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High prevalence of dental caries in Inuit populations: duality of the "distance effect".

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Abstract

Dental caries are considered the third most prevalent disease in the world. In North America, Inuit populations are most severely affected by dental caries. It is assumed that this postulation can be explained by a combination of factors such as remoteness (geographical distance), low economic status, and low health literacy (cultural distance) which are being shared by multiple Indigenous populations across the world. We tested the validity of this hypothesis of "distance effect" by exploring the caries prevalence in other Indigenous populations living in high-income countries using a bibliographic approach. Furthermore, we also tested whether the high prevalence of caries is due to population-specific characteristics by tracking caries prevalence over the past few centuries. Our results have shown that all Indigenous populations are in particular more impacted by caries than the general populations. Moreover, the Inuit populations present the highest prevalence among all Indigenous populations of the world, and the result showed paradoxically that past Inuit populations were almost immune to caries before 1950. These two elements suggest that the prevalence of caries observed presently is a recent maladaptation that is beyond the effect of cultural and geographical distance, and there is a need for specific bicultural factors to be investigated.

Introduction

Dental caries are considered the third most common disease in the world by the WHO (1)**.** It is quite possibly the most widespread illness and most people are impacted somewhere around once in the course of their life (2). It is characterized by the softening of the hard tissues of the tooth which may evolve into a cavity due to the production of acids by bacteria in contact with sugars (3). These cavities are painful and have important impacts on overall health by altering eating, attention, sleep, mood, and social relationships. Most importantly, if left untreated, dental caries can lead to death from sepsis (4, 5) but these are often neglected and underestimated. Therefore, dental caries is a critical global health issue, especially in areas where dental care is not readily available, such as in circumpolar areas (6, 7).

In North America, Inuit populations are more severely affected by dental caries than the rest of the population. In Canada and the United States (6–9), for example, the prevalence of caries in Inuit children aged 3 to 5 is estimated at 85.3% in the Nunavut region (6). Because Inuit children are affected by dental caries from an early age, their treatment often requires general anaesthesia increasing the concern for oral care (10,11). Also due to their geographic location, the high level of dental caries poses significant challenges for Canada and the United States (10). It is therefore particularly important to identify why circumpolar populations present a higher prevalence of dental caries than the rest of the populations.

Since the causes of caries are considered universal, only a few studies have focused on the specific risk factors of Inuit populations. However, the risk factor for caries depends greatly on the way of life. For example, in the populations of European ancestry, dental caries were moderately frequent for a few thousand years until the prevalence increased considerably after the industrial revolution and the abundant consumption of industrial sugars (5,12). Very recently, the severity of dental caries has decreased in these populations due to considerable efforts in prevention (13–15). In circumpolar regions, the evolution of caries prevalence is not as well known. But it has been assumed that the high prevalence of caries is due to the fact the prevention effort might have been less efficient due to geographic and cultural distances. Indeed, it is documented that populations living in areas geographically distant from the health system and/or with low health literacy and/or low economic status are particularly prone to poor health conditions (16–18). Such populations are also more affected by caries than the rest of the population of the countries where they live due to a cultural gap and a lack of impact of adapted prevention policies (19).

Therefore, one could hypothesize that circumpolar populations who have an original culture, a different language, and a lower income than the rest of the population could be subject to this 'distance effect'. We define the 'distance effect' as the consequences of geographical distance for a population on the carious risk and access to health care and especially dental care in our study. Other hypotheses can be proposed for instance that specific cultural or biological risk factors may play a role in the differences in caries prevalence between populations. For example, there is population variation in the salivary microbiome or tooth mineralization (20, 21). In Greenland, Inuit populations have larger molars, a higher frequency of shovel-shaped incisors, and a higher absence of the third molar and Carabelli tubercle than European populations (22).

In this article, we intended to explore these two hypotheses based on a bibliographic approach. Firstly, we hypothesized that if the "distance effect" explains the high caries prevalence in Inuit populations then we should find a similarly high prevalence in Indigenous populations now living in high-income countries (Australia, Canada, New Zealand, and the United States). Secondly, we hypothesized that if the high caries prevalence is due to population-specific characteristics, the high prevalence of caries might be ancient and could be observed by tracking the caries prevalence across the last centuries.

Methods

The severity of dental caries in Inuit populations and comparison with indigenous populations and general populations: the literature review of the oral health of indigenous populations.

We compared the severity of dental caries of Inuit populations with indigenous populations and general populations of four countries, Australia, Canada, New Zealand, and the United States. We focused on similar western industrialized and democratic countries where indigenous populations and European ancestry populations still cohabit in addition to similar developed medical research

We extracted DMFT indices of the general population of these countries from the World Health Organization's epidemiological database on dental caries (23). A DMFT index is the number of teeth decayed, missing, or filled in 12-year-old children and ranges from 0 to 28

(wisdom teeth are not counted). This index was chosen in this study because it is the most commonly used measure to compare the severity of dental caries in the world (24).

For the indigenous populations, we then performed a literature review (Figure 1) to collect epidemiological data on dental caries in Aboriginal populations in Australia, Inuit and First Nation populations in Canada, Alaskan Native and Native American populations in the United States, and Maori populations in New Zealand. On the PubMed bibliographic data search engine, we used the keywords "oral health", "dental caries/caries" and "tooth decay" associated with the keywords "Aboriginal" and "indigenous Australia" or "Maori" and "indigenous New Zealand" or "Alaskan native", "Inuit", "Native American" and "First Nation". We identified 1,955 publications from this research, which was reduced to 828 by removing the duplicated items.

From the 828 references obtained in the bibliographic research, 315 articles were selected based on the abstracts. To be selected, an article had to (i) concern indigenous populations, and (ii) concern oral health.

