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Introduction

Why do we need another book about osteoporosis? Don't we already know that the disease is just caused by calcium deficiency and lack of exercise? I beg to differ. If it were that simple, we would not be hearing about the disastrous statistics that are outlined in chapter 1, and, for example, the incidence of hip fractures in Canada would not be expected to quadruple by the year 2030.[1] Somehow, the prevention messages (or should that, in some cases, be 'mixed messages'?) are not getting through.

I have a particular interest in bone health. First, because my mother had this diagnosis and I wanted to research how she could reverse the condition. Second, because I have had a fair few broken bones in the past, and I can tell you, it hurts. I don't want anyone else to have to experience the same degree of pain and debility that I have managed to subject myself to in my life. I'm known as a bit of a daredevil, and during my first 18 years on the planet I broke three arms (OK, I broke my right arm twice), my nose, and shattered my coccyx (the base of my spine) – I still have a lump there to this day. Later on I broke two toes in a karate grading when my foot got slammed out of the way by my opponent, and went on to rupture my cruciate ligaments in a skiing accident in which I fell 200 feet on ice. (Alright, so this wasn't a broken bone, but it was actually harder to fix.) I would like to stress at this point that I have very robust bones – it was

just that the impact forces in all of these accidents were huge, and more than even my strong frame could withstand. Just imagine what could have happened to someone whose bones were much more fragile.

I do wonder if we would be more inclined to take care of our bones if they were visible. How many skin care products do we see, lining the shelves of every supermarket, pharmacy and specialist store? They give vague promises of 'younger-looking skin' and purport to be 'anti-wrinkle', with the cosmetics industry itself being worth billions a year. We never hear of a 'bone care routine' in the same way in which we hear of a skin care routine (although to make up for this, I have added one at the back of this book, see page 167). What a great pity that is, since the challenges associated with poor bone health far outweigh any physical challenges that one might experience with developing the odd wrinkle or two.

As you progress through this book, you will find that I have not just written it from the perspective of bone health, important though that is. For every element or principle involved in bone care, there are many other whole-body benefits that will be enjoyed as a result.

I am often asked, when I give presentations or conduct private consultations, 'Will a change in diet help with..?'. My answer is always the same. A correctly conducted nutritional regime will improve health at a cellular level, and kick-start the reversal of many disease states, but food alone is not the answer to everything. There are, in my opinion, as many as eight 'Pillars of Health', and an excellent diet is only one of them. The other seven are exercise, rest, sunshine, hydration, stress relief, the cultivation of a positive attitude, and incorporation of some type of spiritual practice or 'life purpose'. These are all as important as each other, and by ignoring one we diminish the benefits of all. We are only as strong as our weakest link.

I have met many people through the years who focused

intently on one of the eight, whilst ignoring all the rest. A friend of mine with whom I did triathlon training in the mid-1990s was incredibly strong and fit, having represented Great Britain at the 1988 Olympics in Seoul. He never fuelled his body correctly for the demands he placed on it, and always laughed at me and my 'rabbit food diet', as he described it. I will always remember going out to dinner with him one night after a particularly heavy circuit training session, and him saying to me, whilst he tucked into a massive plate of spaghetti Bolognese with extra cheese – 'You're too scrawny, lass – you need to eat more lard!' I was never offended by this comment, being proud of my lean, muscular physique, maintained at that time by a high-percentage raw food diet and an intensive exercise programme. A few months later he became unwell with very vague signs that he sadly ignored, believing that because he was fit he was therefore indestructible. He died six months later aged just 34.

Likewise, but in rather sharp contrast to my Olympian friend, I have met numerous people with a very strong religious belief who have ignored the other seven pillars of health, not treating their bodies in the way that I believe their Creator would have wished. I have seen them develop degenerative disease that severely compromised their enjoyment of life, accepting it as 'God's will'. Personally, I don't think people's gods pick on them to suffer. They may just want us to learn something.

So, whilst this book is entitled 'Love Your Bones' and we often think of food as the most important aspect of bone health, you will notice in the following chapters that I have also included some 'non-food' items. If I had not done this, I would be short-changing you, dear reader. Even now, some experts are telling us that osteoporosis is just a deficiency of weight-bearing exercise. But just like the people mentioned above who focused on only one of the eight pillars, I don't want you to focus just on, for example, exercise, or only on the umbrella term 'hormone replacement', in the expectation that it will reverse bone loss.

