The Book of Teeth and Bones

The Book of Teeth and Bones

By

Masayuki Okazaki

Cambridge
Scholars
Publishing

The Book of Teeth and Bones

By Masayuki Okazaki

This book first published 2021

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-6410-X
ISBN (13): 978-1-5275-6410-7

CONTENTS

INTRODUCTION

I have been engaged in education and research in medical materials (biomaterials) used for dental or medical treatments at a university. However, my family often say, “Daddy is poor at explaining things and is difficult to understand.” People talk about “nerd” or “geek”, but I seem to be fascinated by the charm of apatites and have shut myself in an ivory tower without realizing it. Formerly, I wrote a book titled “Chemistry of Apatites, Materials of Teeth and Bones”[1] in the hope of giving future dentists, doctors, and researchers knowledge about the material chemistry of “apatites” (primary components of teeth and bones: I will take time to explain them later). Recently, I have occasionally heard comments like, “I am using that book regularly,” which makes me happy in the back of my mind, but the book seems to be boring to regular people, and I have always wanted to do something about it.

Unfortunately, however, I got involved in education and research at college and, somewhere down the line, became preoccupied with words such as “principles of competition” and “self-assessment”. I became so wrapped up in daily life that I had no time to enjoy teaching or conducting research, let alone writing books catering to the interests of regular people. Fortunately, I retired and was blessed with the opportunity of visiting Garmisch-Partenkirchen, a German country town full of memories. While I was hiking through the mountains there, the plan for this book occurred in my mind.

After I visited the graves of a German couple, whom I owed a lot to in my student days, I thoroughly enjoyed hiking, which had long been my dream, for a full week (Fig. 1). I had previously been taken by the husband to the grave of his wife when she died, but since he drove me there, I had completely forgotten the location of the grave. After the husband also died, their relatives seem to have lived in their house for a period of time, but when I visited this time and asked their neighbors, no one knew about the couple. Fortunately, when I asked the city office, they kindly gave me the location, and I could finally visit the grave. The weather also happened to be beautiful, and, being gently wrapped in the bosom of calm nature, I could shed plaques that had deposited on my spirit over decades.

Here, I noticed that small children to aged couples enjoyed mountain hiking in their own styles, using cable cars and ropeways. Nothing is better for the mental and physical health of us humans.

Just at that time, the great earthquake struck the Tohoku District. My heart ached when I thought of the many lives that were lost and the people who were suffering, but the incident made me think all the more that it was time for me to write.

Concerning the unexpected damage caused by the accident at the nuclear power plant, the accumulation of isotopes in bone is closely related to the book I have just written. Since I studied technology, I do not insist that all nuclear power plants should be dismantled, but I think it is about time that we Japanese reconsider our lifestyles. In Germany, solar electric generators often catch my eye when I am on a train or walking in a town. Occasionally, nature suddenly bares its fangs and attacks humans, but it is intrinsically very gentle. Cherished in the bosom of nature, teeth and bones

remain in mother earth for tens or hundreds of millions of years. This is the marvelous world of science.

Now, let's step into the world of apatites. I am sure it will boost your interest in dental materials, medical materials, and even dental practice and improve your understanding about the daily efforts of dentists, dental technicians, and hygienists, and about dentures and implants.

While attending, I added newly summarized PART II in the latter half for the people, who are interested in more detailed knowledge of apatites.

PART I

VALUABLE TALES OF TEETH AND BONES

I-1. OH, I GOT IT! THE STORY OF DENTAL MATERIALS

What I definitely want young people to know

I am sure you know that bones regenerate, but teeth do not, once they are damaged. This is exactly why we need dental materials. Of course, it would be best if we did not have to use them. Unfortunately, it is impossible to create artificial teeth exactly the same as natural teeth using today's dental materials and technology. So, I would advise you to pay attention to your teeth and routinely take good care of them if you do not want to regret the loss of your teeth in your old age. I hope this book helps you a little with protecting your teeth.