We chose to include only recent articles on the DMFT index of children aged 12 +/- 4 years to make the data comparable with the WHO dataset. Therefore, we limited our study to articles that (i) include a DMFT index, (ii) concern children between the ages of 8 and 16, and (iii) date between 1980 and 2018. Forty-seven (47) articles were finally included in the study.

Data were extracted from the 47 relevant articles and analyzed using R software and the ggplot library (25, 26). We applied the Student test to the results to compare the caries rate between the general population and the indigenous population for each country.

Evolution of prevalence of caries in Inuit populations: A historical literature review of oral health of Inuit populations

To focus on the oral health of Inuit populations, we studied the evolution of dental caries among these populations, taking the oldest records to the 21st century.

We conducted a historical literature review of dental caries in Inuit populations. In this historical literature review, we included the Arctic populations of Canada, called "Inuits"; of the United States, called "Alaskan Natives"; and of Greenland, called "Kalaallits".

We performed a bibliographic search on PubMed search engine and other sources with the keywords "oral health", "dental caries/caries" and "tooth decay" associated with the keywords "Alaskan native", "Eskimo", "Inuit" and "Greenland". Apart from that we also performed another search with the keywords "archeological", "prehistoric", and "mummies" associated with the keywords "Alaskan native", "Eskimo", "Inuit" and "Greenland" (Figure 2). We identified 280 publications from this research, which got reduced to 151 by removing the duplicated items.

Subsequently, 151 publications were identified, of which 100 articles were chosen. The criteria of the selection of articles were (i) concern Inuit populations, and (ii) concern teeth or oral health.

Finally, 56 articles were included based on different inclusion criteria. To be included, an article had (i) the prevalence or DMFT of caries, (ii) concerning French or English speaker adults, and (iii) being accessible.

We had data concerning the Inuit populations of Alaska in 25 articles, while for Canada and Greenland, it was 17 and 13 respectively. Only one article in the selection concerned all three regions. These data are distributed over time, like 8 articles before the 19th century, 15 articles in the 20th century, and 35 articles in the late 20th century and the 21st century.

We extracted the prevalence of dental caries in Inuit populations over time from the 56 relevant articles for analysis. The prevalence is the percentage of individuals with at least one cavity in a population found in 23 articles about the DMFT of dental caries.

Results

To better understand the severity of dental caries in Inuit populations, we compared their DMFT with other indigenous populations living in similar western and industrialized countries in which indigenous populations and general populations cohabit.

In all countries studied, we observed the same pattern with indigenous populations being more impacted. In Australia, Aboriginal populations presented a significantly higher DMFT than the general population of Australia (p-value <0.001), with 1.90 for Aboriginal populations versus 1.06 for the general population. Similarly, in New Zealand, Māori populations also presented a higher DMFT than the general population i.e. 1.86 compared to 1.28 for the general population (p-value >0.05). In Canada, the Inuit population had a

significantly higher DMFT e.g. 7.22, four times higher than that of the general population of Canada, which is 1.72 (p-value <0.001). First Nations also had a significantly higher DMFT (p-value <0.001), 5.36 for Natives versus 1.72 for the general population. Finally, in the United States, Alaskan Natives and Native Americans had a significantly higher DMFT of 3.21, nearly three times higher than that of the general population of the United States, which is 1.27 (p-value <0.001). For Native Americans alone, their DMFT is significantly higher than the general population (p-value <0.05), with 2.88 for Native Americans against 1.27 for the general population.

Globally, 87.21% of the studies showed that indigenous populations are more severely affected by dental caries than the general population (Figure 3). Since dental caries prevalence fluctuates according to time, we controlled this factor in a new analysis splitting the dataset into two sets: before and after the y. 2000. For studies published between 1980 and 1999: 91.52% of the studies reported that indigenous populations had higher rates of DMFT than the corresponding general populations. Similarly, in the 21st century, 84.96% of studies on indigenous populations also reported higher rates of DMFT (2000-2018). It is therefore unlikely that the observed difference is due to a temporal bias.
American Indians, Alaskan Natives, First Nations, and Inuits are the populations most severely affected by dental caries in industrialized countries (Figure 4). This difference is particularly striking for the indigenous populations of Canada. Inuits in Canada have a DMFT of 7.22, which is four times higher than the general Canadian population which has a DMFT of 2.5. Therefore, these Inuit populations have the worst DMFT index of all the populations compared. Based on the WHO dataset on all populations worldwide, Inuit populations are among the populations with the highest level of DMFT.

To understand the origin of this high severity of dental caries in these populations, we retraced the historical evolution of dental caries in Inuit populations based on a literature review of 56 articles with epidemiological data on Inuit populations from the archeologic period to the 21st century. In this present study, we named "Inuits" the Arctic populations of Canada; "Alaskan Natives" the Artic populations of the United States; and "Kalaallits" the Artic populations of Greenland. In 1977, the term "Inuit", which means "man" in the Inuit language, was adopted by the majority of Arctic populations during the creation of the Inuit

Circumpolar Conference, a group whose objective of obtaining greater autonomy and defending the interests of Arctic populations (27,28).

Of the 56 articles, 5 are archaeological reports describing the population living between 950 to 1900. All these archaeological reports show a prevalence of caries of less than 1%. For instance, Pedersen counted 5 cavities on the 526 skeletons of Kalaallits from Greenland and their 7606 teeth, dating from the 1700s (29). A study by Mayhall in 1970 reported 2 cavities on the 301 Inuit skeletons dating between 900 and 1650 (30). Gessain collected 15 skulls from the Ammassalik district in Greenland, dating before 1884. Gessain did not note cavities on the skulls (31).