It may not, for reasons we will come on to. And here I should also mention that whilst scaffolding (i.e. our bone strength) is important, by practising all of the recommendations given here, you may find that other health challenges and minor niggles (or even more major ones) could also be resolved. Brian Clement, Director of the Hippocrates Health Institute in Florida, notices this all the time with guests that present themselves at the Institute for a specific health problem. He hears comments such as 'I came here to recover from cancer, but you didn't tell me that my high blood pressure would also be reversed!', or 'I came here to lose weight, but now I feel more empathy towards my son/daughter/father/mother.'

This is a whole body we live in, my friends. The medical profession may wish to compartmentalise us into different categories according to the sign that presents first, such as cancer, or heart disease, or osteoporosis. Although your main presentation or concern might be osteoporosis, you could be facing additional health challenges, because all of our body systems are related to each other, and lifestyle choices which damage one body system are silently damaging others.

Finally, bear in mind that there are numerous types of 'healthy eating plan', which I will discuss in more detail once we get going. I will give plenty of information on the best type for osteoporosis, and indeed the health of the whole body, as we progress, and in the recipe section at the end of the book. Let's get started, let's get strong, and let's get healthy.

Note: For those who like their scientific references, you will notice that among the research I have cited through the chapters is work that has been performed using animals. This does not mean I agree with this as a method, but given that the research exists it is important to include it here in the sum of our knowledge.

Chapter 1

Some alarming statistics

One of the main reasons I cite for paying attention to bone health throughout our lives is the devastation that bone ill-health can cause over time if we don't. According to the International Osteoporosis Foundation (IOF), the sheer number of people affected is huge:

- Worldwide, osteoporosis causes more than 8.9 million fractures annually, resulting in an osteoporotic fracture every three seconds.[1]
- Osteoporosis is estimated to affect 200 million women worldwide – approximately one-tenth of women aged 60, one-fifth of women aged 70, two-fifths of women aged 80 and two-thirds of women aged 90.[2]
- Osteoporosis affects an estimated 75 million people in Europe, USA and Japan.[3]
- For the year 2000, there were an estimated 9 million new osteoporotic fractures, of which 1.6 million were at the hip, 1.7 million were at the forearm and 1.4 million were clinical vertebral fractures. Europe and the Americas accounted for 51 per cent of all these fractures, while most of the remainder occurred in the Western Pacific region and Southeast Asia.[4]
- Worldwide, one in three women over the age of 50 will experience osteoporotic fractures, as will one in five men aged over 50.[5]

In North America more specifically, according to further data from the IOF, the trends are equally alarming:

- Canada: Osteoporosis affects approximately 1.4 million Canadians, mainly postmenopausal women and the elderly. Osteoporosis affects one in four women and more than one in eight men over the age of 50 years, with one in four men and women having evidence of a vertebral fracture.
- Canada: Almost 30,000 hip fractures occur each year. By the year 2030, the number of hip fractures is expected to quadruple.
- USA: Osteoporosis and low bone mass are currently estimated to be a major public health threat for almost 44 million US women and men aged 50 and older.
- USA: The 44 million people with either osteoporosis or low bone mass represent 55 per cent of the people aged 50 and older in the United States.

Osteoporosis is often referred to as 'the silent killer' because it can be present for many years, often undetected, until a bone suddenly breaks; usually, in women, the hip. A fracture is just the acute manifestation of a chronic long-term problem, and by the time the bone breaks, it can be very difficult to undo the damage. Worryingly, 20 per cent of osteoporotic hip fracture victims die within one year of the fracture occurring, whilst a further 30 per cent are forced into nursing homes. Overall, only 30 per cent of patients manage to recover fully from osteoporotic hip fracture. It therefore follows that to avoid being one of the increasing number of people suffering the devastation that this disease can bring, prevention is the key. However, if you have already been diagnosed, please do not despair, since bone mass can be improved in both sexes, and at any age.

For longevity, wellbeing and reversal of disease states, the dietary regime outlined in the chapters that follow has been

demonstrated to give unparalleled results. The correct diet and exercise programme genuinely can rebuild your failing structural elements. It really is time to love your bones and think of them as living, breathing entities, rather than just boring inert scaffolding. They deserve as much attention as your heart, liver, skin and brain. Treat them well and they will support you forever.