Story of dentures

Are you not expecting too much from dentures? You must not think that dentures fit. If they fit, you are lucky. Our bodies change every day as we age. The environment in the mouth is also changing. Dentures become poorly-fitting even if they are originally made perfectly. If your glasses fit you poorly, you do not blame glasses shops or ophthalmologists, but you complain of the poor skills of the dentist or technician if your dentures fail to fit you. This is unfair. Of course, there seem to be differences in dexterity. There are dentists and technicians who can foresee gingival changes from their long experience and cleverly adjust dentures (Fig. 2). Good cooperation between dentists and technicians will make an even better job possible.

As vision deteriorates with age, the oral environment also changes and declines. If your dentures happen to be less than you expected, it may be necessary to accept them and learn to be content.

Fig. 2 Denture (By courtesy of Mr. T. Seo).

There is the term “pocket dentures (dentures that are deserted in pockets)” among dentists. This mocks dentures that have been made one after another but have been scarcely used and ended in pockets or drawers. If your first dentures do not fit you, you think that it is because of the poor skill of the dentist or technician and go to another dental clinic. But your new dentures also become unfit soon, and you go to another dentist, and while you keep going from one dentist to another, you end up with scores of unused dentures forgotten in your pockets or drawers. Such a comical story is actually happening. Since you can get dentures relatively inexpensively under health insurance, this occurs repeatedly.

But hold on a little! Are you not expecting too much from dentures? Unfortunately, current dentures do not transform with changes in the body. In a sense, it is the fate of artificial materials. The oral environment is changing slightly every day. Particularly, when you catch a cold or are not

well, the gums change quickly. They also change slowly with aging. When you get old, they begin to change more markedly. If the alveolar bone stops receiving force, it is resorbed rapidly, accompanied by progressive retreat of the gingiva. Bone resorption progresses further if you stop eating hard food or lose teeth due to caries or pyorrhea. Hence, your dentures, on which you have spent time and money, soon become unfit.

The same thing happens even to expensive alloy dentures (metal dentures in technical terms). Metal dentures are considered more durable and have less effect on the taste of food than plastic dentures, but there is little difference in fitting. In addition, the part that corresponds to the gums is made of a polymer called polymethyl methacrylate (PMMA) in both plastic and metal dentures.

Then, what should we do? After all, I think it is best to keep new dentures made at appropriate timings. You can have the part of your denture that rubs against the gum planed, but its effectiveness is limited. It may instead change the balance of the denture and cause sores at other places. Although the use of a denture stabilizing material or tissue conditioner is an option, it is reported that overuse of a stabilizer is not recommended, because it increases the thickness of the part that rubs against the gums and induces bone resorption or tissue change under the area of its application. In the past, Japanese paper was once used as a tissue conditioner, but it is no longer in use, because bacteria are likely to attach to it and make dentures unclean. However, there are times when the body gets somewhat used to even dentures that do not fit well as they are used over a long time. Unlike inflexible artificial objects, the body seems to be somewhat friendly to foreign objects.

Formerly, attempts to make dentures using soft plastics have been made. Unfortunately, however, they were deformed rapidly and were not usable. Dentures are not easy to make. In Japan, there used to be special craftworkers called “denture masters”. They correspond to dentists and dental technicians in modern dentistry combined. They were mostly house craftworkers serving upper class people. A typical example of their craftsmanship is the wooden dentures (*mokusho gishi*) of Ieyasu Tokugawa, which were made of boxwood (Fig. 3)[1]. The artificial teeth were made of ivory or stone. The shape of the oral mucosa is reproduced so excellently that I wonder how they took impressions in the mouth. This wooden denture is considered to have superb adhesiveness to the oral mucosa.

I recommend that you take time to consult with your dentist, let him/her understand well about the condition of your mouth, and have dentures that fit you well made by patiently maintaining communication. It may be a good idea to review changes in your physical condition and oral environment before you complain about the skills of your dentists and technicians.