Early epidemiological studies confirmed that Inuit populations were little affected by caries until the middle of the 20th century. Nine studies in Greenland and Alaska showed that Inuits have a prevalence of caries between 0 and 20%, from the beginning of the 19th century, until the 1930s (Figure 5; 29–37). In Greenland, a study conducted in 1934-1935 by Gessain (38) focused on the Kalaallits during this period of contact with the Danes. Among men, 7 individuals had caries out of 302, i.e. a prevalence of caries of 2.6. Among women, there are 17 individuals with caries out of 325, i.e. a prevalence of 5.2%. Before the contact with the Danes, in the same village of Angmagssalik, Poulsen had found no dental caries in 47 Kalaallits in 1898 (38).

From this point, this prevalence increased to exceed 50% until reaching 90 to 100% in the 1970s (Figure 5; 30, 31,39,40). Two longitudinal studies illustrated this increase in prevalence in the 1950s. In the United States, 90 Alaskan Natives of the Nunaminut community, previously free of caries, developed cavities within 8 years, between 1957 and 1965 (40). Between 1955 and 1957, the dft was 3 and the DMFT was 0.8, and the natives over 30 years of age had a prevalence of caries of 0%. From 1965 onwards, 8 years later, the dft was 5.6 and the DMFT index increased to 3.1 and the natives had a prevalence of 100% (40). In Canada, Mayhall reported an increase in the prevalence of caries between 1969 and 1973 in two Inuit communities in Igloolik and Hall Beach. In Igloolik, the prevalence of caries increased from 59.7% to 77.9% in only 4 years, while in Hall Beach, the prevalence increased from 43.1% to 64.2% (30).

In the late 20th century and the 21st century, 35 studies showed that the prevalence of caries in Inuit populations increased considerably, almost 90% (41), and from the end of the 20th century, Inuit populations had higher indices than the general populations of their country. In the 1980s, 97% of Inuits had cavities compared to 50% of Canadians (41). In the United States, a 1987 study found that the prevalence of caries among Alaskan natives aged 3 to 5 years was 44 to 85% compared to 5 to 11% for Americans (42). In the 21st century, in the United States, the Native Americans and the Alaskan Natives aged 3 to 5 had a DMFT three to four times higher than American children of European descent (7). In Greenland, the DMFS 15-year-old Kalaallit children were 9.2 in 2008, while it was only 2.3 for Danish children (9).

To summarize, Inuit populations were almost unaffected by cavities, until the first half of the 20th century. Alaskan natives had a DMFT close to 1 and a prevalence of caries of 0% for adults and Inuits in Canada had a DMFT of 2 and a prevalence of caries of less than 10%. In a few decades, starting in the second half of the 20th century, dental caries increased dramatically in these populations. In Alaska, the DMFT multiplied by 3 in 10 years and the prevalence of caries reached 100%. In Canada, the DMFT multiplied by 10 and the prevalence of caries is also close to 100%. In the middle of the 20th century, Inuit populations started interacting with Populations of European ancestry and a few years of contact were enough to drastically change the oral health of these populations.

Discussion – Conclusion

Our study has shown that indigenous populations living in Western countries are significantly more affected by caries than the general population of the same countries. Our original hypothesis aligns with this shared high prevalence of caries suggesting a common element that unites these populations. It is important to note that Aboriginal, Maori, Inuit, and Native American populations have very different genetic backgrounds, live in very different environments, and have very different histories and cultures. They are culturally and sometimes geographically distant from the general population of these countries. In each of these countries, the prevalence of the general population has recently decreased due to prevention efforts (15,23). Our study suggests that the remoteness of Inuit populations makes modern prevention strategies less effective and causes a high caries rate in Inuit populations.

Cultural and geographical remoteness lead to difficulties in implementing prevention policies (language barrier, traditional medicine, non-accepted prevention measures.) and in accessing care (rural areas difficult to access, population scattered over large territories, lack of health professionals, poor water supply). This distance being the major was proposed by us that based on work with Inuit communities and taking into account their way of life and culture, specifically adapted prevention strategies could be more effective. Importantly, we have shown that Inuit populations are more affected by caries than other indigenous populations in the study. It should be noted, like the Inuit populations, the First Nations are also highly affected by caries and the factors responsible for this disease may be related not only to the Canadian North American environment but also vital to ask whether there are biological characteristics specific to North American populations that may explain why these populations remain more affected by caries than other indigenous populations.

In this study, we showed that the prevalence of caries in this population has risen from 0 to 100% for those over their 30s in just 10 years (40). It should be noted that during this contact phase and contrary to today, it has been observed that the 'distance effect' (cultural and/or geographical) plays a protective role. Indeed, the more individuals or populations keep a traditional lifestyle and diet, the less they are affected by caries. It is therefore very likely that the high prevalence of caries is a maladaptation of the Inuit populations with this new diet. It is important to note that this phenomenon took place within a generation. Thus, the people who lived through this transition saw a very painful phase in which an unknown disease gradually affects all the individuals in the community, starting with the children with no or few traditional responses. This is very different from populations of European origin where the prevalence of caries has increased in stages since the adoption of agriculture in the Neolithic period. These results reinforce the importance of a specific approach for Inuit populations to combat caries.