Chapter 1 summary

- Osteoporosis is a potentially devastating condition and the worldwide incidence is increasing.
- It is more common in women, but men are not immune from the disease.
- Less than a third of people sustaining an osteoporotic fracture return to a normal life afterwards; a fifth of those who break a hip die within one year.
- Prevention of the disease is key, but osteoporosis can also be reversed with appropriate dietary and lifestyle intervention.

Chapter 2

Bone structure and development: understanding your scaffolding

We often don't give our bones a lot of thought, but there they are, the very essence of our structure, allowing us to enjoy the uninterrupted movement and strength that our daily lives demand. It's often only when we break a bone, or we are given the frightening diagnosis of the life-limiting condition described as osteoporosis, that we might give due consideration to this essential, 'alive' crystalline matrix that lies beneath our muscle mass.

Often considered to be just a boring inert framework that doesn't really do much apart from allow the rest of the bodily structures to be built on and around it, bone is in reality living tissue, with a blood and nerve supply, a highly active internal marrow and an impressive ability to naturally repair itself and restore its own function even after major traumatic injury. In other words, bone tissue is, like many other parts of the body, self-regenerating. Having operated on hundreds of bones during my 30-year career as a surgeon, I can honestly say that the post-operative X-ray follow-up series continues to amaze me, even to this day. Over time, such radiographs show an unmistakable fact: the living tissue regeneration and remodelling is there for all to see. Bone is a fascinating and highly dynamic substance. Once we are aware of this, we can finally appreciate that the elements which allow such tissue restructuring and regeneration have to

come from somewhere. That 'somewhere', as true for bone as for any of our other bodily tissues, is our food.

What is bone made of?

Bone is comprised of approximately 35 per cent organic material and 65 per cent mineral-based material. Organic material refers to carbon-based structures, such as proteins. 90 per cent of the organic component of bone is collagen, a structural protein which also gives integrity to the skin, tendons and ligaments. 99 per cent of the mineral-based material is a compound called hydroxyapatite, a crystalline complex of calcium and phosphate. The mineral component provides mechanical rigidity and load-bearing strength to bone, whereas the collagen-based organic matrix provides elasticity and flexibility. Both of these properties are vital to bone's overall strength and resistance to fracture. Bone tissue is the body's largest store of minerals, and as such is closely involved in mechanisms that regulate the body's acid/alkali balance, which you'll learn more about in chapter 4. The formation and maintenance of bone are under the control of numerous cells, hormones and growth factors which are discussed in more detail below, and in the chapters that follow.

Anatomically, bone has two major components: cortical bone, which is solid, dense and surrounds the bone marrow, and trabecular bone, which is a honeycomb-like network of plates and rods in the bone marrow compartment in the centre.

Bone cells

There are three major cellular components to bone, which are:

Osteoblasts – the bone-building cells
Osteocytes – osteoblasts that have become incorporated into the bone matrix

Osteoclasts – cells that remove worn-out bone.

All three types of cell are essential to the correct functioning and strength of the bones. Let's look at them all in a little more detail.

Osteoblasts

Osteoblasts secrete the organic matrix of collagen and other structural proteins, such as osteocalcin and osteopontin, in a dense array of cross-linked 'ropes' that give bone a very high tensile strength; see also 'bone glue' below. The osteoblasts also secrete the minerals from which the crystalline hydroxyapatite compound is formed: the inorganic mineral component of bone which gives it its rigidity.

Osteocalcin is a protein which deserves special mention, since it is closely involved in ensuring that the hydroxyapatite crystalline structure forms the correct shape for greatest strength and rigidity. The formation of the osteocalcin protein involves two important steps, fascinating to those interested in organic chemistry, which involve vitamin D and vitamin K2; both of which you will read more about in chapter 9. When osteocalcin comes into contact with calcium ions, the protein folds in a special way to allow it to 'dock' onto the hydroxyapatite crystal, and add more calcium where it is needed, allowing the bone to grow. In organised groups of connected cells, osteoblasts deposit minerals into the organic matrix, subsequently forming a very strong and dense mineralised tissue known as the mineralised matrix.

Osteocytes

These cells are former osteoblasts that have, in effect, become buried in the bone matrix. They possess long dendrites; thin, finger-like processes that protrude from the cell surface and

sense the forces which are applied to the bone. They are the 'communicators' within the bone structure, and signal to the other bone cells whether to make more bone, or reduce further bone development. They perform a very important function during exercise: when the bones are loaded and under stress from muscle and tendon tension, osteocytes convey these messages to the osteoblasts and initiate bone strengthening and further development as a response to these forces.