Fig. 3 Wooden denture (By courtesy of Dr. I Nakahara).

Pitfalls of the 80-20 campaign

If you feel this way, it is best to keep your natural teeth as much as possible. “Having 20 natural teeth by the age of 80”. This is the motto of the 80-20 campaign. Recently, the idea of “minimal intervention” when treating dental caries as early as possible and preserving the teeth with minimum treatment without extracting them has become prevalent. Therefore, I recommend that you periodically visit your dentist, have dental scales and plaque removed, and have dental caries found in the earliest stage. Particularly, pyorrhea progresses without your knowledge. Those around 40 are already at risk.

Also, dentures are better stabilized in your mouth if you have more natural teeth remaining. Therefore, it is important to keep as many natural teeth as possible. However, the remaining teeth are also subject to unnatural forces in attaching and removing dentures, or the soft cement layer at the base of the lateral surface of the teeth is frictioned and wears off by the hooks called clasps, which keep dentures in position, and they are likely to develop caries and may eventually get extracted.

Also, if you develop dementia and become bed-ridden, this motto ceases to apply. Ironically, if you retain a few teeth in such a condition, they may interfere with cleaning of the oral cavity. If the teeth cannot be brushed, or the oral cavity cannot be cleaned well, oral bacteria proliferate, and, if they are aspirated into the lungs, they may cause pneumonia (Fig. 4).

Story of implants

Recently, it has become easy to get dental implants (artificial dental roots) (Fig. 5). Since they look cosmetically favorable and do not have to be

removed like dentures, everything seems wonderful. But, be careful!

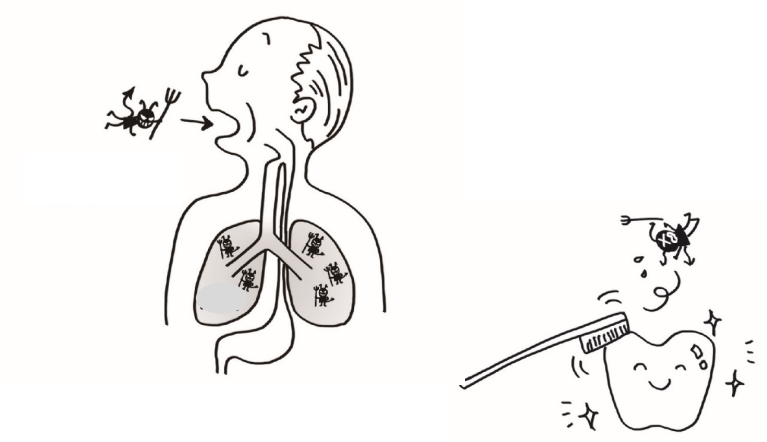

Fig. 4 Pneumonia caused by oral bacteria.

Fig. 5 Ti Implant (Photo: by courtesy of Taishin Boeki Co. Ltd.).

Not everybody is happy. If implants are set in the wrong direction, the bone that supports them is stressed and may be destroyed. Particularly, people with a small jaw are at risk. The roots of natural teeth curve smoothly along the jaw bone, but implants simply stand straight. So, in the worst case, the bone is penetrated all the way in making holes for implants. If implants are not placed exactly in the direction of occlusion, you may not be able to bite well, or the force of biting continues to work in the wrong direction, eventually making implants wobbly. In addition, if you get demented or bed-ridden, it becomes difficult to brush your teeth by yourself, and as your mouth gets unclean, bacteria are likely to proliferate. Therefore, implants are recommended to healthy people with well-developed jaws but not so much to those with a small and graceful mouth.

In fact, implants have a long history and date back to 700 B.C. In these days, implants seem to have been popular in Etruscan, Italy, and many relics of teeth bridged with gold remain. Probably, the gold bridges supported teeth that were lost due to pyorrhea, but the question of whether they actually worked or not is open (Fig. 6)[1, 2].

Fig. 6 Ancient Etruscan implant (By courtesy of The Gold Information Center, NY).