Finally, these results suggest that, unlike other populations, there may not have been ancient biological or cultural adaptations of Inuit populations to caries. It would be interesting to study whether biological characteristics such as enamel thickness, bacterial flora, or dental morphology are more common predisposing factors in Inuit populations than in other North American populations. Understanding the biological and cultural predisposing factors would allow the implementation of patient-centered dentistry in Inuit populations and the adaptation of oral prevention policies in these populations

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Table 1 : Comparison and evolution of the risk factors for caries in Inuit populations protective factors (+) and harmful factors (-) in Inuit populations in the 21th century and in the 20th century, and in general populations

Protective factors (+) Harmful factors (-)	**General populations**	**Inuit populations in the 21th century**	**Inuit populations in the 20th century**
Diet	- (high-sugar diet)	- (high-sugar diet)	+ (high-protein diet)
Ritual dance		NA	-
Working with teeth (chewing animal skins, making bows)		NA	+
Fluoridation	+	+	+
Dental hygiene	+	+	+
Milk and fruit juice	-	+	+
Socio-economic level	+	+	-
European education	+	+	-
Cultural remoteness		-	+
Life in rural areas	-	-	+

Figure 1 : Prisma 2009 flow diagram for selecting studies on dental caries in indigenous populations in Australia, Canada, New Zealand and the United States

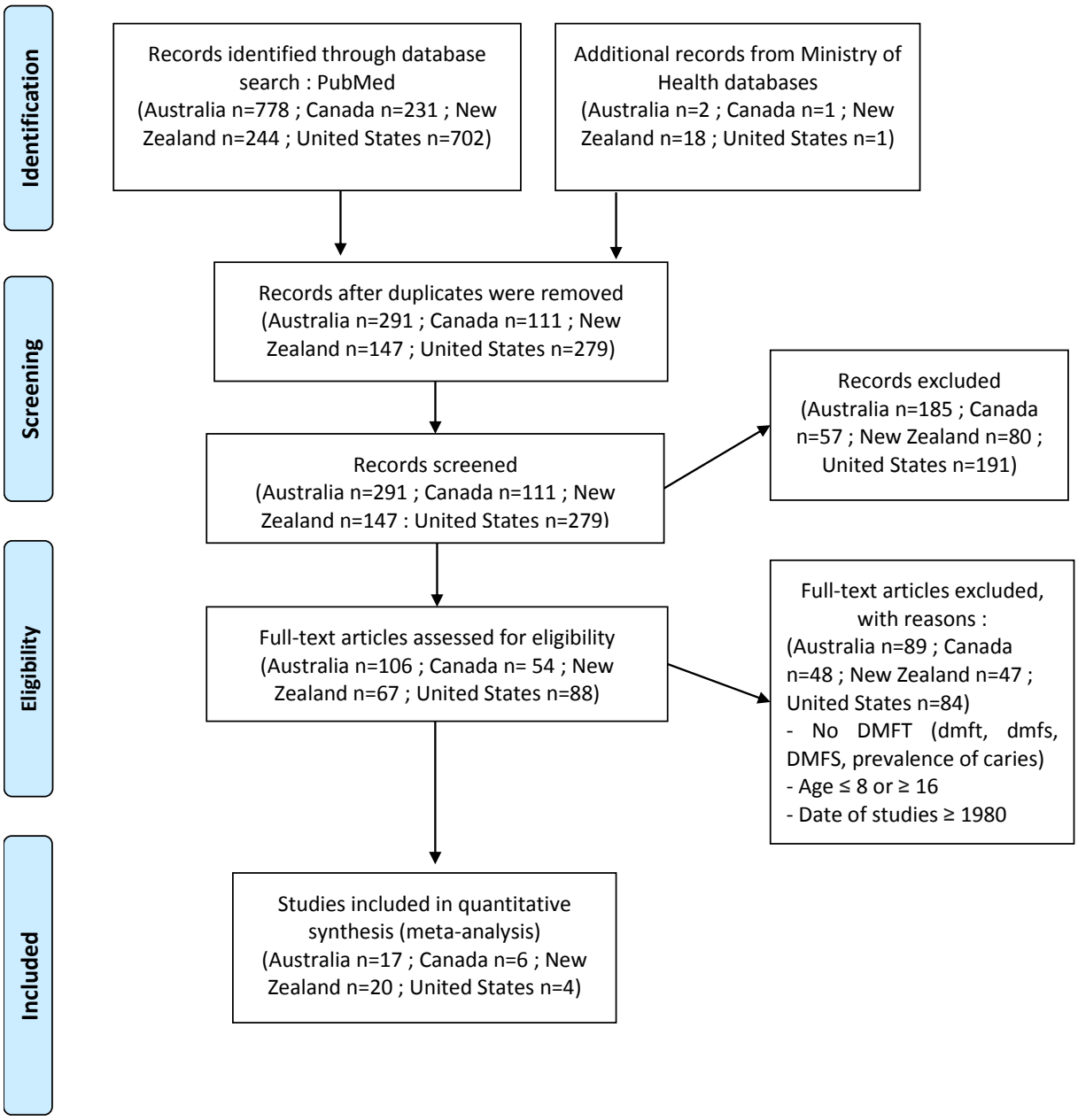

Figure 2 : Prisma 2009 flow diagram for selecting studies on dental caries in Inuit populations