Recent studies have also indicated that depriving the osteocytes of oxygen is a factor in the determination of overall bone strength.[1] Less oxygen means reduced strength of bone as a result of lack of stimulation of the bone-building mechanism. It is possible therefore (although more research is needed) that anything which delivers higher levels of oxygen to the tissues might have a positive effect on bone health. Exercise is just one way by which tissues become more highly oxygenated; others depend on our food and lifestyle choices.

Osteoclasts

Osteoclasts are the cells which break down old, worn-out bone. They too are under the control of hormones and other chemical regulators. Osteoclasts perform numerous important functions, including ensuring that the bones do not overgrow, preventing them from becoming too thick or dense. They are also involved in remodelling of the bone so that it retains its correct shape, for example during fracture healing when bone calluses are remodelled. In post-menopausal women, the activity of osteoclasts is often greater than that of osteoblasts, resulting in a decline in bone mineral density and net bone loss as time goes on. As a result, osteoclasts are considered by some to be the 'bad guys', but this is not necessarily correct. Many drug interventions for osteoporosis focus on blocking osteoclast activity; you'll read more about this, and its potential side effects, in chapter 10.

‘Bone glue’

Discovered by Professor Paul Hansma, with publication of the discovery in the journal *Nature* in 2005, ‘bone glue’ could be the missing link in our knowledge of how our bones work to resist fracture. Inspired by some very interesting mechanical properties of abalone shell, which is 97 per cent crystalline calcium carbonate and 3 per cent organic material, Professor Hansma initially wanted to investigate why it was that the incorporation of just 3 per cent organic material in the shell made it 3000 times more resistant to fracture than 100 per cent pure crystalline calcium carbonate. Could such a small proportion of organic material really make that amount of difference? And if so, how? It turns out that it does.

Professor Hansma not only ascertained how this is possible on a molecular level (you can read about some of the science, which I find fascinating, on page 10), but subsequently investigated to see if this incredible property of abalone shell existed elsewhere in nature. Fortunately for us, it does – in our bones. Essentially, bone glue amounts to a physical phenomenon which is measured by an atomic force microscope. This breakthrough science is leading on to the development of exciting technology for the more accurate evaluation of fracture risk and earlier detection of people at risk of fractures; something that you can read more about on pages 15–17.

I was very fortunate, just prior to going to print, to be able to ask Professor Hansma some questions about bone glue, which will aid in our understanding of how bones work and what determines their strength. This is quite scientific, so if you’re not scientifically minded you’re allowed to skip this section; neither of us will be offended.

A short scientific interview with Professor Hansma

Max Tuck (MT): What is bone glue? We know apparently that it is not collagen, but do you have more information about what exactly it is?

Paul Hansma (PH): The current best evidence[2, 3] is that heavily phosphorylated proteins such as osteopontin and bone sialoprotein are primary constituents of bone glue. In the presence of calcium ions, strong ionic bonds are formed between phosphate groups on the same phosphorylated protein polymer or between phosphorylated polymers. It is important to know that proteins like osteopontin and bone sialoprotein are known to have no tertiary structure. That is, they do not fold into compact structures like biology books are full of. Rather they remain as unstructured, unfolded polymers, which are ideal for their putative role as adhesives.

MT: Can bone glue regenerate?

PH: Yes! The osteocytes that are maintained by the body at high density and correspondingly high metabolic 'cost' can produce and secrete these proteins. My own theory is that one of the major roles of the osteocytes is to replenish degenerated bone glue. In support of this theory is the fact that osteocytes are known to produce more of these proteins in the presence of shear stress of fluid moving over the cells, which occurs when bone is strained – the strains create fluid flow in the canaliculi that contain the processes of the osteocytes. This could be an elegant mechanism. Too much strain in a bone results in the production of bone glue to reinforce it.

MT: Is bone glue evenly distributed through the skeletal structure or is it more concentrated in certain parts of the body?