Story of composite resin

In the past, dental filling materials were limited to cement and amalgam. Many of my teeth are also filled with amalgam. Amalgam is tough, because it is a metal (alloy of Hg and Ag), but as it contains Hg, it has recently been avoided as much as possible. Actually, Hg contained in amalgam is inorganic Hg, which is not as dangerous as organic Hg, and since it is alloyed, little Hg remains. So, we do not have to worry so much.

Composite resin has replaced amalgam from the viewpoint of safety and security. Composite resin is hard inorganic particles called silica cemented with plastic. It is particularly popular among young people, because its color can be adjusted to the natural color of teeth. However, since the particles are cemented with plastic, composite resin is bound to deteriorate. Fortunately, it has served well for more than 10 years in my mouth, but it may become fractured or detached in a few years. There are no such worries with metal filling materials.

Recently, ceramics are attracting attention because of both the color and strength. However, to my regret, the use of ceramics hikes the cost of treatment as it is not covered by health insurance.

Story of tooth blackening

Taira no Atsumori, the kindachi (high-ranking noble) killed by Kumagai Naozane in the Battle of Ichinotani, a famous episode in the Tales of the Heike (1184), is considered to have applied tooth blackening. Tooth blackening appears to have been a habit restricted to high-ranking noble men in the Heian period. In the Edo period, it became popular among women, and a tooth blackening set (Fig. 7)[2] was part of the marital package.

This custom is considered to have been restricted to married women. Tooth blackening uses a non-aqueous solution prepared by mixing a powder called fushiko, which contains a large amount of tannic acid, with a brown liquid prepared by adding iron to vinegar (acetic acid). It smelled so awful that they made sure to rinse their mouth after applying it. However, from the viewpoint of dentistry, tooth blackening, which is like paint over the enamel of the teeth, is considered to have been effective for the prevention of dental caries because of the coating effect and anti-lytic effect of iron. In addition, tannic acid with its protein astringent and antibacterial actions seems to have contributed to the prevention of pyorrhea. This custom faded away by the beginning of the Showa period.

Fig. 7 Ohaguro (Tooth black)

(Picture: by courtesy of Dental History Library, Nihon University).

Unexpectedly little-known constitution of teeth

If all teeth have erupted, there are 32 teeth in the mouth, but this is rare today. Most people have 28-30 teeth. First, 20 milk teeth grow, and they are replaced by permanent teeth by the age of about 20 years. That's all, and no third teeth come up. However, wisdom teeth may stay below the gum without erupting or morbidly come out sideways. Although rare, some teeth may remain unerupted. So, if you worry about the growth of your teeth, you should have X-rays taken and consult your dentist.

You may have healthy teeth extracted to correct the alignment of your teeth or lose teeth due to pyorrhea even without caries. These teeth used to be used simply as materials for clinical training of dental students, but studies to preserve them in a "tooth bank" until their use for regenerative therapy becomes a reality are in progress.

Teeth are supported by the gums, but they are not as rigidly fixed as implants. They are bound tightly by connective tissue called the periodontal membrane, which absorbs the impact of biting.

White teeth?

When we see pictures of entertainers smiling with their white teeth exposed, we cannot resist their charm. But, be careful! Healthy teeth are not necessarily white teeth. I want to remind you that healthy teeth are those that allow you to bite and speak well. Of course, white teeth look clean, and teeth stained by tobacco tar are disenchanting. Recently, whiteners containing agents, such as hydrogen peroxide, have become easily available, but problems are concealed in the whitening technique. Occasionally, problems happen, such as that the teeth become white but are soon stained

again, that metal crowns and fillings in the neighborhood are discolored, and that the tooth surfaces are roughened. Before you try whitening, you had better check with your dentist carefully.

Why do lost teeth not regenerate?

Human teeth are called “lifetime teeth”, and once milk teeth are replaced by permanent teeth, we keep the same teeth to the end of our lives. Therefore, if we develop caries, teeth do not regenerate as bones do.

