and white bread combined with a high intake of sugar and sweet beverages. Although diets rich in starchy staple foods (cooked or uncooked) are of low cariogenicity, the addition of sugars and sweets to the diet increases cariogenicity[25,67], which is the case with Indian food. The consumption of sugar and sweets is intrinsic to the Indian way of life. Sugar is celebrated and the consumption of sweets marks every special occasion. Usually, after every meal, joyous occasion, religious feast or social gathering, Indians like to "sweeten their mouth"[68]. Consequently, Indians have a yearly sugar intake/capita of 20.5 kg, which is well above the WHO guideline of 15 kg. Furthermore, large parts of the Indian population prefer a vegetarian diet for religious reasons. This sort of diet is more cariogenic than mixed food[56,57], and is associated with greater tooth loss[69]. Due to these pathological factors, and the lack of counteracting protective factors, it is a mystery why the rate of caries lesion progression is so slow in India. Therefore, the relatively favourable dental health status of the Indian population remains implausible and has to be interpreted with caution, all the more so as some regional studies in rural areas reveal significantly higher DMFT values in adults and edentulousness rates in seniors[65,69,70].

The two emerging countries where individuals exhibit the lowest dental health status are the upper middle income country of Malaysia and the lower middle income country of the Philippines (Table 3). Although, over the last decade, Malaysia experienced a decline in caries in all age groups, the findings for the Malaysian population are characterised by a dichotomy - a lower level of caries prevalence in toddlers and adolescents but a comparatively high level of caries experience in middle-aged adults and seniors, particularly with respect to the M-component (Table 6). Within a period of 30 years, from middle age to becoming seniors, the yearly tooth loss in Malaysians reaches 0.52 M-T - the highest increment in all of the Asian countries under comparison. The reason for this contradiction is not easy to explain. The unfavourable dietary habits of Malaysians, who consume four times more than the amount of free sugars per year recommended by the WHO, applies to children as well as to grown-ups. On the other hand, the protective feature of water fluoridation, which covers 78% of the population, partly neutralises this pathological factor. In combination with widespread school dental services and sealant programs for school children who are at risk, these two protective factors seem to produce a low caries lesion progression in the younger generation, whereas adults, who do not benefit from special programs, face stronger caries lesion progression that often ends in tooth loss.

The Malaysian government sets goals for the oral health of children and puts considerable emphasis on oral health for preschool and school children. It has also incorporated the philosophy of prevention, minimal intervention and minimally invasive treatment in the curricula of all 15 dental schools[71]. Oral health for adults, on the other hand, is widely privatised. No national health insurance scheme exists and adults have to pay the clinician's bill out of pocket[72], presumably with the consequence of deteriorating oral health in adulthood (Tables 3 and 6).

However, it is the Filipino population that possesses the worst dental status. Children's dental health is poor and the prevalence of caries, measured according to Asian standards, is high in all adult age groups. Practically no treatment takes place (Table 5). The result is an extremely high extraction rate in adults as young as 35 to 44 years of age (M-T: 9.6). There are multiple reasons for this unfavourable situation. Apart from fluoridation measures for children, no further public programs existed until 2005 when a few programs for preschool and school children were started. Owing to the lack of oral health awareness as well as a lack of money, 78% of adult Filipinos have never seen a clinician[73]. The national Philippines Health System (PhilHealth) covers no dental benefits, with the exception of extractions and dental check-ups if provided by public facilities, which are very rare. The majority of the dental sector is privatised and requires out-of-pocket payments[74]. Given this wretched oral health situation, the government began to take action in 2005 and also developed programs targeted at adult groups[75]. As this study includes the latest Philippine survey findings from 2011, it has not been possible as of yet to detect any positive effects as a result of these programs. Furthermore, the high sugar intake/capita/year (24.0 kg) proves there is a correlation between high sugar intake and elevated dental decay.

Table 9 Comparison of factors influencing adult dental status in Asian high income countries or regions around 2010 to 2013 using Sweden as a world benchmark.