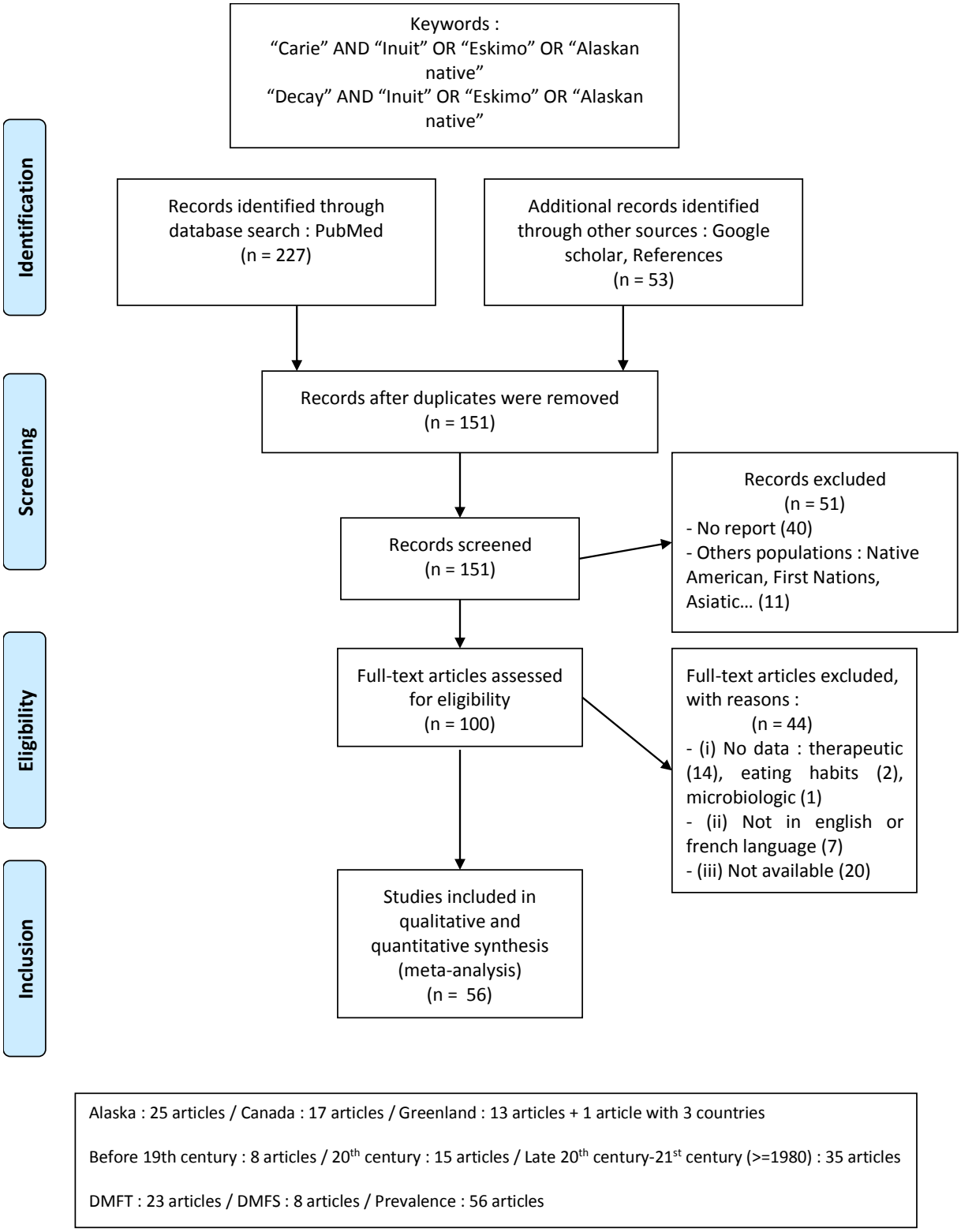

Figure 3a : Forest plot of DMFT (number of decayed, missing and failed teeth) in indigenous populations compared to the DMFT in the general populations (red line) of <u>Australia</u>, over two periods, between 1980 and 1999 and between 2000 and 2018, based on a systematic review of the literature.