Fish, on the other hand, are called polyphyodonts, which means having many sets of teeth that are generated and replaced in succession. If humans were polyphyodonts like fish, we would not be troubled by caries, but we have only two sets of teeth, because the primordia of teeth called dental papillae disappear after they make teeth once. Recently, however, it has been reported that the gene that controls dental papillae are asleep and that having a third set of teeth may not be a dream if we succeed in waking up this gene. This story sounds great if it comes true.

If you observe the teeth of killifish, you will see that they have many teeth and that more teeth are waiting for their turn under them (Fig. 8)[3].

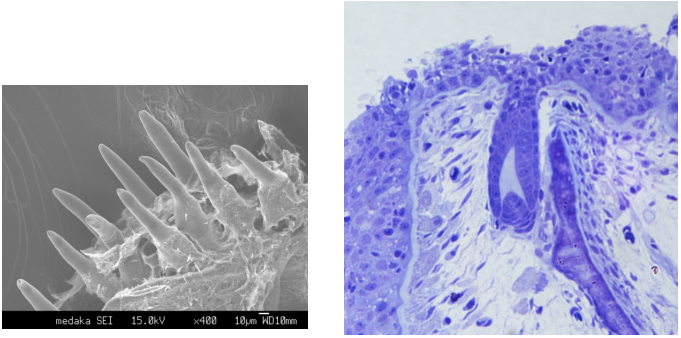

Fig. 8 Teeth of Killifish.

Bones regenerate of themselves

Bones, on the other hand, are metabolized all the time, and new bone is generated while old bone is resorbed (Fig. 9). Osteoclasts cover the part of bone to be destroyed and lyse apatites by secreting acid (hydrogen ion). In contrast, osteoblasts diligently make bones using the calcium (Ca) and phosphorus (P) released from lysed bone. This balance is maintained superbly. Because of this ability of bone regeneration, fractures are repaired naturally by the body. Therefore, no particular artificial material is needed to repair fractures and small bone defects.

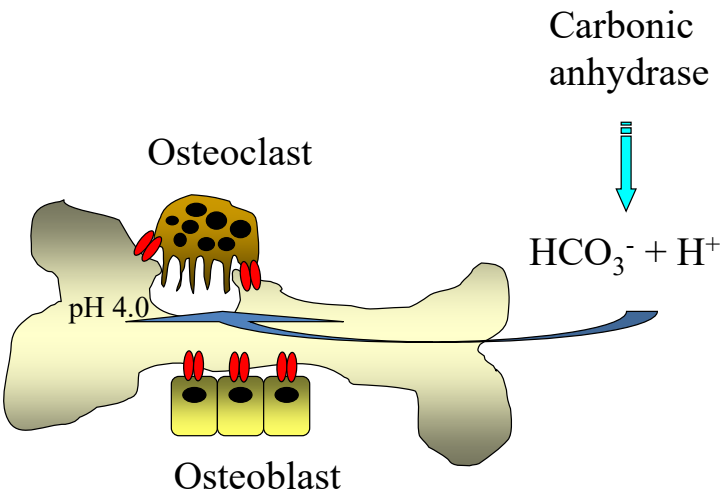

Fig. 9 Schematic model of bone metabolism.

However, the help of artificial materials is necessary to repair large areas or areas with low regenerative ability. The ability of bone regeneration declines with aging, and osteoblasts become less active as we get older. Tissue engineering and regenerative medicine aim to revitalize bones using young

and fresh cells. I will discuss this later.

This is how dental caries are made

It is rather difficult to recall the details of everyday activities in our early childhood, but I remember making great efforts to quickly pull out milk teeth that became loose by deliberately wiggling them or by tying a loose tooth to my toe with a thread to let it get pulled off while I was unconscious during sleep. In these days, I hated to go to see a dentist and would try to bear the pain even with a large hole of caries. I am still plagued by the chilling rasping sound of the electric engine (which has been replaced by the much quieter turbine) in my dreams.