State	Oral health habits (% of people)		Sugar consumed (kg), snacking and smoking habits (% of people)			Health insurance covering dental care?		Policy concern[8]	Total dental costs as % of GDP
	Daily tooth brushing ≥ 2 times	Regular dental visits	Sugar intake/year	Snacks intake between meals ≥ 1-2	Smoker[7]	yes/no	private financing[5] (%)		
JP	58	53	17.2	Few	23.5	yes	24	Yes	0.53
HK	72	40	24.9	71.4	13.0	No[1]	83	Yes	0.21
SG	82	41	55.5	N.a.	16.5	No[2]	> 69	Yes	0.23
KR	85	53	24.4	47.6	28.0	Yes[3]	> 32	Yes	0.52
TW	77	41	26.0	Few, rising	18.7	Yes[4]	> 36[6]	Yes	0.64
SE	85	85	36.9	23	22.5	Yes	60	Yes	0.67

Note: 1, Except for schoolchildren and emergency service; 2, Except for children up to age 18 and subsidies for low earners and the needy; 3, Fillings and prosthodontics are excluded, except for dentures for over 75 yr olds; 4, Except orthodontics and prosthodontics; 5, Private insurance and out-of-pocket; 6, Out-of-pocket; 7, Mean of males and females; 8, Policy concern = Health policy includes oral health and corresponding preventive programs.
References source: [9,11,21,33,34,38,76-92]

The performance of the high income Asian countries or regions should be of special interest for the emerging Asian countries because best practice approaches could be replicated by them. In a recent study that compared the dental status in selected affluent Western countries, the Japanese population achieved a high ranking in oral health outcome and in the efficiency of its dental care sector[1]. Our study findings rank the level of dental health status in the populations of South Korea, Singapore and Hong Kong above the rank achieved by the Japanese and many affluent Western-European countries. In summary, the population of all five developed Asian countries or regions exhibit an advanced oral health status.

To explain these results, Table 9 lists a number of important factors, in addition to fluoride exposure (Table 5) that exert an influence on dental health status.

Sufficient fluoride exposure, covering 100% of the population in Singapore and Hong Kong (Table 5), favourable oral hygiene and dental care habits as well as a positive concern with respect to oral care in policy-making (setting of oral health goals and regular monitoring) characterise the oral care landscape in all five developed Asian countries or regions and build the foundation for beneficial oral health outcomes. The relatively high consumption of free sugars in Japan and the tiger states or regions, particularly in Singapore, Hong Kong and South Korea, combined with frequent snacking between meals and high smoking rates in South Korea and Japan, might largely be neutralised by the previously mentioned factors. As the Swedish and Singaporean examples prove, even an extraordinarily high intake of free sugars hardly has a negative effect on dental health, as long as good self-care practices are carried out. These findings are in line with the findings of Masood et al[52], who ascertained that per capita sugar consumption in high income countries is negatively related to caries prevalence. Only in low income countries do caries rates rise with increasing per capita sugar intake owing to a lack of access to fluoride, the paucity of oral health awareness and oral health habits as well as the absence of dental structures.

However, as the Swedish figures show, significant additional improvements are possible in the younger generation in Taiwan and South Korea and in seniors from Taiwan and Hong Kong, who exhibit relatively high numbers of missing teeth. Moreover, especially in the case of Singapore, the elevated rate of edentulism should be tackled. Table 9 shows where new measures need to be taken. There is room for improvement in Japan, Hong Kong and Taiwan with regard to oral self-care procedures, including the regular use of interdental brushes and dental floss by adults. Incentives for increasing regular dental attendance rates should be introduced (e.g. by a voucher or bonus scheme, which exists in Sweden or Germany). The reduction of sugar

intake and snacking between meals is of minor importance, as long as fluoride exposure, oral hygiene and oral care habits are adequate although, from the perspective of a "Common Risk Factor Approach", which is particularly recommendable for developing countries, the reduction of sugar consumption would be beneficial in any case. As smoking is a risk factor for periodontitis, tooth loss and edentulism[93], the percentage of regular smokers should be brought down, particularly in South Korea and Japan. The current 'gold standard' of 10% to 13% daily smokers, held by California and Utah/USA[94,95], could function as an achievable and realistic benchmark, as indicated by Hong Kong and Singapore.

Whether oral health is included in the health care system is of pivotal importance for the younger generation up to the age of 18 or 20 as dental health in adulthood can only be maintained if the necessary foundations have been laid out in childhood and are practised by everyone. As our study shows for developed Asian countries or regions, and as proven by a previous study in affluent Western countries, good dental status in adults can be achieved in any health system, irrespective of the funding structures used in providing dental care (national health model, social insurance model, private insurance model or a mixed model)[1]. As is the case in the high income Asian countries or regions and also in the world's most advanced dental care systems, with exceptions being made for the needy, corresponding out-of-pocket payments for adults are considered indispensable, in order to avoid moral hazards.