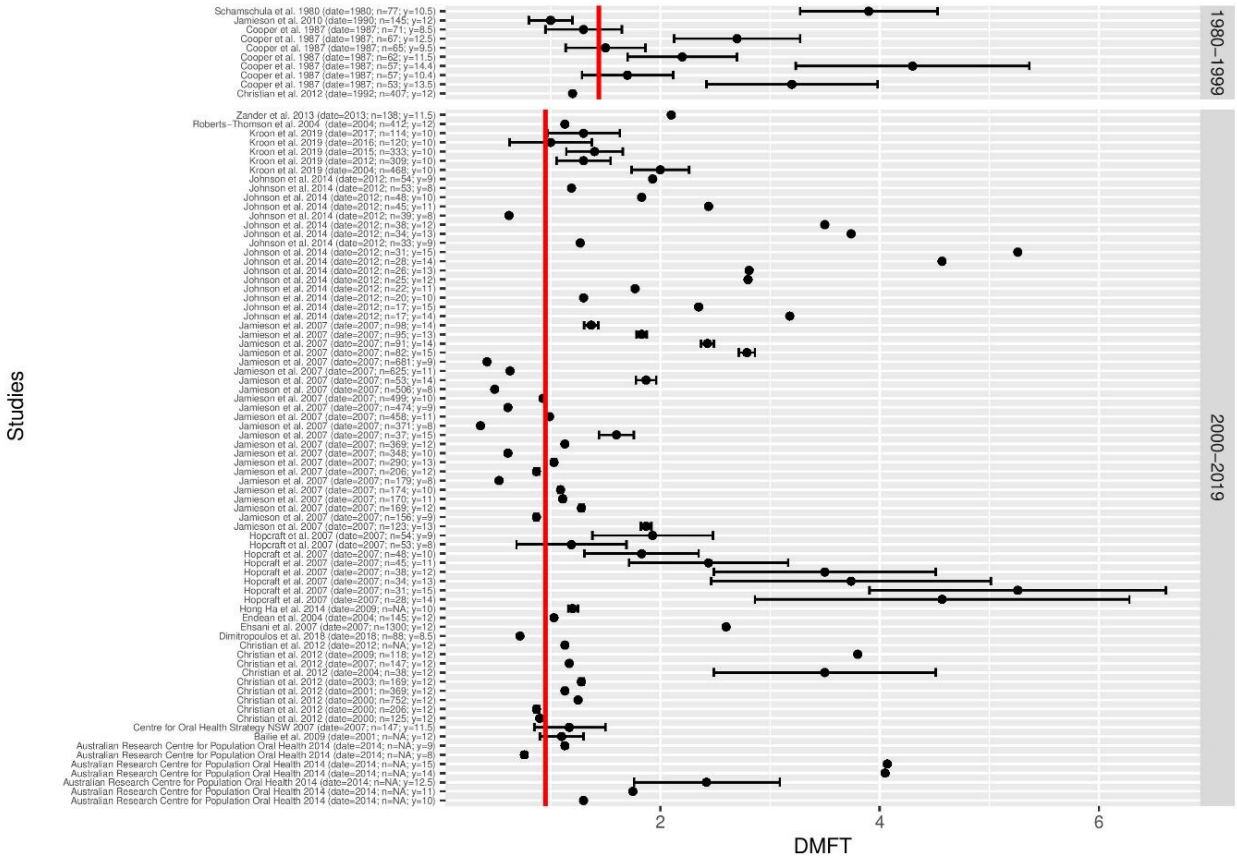

Figure 3b : Forest plot of DMFT (number of decayed, missing and failed teeth) in indigenous populations compared to the DMFT in the general populations (red line) of Canada, over two periods, between 1980 and 1999 and between 2000 and 2018, based on a systematic review of the literature.

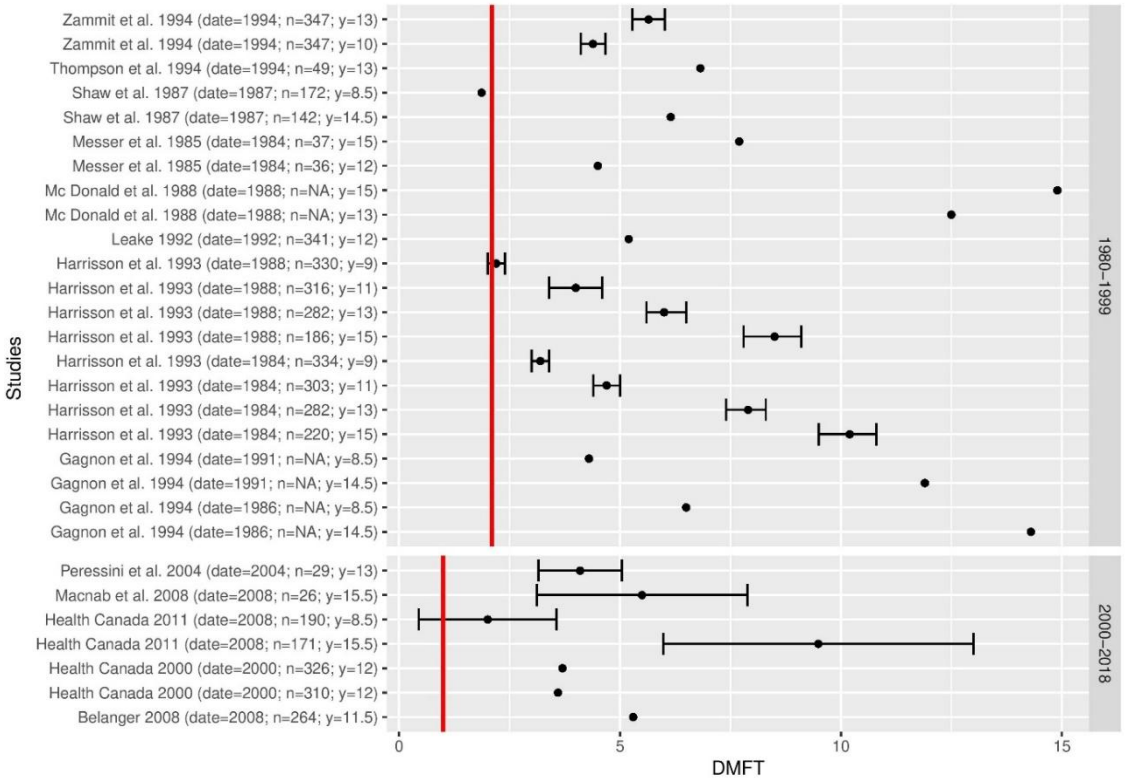

Figure 3c : Forest plot of DMFT (number of decayed, missing and failed teeth) in indigenous populations compared to the DMFT in the general populations (red line) of New Zealand, over two periods, between 1980 and 1999 and between 2000 and 2018, based on a systematic review of the literature.