PH: It is more concentrated where it is needed, for example at the cement lines in bone, which are regions of weakness because they have no mineralised collagen fibrils crossing the lines

to reinforce them. Osteopontin is also, unfortunately, present in gluing plaque to the insides of arteries! See also chapter 7. Phosphorylated proteins are such good glues that the body is very careful about where they occur. One of the routine blood tests most people get is for their Alkaline Phosphatase level. This is an enzyme with the job of dephosphorylating proteins in the blood to prevent things sticking together.

MT: The sacrificial bonds, which you explain and so clearly demonstrate in your lectures and videos; is there anything that potentially stops them from reforming, thereby affecting fracture resistance?

PH: Absence of water will keep them from reforming, so good hydration is essential. This is one reason that mechanical tests on damp bone (or, even worse, dry bone) are so different from tests of bone that is in solution, like it is in the body. This is one reason that tests with the Osteoprobe [see below] are so valuable: they test the bone inside a patient's body, where it is in its natural environment.

MT: Do we know how the bone glue gets into the bones in the first place? Does it form in the foetus, and which tissue produces it?

PH: A lot is known about the production of proteins, including osteopontin and bone sialoprotein during development. In fact, in the past it was believed that their only role was in development for promoting or inhibiting mineralisation at appropriate times. The idea that these proteins have a mechanical role is relatively new and slowly gaining acceptance.

It's not just bone cells

Anything that affects the cells involved in bone building and remodelling will in turn affect not only bone strength, but many other physiological processes throughout the body, since cell receptors that are present in bone are also found in numerous other tissues. Whilst it is very important to look after our bones

as we age, it doesn't stop there. The good news is that anything that is beneficial to bone health will also positively affect our health in other ways. Indeed, the dietary regimes and lifestyle choices that promote our bone health and strength will have the 'side effect' of reducing the susceptibility to cancer, heart disease, diabetes, stroke, obesity and many other common diseases. You'll find out more about these added benefits as we progress through the chapters.

How can we measure bone strength?

'The best way to test the strength of a bone is to break it.' These are the words of Professor Hansma, and in effect, he is absolutely right. Ideally, to work out our risk of fracture, we need to take a bone out of the body, hit it with a hammer and see how much force is required to smash it to bits. Fortunately, modern-day research is not this brutal, but when we consider how to detect if we are at risk of fracturing a bone following, for example, a simple fall, we need to look at ways of measuring the strength and resilience of our bones to such trauma. Current methods are not 100 per cent accurate in this determination, since bone density is only part of the equation, as you'll see from the diagram below.

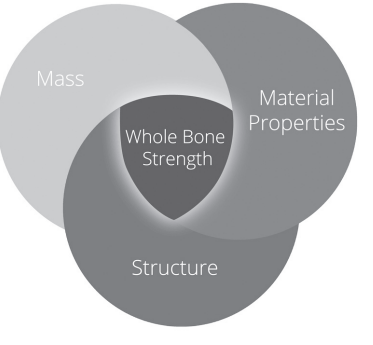

Image provided courtesy of ActiveLife Scientific Inc, manufacturers of OsteoProbe and BioDent technologies, Santa Barbara California, USA.

Chapter 2

Current methods for evaluating bone health

DEXA (DXA) scanning

We often hear about bone density measurement, but the density of the bone is not always an accurate indication of how likely it is to break when an external force is applied to it. Bone density is measured by a dual-energy X-ray absorptiometry (DEXA or DXA) scan, which is an assessment of how much calcium is present in the bone. (Read more about calcium in chapters 3 and 7.) The scan is essentially a two-dimensional X-ray, which provides an estimate of the mineral density of the bone in the region studied. Common areas to examine are the total hip, femoral neck, spine and wrist. Since the test is based on two-dimensional imaging, and of course bones are three-dimensional, it gives an estimate of density rather than a direct measurement.

The accuracy of this density estimate is affected by many factors. Smaller people with smaller bones, (i.e. those with a small frame and low body weight, such as myself) will achieve lower scores, machines from different manufacturers might give non-comparable results, different anatomical sites might give different results for men but not women, and any abnormalities in the area being scanned, such as surgery or compression fractures, will also affect the results. The density measurement is generally reported as a 'T-score', which is the amount of deviation from the average reading seen in a young adult of the same sex. The reading you get from a DEXA scan is therefore not an absolute value, but one that is compared to general population statistics.

Despite these limitations, DEXA scans can provide some useful information about bone health. While the T-score cannot tell an individual their absolute risk of fracture, it does give an estimate of relative risk, the risk compared to others with 'normal' density. It is currently regarded, in the medical profession, as the best measurement test available to provide this information.