With regard to the younger generation, a positive policy concern exists in all five of the developed Asian countries or regions. To further improve the status of the whole population, health policy could expand its preventive and tooth preserving treatment approach into adulthood (either by law or indirectly by incentives) and ensure regular scientific supervision, as was carried out in an exemplary manner in Hong Kong's 2011 Oral Health Survey[21]. As a means of keeping the necessary financial resources reduced, a risk-oriented component should also be implemented by directing preventive strategies towards known high-risk subpopulations or groups.

The significantly lower caries level, as well as the slow rate of lesion progression, also seen in high income Asian countries or regions in contrast to many Western-European countries, seems to be due to the healthy and low cariogenic Asian diet that is normally consumed by Japanese, Chinese, Korean and Singaporean nationals. Although, in all of these countries, Western food is on the rise, Asian populations generally tend to prefer typical Asian food[96], which is a low-fat diet, rich in fish, lean protein, vegetables, fresh fruit, beans, legumes, nuts and vegetable oil, and contains only a small proportion of processed food with its high content of trans fats[97].

In summary, the assumed high caries burden in some Asian regions, measured in DALYs, cannot be confirmed for the countries or regions under investigation. In most countries or regions, the caries level, measured by DHI, is relatively low, in the early stages, and lesion progression is slow. Only in Malaysia and the Philippines are caries severity stages significantly higher and lead to pronounced edentulism rates at adult and senior age, which signals an absent or failed dental care system.

Furthermore, with rates ranging from 7% to 14%, the number of households affected by CDHE in emerging Asian countries is indeed sizeable but is not as elevated as in other parts of the developing world.

Given the existing economic constraints, the best method for controlling oral diseases in emerging countries with a low level of caries and a slow rate of progression, might be improved oral hygiene practices[98], supported by the frequent use of sugar-free chewing gum and, if possible, combined with some form of fluoride exposure, at least among the younger generation. The lack of dental services in these countries could be diminished by the introduction of dental therapists trained in preventive procedures. As the treatment needs in these countries mainly concentrate on one- or two-surface fillings and extractions, the existing dental facilities should deliver minimal intervention dental care and minimally-invasive filling techniques including Atraumatic Restorative Treatment (ART)[41,99]. The Basic Package of Oral Care (BPOC) has been specially developed for such countries[100].

Among those that perform rather well are the high income Asian countries or regions, whereby the city regions of Hong Kong and Singapore, due to the unique conditions they enjoy, achieve a very high efficiency within their dental care systems, as they only utilise one-third of the resources expended by Sweden and Taiwan and less than half of that expended by South Korea and Japan (Table 9). They also demonstrate that, with a rising standard of living and changing lifestyles, dental status should not deteriorate in the presence of good self-care and well-functioning dental care systems. Although they perform more favourably when compared with many wealthy Western-European nations, they are unable to achieve Sweden's outstanding level of performance. If the populations of the affluent Asian countries were to receive incentives to further improve their oral hygiene practices and oral care

habits, they might succeed in meeting the Swedish outcomes in terms of dental health. It is important to note, both in the Asian states as well as in Sweden, many preventive measures are efficiently being provided by well-trained dental therapists.

Conclusion

Even though some of the high income countries or regions offer unique possibilities that can only be replicated with difficulty by emerging countries, they exemplify those measures and care facilities that are successful in lifting the level of a population's dental status, in times of rising standards of living and increasing urbanisation.

Given the low caries and severity levels that were obtained in emerging as well as in developed Asian countries or regions, a strictly preventive dental approach that emphasises a population-centred or group-centred, risk-oriented strategy, is very promising. As improved dental care facilities are needed in any event, it is beneficial to start directly with preventive care facilities. Thus, such systems which already exist for children in a rudimentary form in some of the emerging countries, should be extended to cover the entire younger generation up to the age of 18. Later on, should it prove affordable, these systems can be expanded, step-by-step, into the adult age brackets. As a means of lowering the catastrophic dental cost burden among parts of the population in emerging countries, the creation of a safety net for those who are really needy is urgent and vital.

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Conflicts of interest

The author reported no conflicts of interest related to this study.

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