Of course, I never knew that teeth are made of apatites, which are calcium phosphates, and that they are lysed by acid produced by bacteria that cause caries. My idea was that caries bacteria holding spears live in the mouth and that they dig holes in the teeth when I eat sweets. Still less did I even dream that enamel is a structure consisting of layers of robust hexagonal apatites. Today, however, knowledge about the prevention of caries has spread by improved dental education, and caries are becoming less prevalent year by year. This is wonderful. One thing that we must be careful about is that the children of parents indifferent about dental hygiene often have severe caries. After all, our world is full of sweets. I will talk about apatites in detail later in the technical sections.

Since primitive times, mankind appears to have been troubled by caries. Some of the teeth of our ancestors unearthed from their remains show large holes caused by caries or have worn so thin due to severe clenching that the pulp is exposed. Since they had no dentists in those days, I feel sorry for

them, guessing that they suffered so much. However, I suppose common people began to have relatively easy access to dental consultation after the civilization and enlightenment of the Meiji period. Today, patients are lucky, because dentists are considered to exist in excess. Until the end of the Edo period, dental care was out of reach for average people.

Now, 3 factors are considered to be involved in dental caries, namely, tooth apatite, bacteria, and glucose (Fig. 10). The phenomenon sounds a little complicated, but, eventually, sugar decomposed by caries bacteria produces H^+ (hydrogen ions), and these H^+ ions lyse the host, i.e., apatites of teeth. In simple terms, caries are formed by the lysing of ceramics by acid. Therefore, in experiments, teeth immersed in carbonated water for a long period are lysed by acid and are eroded. We do not have to worry about carbonated drinks, because we immediately swallow them, but if a baby falls asleep holding a feeding bottle containing a lactic acid bacilli beverage in the mouth, the milk teeth are soon affected by caries. While the pH of water is 7.0, that of carbonated soft drinks is often about 2-4, even lower than the pH of the habitat of caries bacteria, which is 5-5.5.

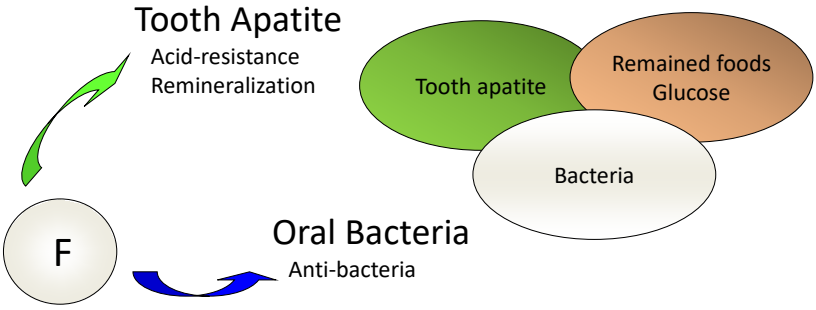

Fig. 10 Essential factors of dental caries.

Some of the Ca and P released as apatite is lysed may be deposited and crystalized again. This is called remineralization (recrystallization). When this process is studied in detail, crystals formed by redeposited Ca and P do not develop into crystals of the original enamel. Therefore, strictly speaking, once a tooth is affected by caries, it is never restored to the original condition. Furthermore, if a large hole has been made, repair using dental materials, such as composite resin, metal, and ceramics, is necessary.

In repairing teeth using such dental materials, how they should be attached to the tooth substance is a problem, because the oral cavity is a harsh environment that is constantly exposed to hot and cold foods and beverages. Fortunately, firm adhesives and cements have been developed one after another due to recent advances in adhesive dentistry. However, many of these materials are primarily made of macromolecules, and they are bound to deteriorate over a long period. In addition, their deterioration is accelerated in the severe environment of the oral cavity by the stress of temperature changes due to food and the force of occlusion. On the other hand, the durability of metals and ceramics themselves is sufficient, but as they are not adhesive, the above organic adhesives and cements are necessary for their use, and caries often develop again due to deterioration of these parts. Formerly, inorganic zinc oxide cement was widely used, but as it often caused recurrence of caries, it is mostly out of use today.