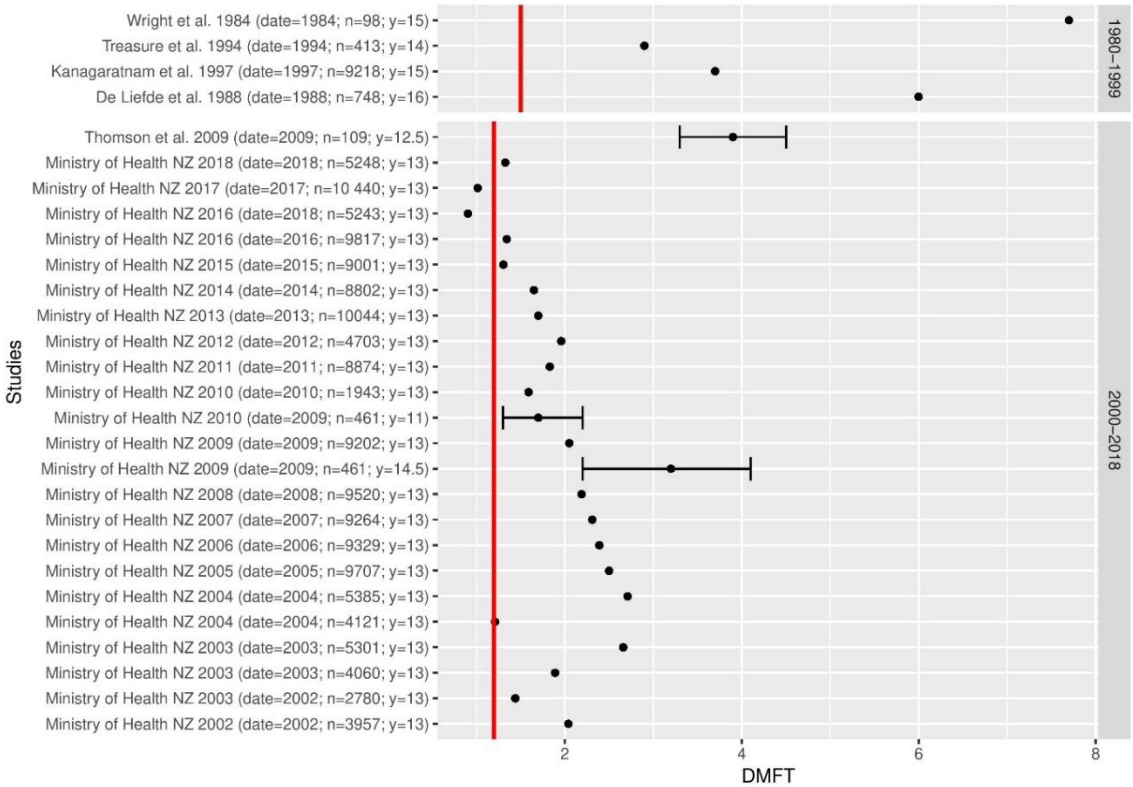

Figure 3d : Forest plot of DMFT (number of decayed, missing and failed teeth) in indigenous populations compared to the DMFT in the general populations (red line) of the United States, over two periods, between 1980 and 1999 and between 2000 and 2018, based on a systematic review of the literature.

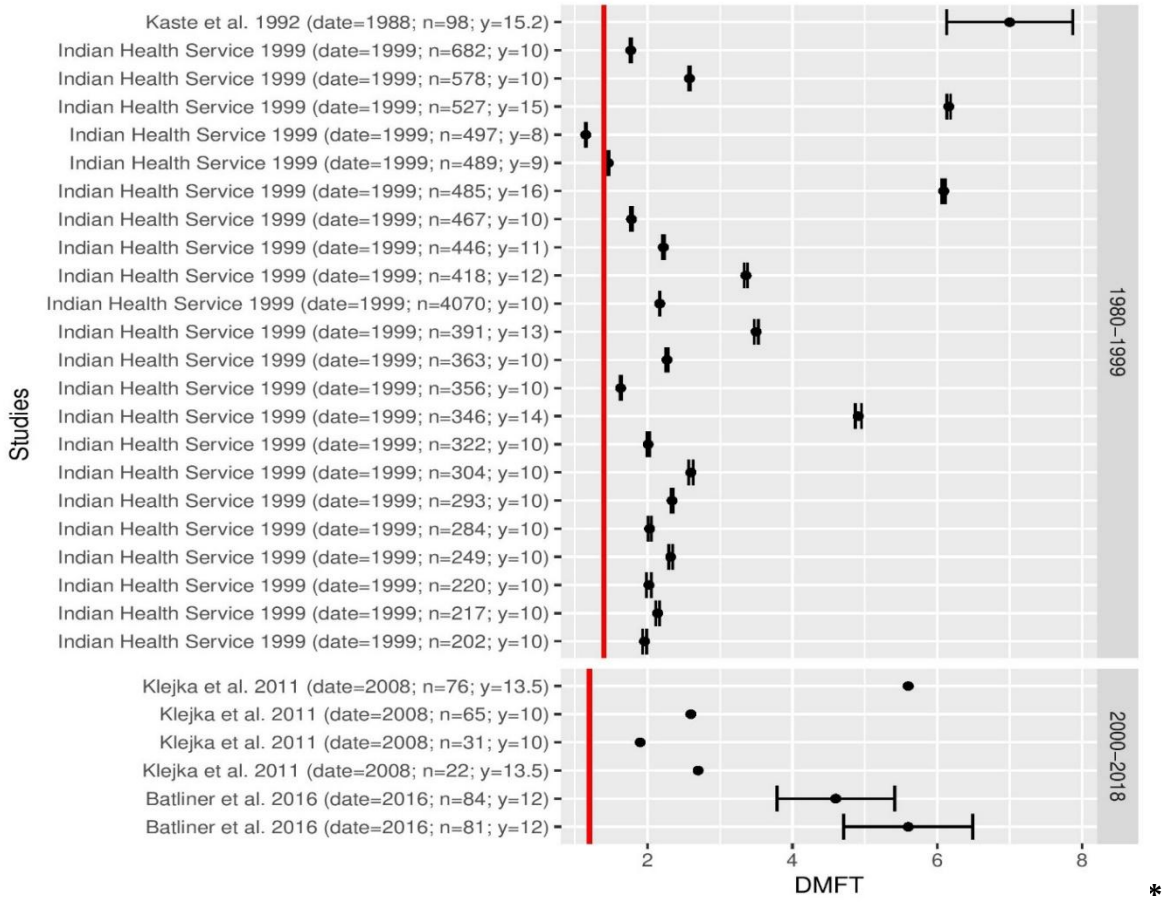

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Figure 4 : Box plot of DMFT (number of decayed, missing and failed teeth) in indigenous populations and the general populations of Australia Canada, New Zealand

and the United States between 1980 and 2018, based on a systematic review of the literature.

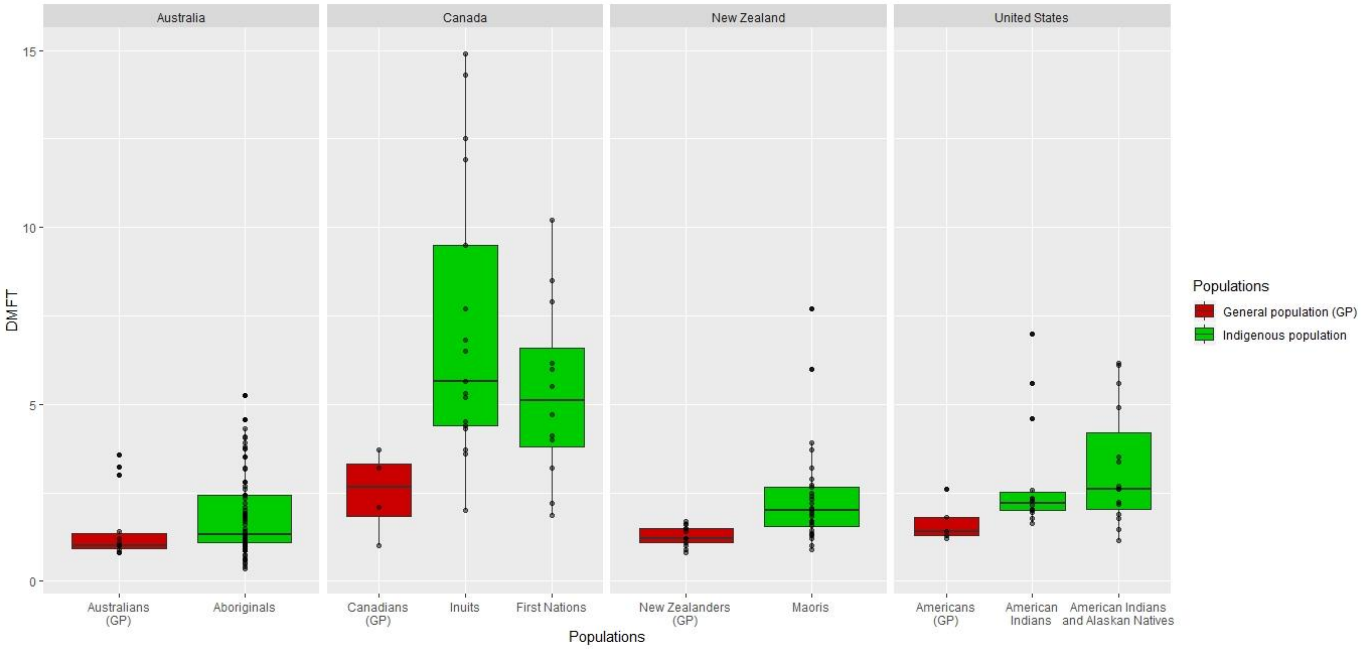
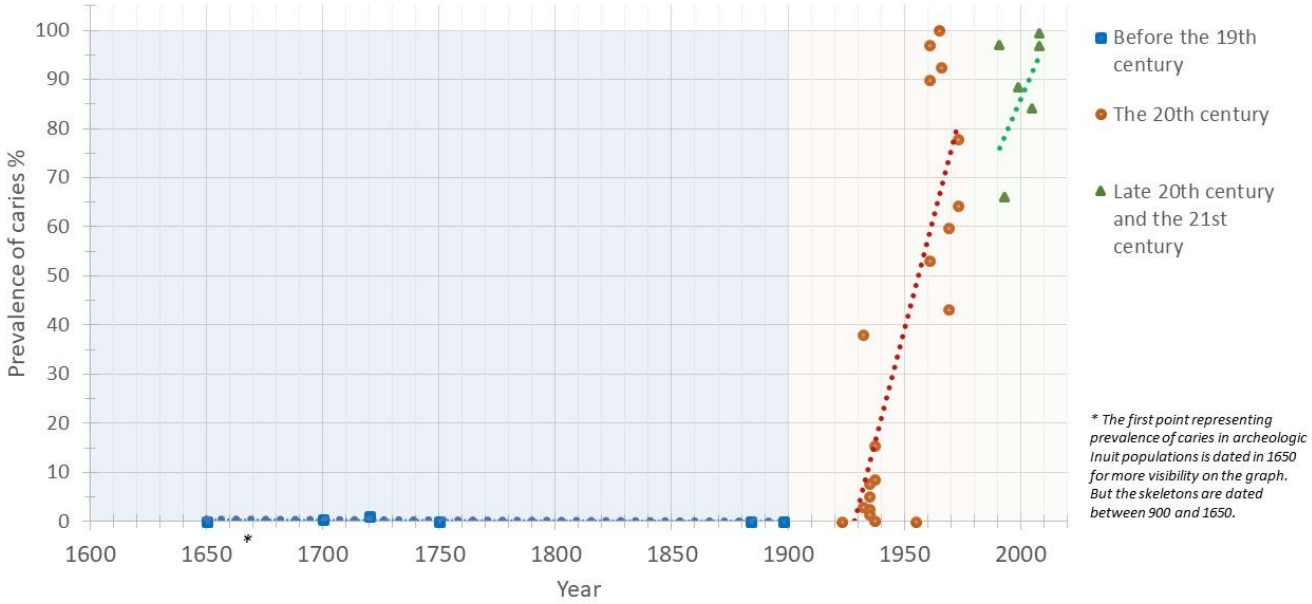


Figure 5 : Evolution of the prevalence of caries (%) in the Inuit populations of Canada, Greenland and the United States between 900 and 2008, based on a historical review of the literature.


Prevalence of caries %
100
90
80
70
60
50
40
30
20
10
0
1600
1650
*
1700
1750
1800
1850
1900
1950
2000
Year
Before the 19th century
The 20th century
Late 20th century and the 21st century
* The first point representing prevalence of caries in archeologic Inuit populations is dated in 1650 for more visibility on the graph. But the skeletons are dated between 900 and 1650.