Fluorine (F) is known to be a silver bullet for the prevention and control of caries[4]. As I explain in the following sections on apatites, F has been shown to stabilize apatite crystals and to have an antibacterial activity. It is safe, because it is effective at a very low concentration. While water fluoridation is not practiced in Japan today, the WHO sets the safety

criterion for fluoridation of tap water at 1 ppm (10^{-6} g/g, g/mL in water solution). In direct application of fluorine to teeth, it is applied at 1,000 ppm or more, and while it is still a very low concentration, we must ask a dentist to do it. At a higher concentration, F is a dangerous drug that can lyse even glass and must be handled with caution. There are regions of the world in which natural water contains F at relatively high concentrations (10-50 ppm), and, in such regions, people may develop a disorder of tooth development called mottled tooth. In Japan, fluoridation of tap water was attempted in some areas, but as a high concentration of F was supplied to a water tank by mistake, causing mottled tooth, water fluoridation was given up on thereafter. However, please do not misunderstand. There is no reason to worry about mottled tooth, because it is a phenomenon that occurs in the period of tooth formation and is not observed in mature teeth. Attention is necessary in babies and children during the tooth replacement period. Also, in areas where natural water with a high F content is used, a disease called osteosclerosis may occur. Although its causal relationship with F has not been fully elucidated, the disease makes bones less flexible and more fragile.

Risk of pyorrhea

The gums (periodontal tissue) have an amazingly delicate structure. The dental root and jaw bone are bound by connective tissue called the periodontal ligament (periodontal membrane) (Fig. 11), and teeth become loose if the periodontal ligament is damaged. Inflammation of the gums is an index of tooth instability. If the gums are red like an apple and swollen, we can imagine that the periodontal ligament inside is considerably damaged. Since inflammation is caused mostly by bacteria, it spreads

rapidly without being restricted to a single tooth. That is a difference from caries, which is limited to the areas with holes. So, if you get pyorrhea, a considerable number of teeth may become loose at one time. People who had confidence in their teeth are shocked the most. Those who have boasted that they have no worries about caries or pyorrhea because they smoke and have their teeth coated and disinfected with nicotine may well suddenly suffer pyorrhea around the age of 40 years.

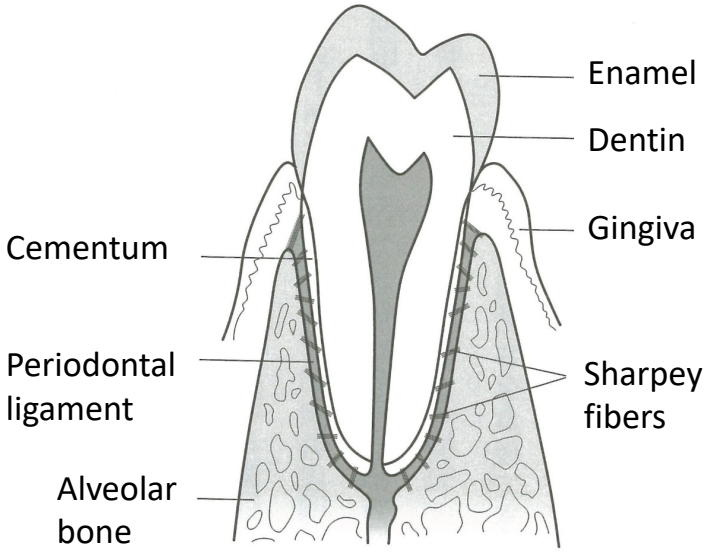

Fig. 11 Periodontal ligament of tooth.

In the periodontal ligament, many bundles of thin but very strong threads woven like ropes called Sharpey fibers are arranged perpendicularly to the periodontal ligament and tie the dental root and jaw bone sideways. Both ends of the bundles penetrate deep into the dental root and jaw bone