However, it is still stated that a DEXA scan cannot diagnose over 80 per cent of the 200 million people worldwide who may be at risk from a fracture.[4]

The DEXA scan tells us about the amount of bone (the quantity), but not the quality of the bone itself. And quality, the underlying strength of the bone material, is probably the most important consideration. As with any structural material, both the quantity of that substance and its underlying quality are critical in determining its overall strength.

Is there a better way?

New techniques are currently being examined to evaluate whether they are better predictors of fracture risk than bone mineral density (BMD) measurements via DEXA scans. As we now know, DEXA scans do not give information regarding the health and thickness of cortical and trabecular bone, only the overall density, which, as we have seen, does not always accurately correlate with the likelihood of a fracture and the resistance to applied forces. Greater accuracy may be provided via CT scanning, which gives an indication of bone structure, and such techniques are being used experimentally in Europe to evaluate better ways of predicting fracture risk.[5] The disadvantage of this method, aside from cost, so far has been that a relatively high dose of radiation is required, although early results are encouraging.

Results from recent studies using new applications of ultrasound techniques and MRI imaging are becoming available, and preliminary studies show the value of these new techniques in the measurement of bone structure, to estimate bone strength and assess fracture risk more accurately. However, to become clinically useful, many of these methods require further investigation to increase their ease of use and decrease their cost. They are techniques which might show us, in the future, that

we were possibly worrying unduly about a low BMD reading, and that it was not necessarily giving us the full picture on our fracture risk.

The FRAX Algorithm

The FRAX Algorithm has been developed by the World Health Organisation (WHO) to give an indication of 10-year hip or other major osteoporotic fracture risk.[6] It is based on individual patient models and integrates clinical risk factors with BMD (bone mineral density) measured at the hip. Where BMD readings are not available, charts have been produced that can be used with body mass index (BMI) readings, which is calculated by taking your weight in kg and dividing it by your height in metres squared. As an example, I weigh 53 kg and I am 1.65 metres tall. To calculate my BMI, I multiply 1.65 by 1.65. This gives 2.72. I then divide my weight (53 kg) by 2.72, giving me a BMI of 19.48.

Risk factors listed in the questionnaire are quite limited. They include smoking, previous osteoporotic fracture, a parent sustaining a hip fracture, use of glucocorticoid (steroid) drugs, consumption of more than three units of alcohol per day (see chapters 4 and 10), and being affected by rheumatoid arthritis or secondary osteoporosis. It does not take into consideration any of the other factors that you will discover, through this book, to be detrimental to bone strength; for example high animal protein consumption (chapter 5) and a sedentary lifestyle (chapter 12) to name but two. It is a useful tool nonetheless for those who do not have access to other diagnostic modalities.

A long-awaited breakthrough

Some very good news on bone quality testing is just now emerging from the USA, and a new 'bone probe', invented by Professor Hansma, has been developed by a company called ActiveLife

Scientific in California. They have so far developed two types of bone probe: the OsteoProbe, which is currently being used for research purposes only, and the BioDent probe, which has been the subject of numerous published studies. 'Microindentation', which is measured with these probes, could indeed be the new buzzword in the diagnosis of osteoporosis, and in the future may become the gold standard of assessment of fracture risk, if the early, encouraging studies prove to be correct.[7, 8] By using bone probes, it has been ascertained, so far, that diminished bone quality in the tibia (shin bone) is a good indicator of the quality of bone throughout the body.

Briefly, microindentation is a technique of using a microscopic probe, inserted into the bone, to give a reference reading of how hard the bone tissue is; i.e. how resistant it is to insertion of the probe. Previous attempts at measuring such forces have been difficult, since when you push on something, be it bone or anything else, it moves away from you. Professor Hansma's device uses the concept of 'reference point indentation (RPI)' which gets around this problem. The readings obtained relate to how easy, in effect, it is to insert the probe into the bone: the greater the resistance to insertion, the stronger the bone, and vice versa. The wonderful science behind this instrument is as follows (from Professor Hansma's website):

> *The Reference Point Indentation instrument will measure microscopic materials properties of the bones of living patients with accuracy and ease. Our hypothesis is, and our preliminary results are in agreement, that a measure of microscopic fracture resistance with the Reference Point Indentation instrument in an individual's bone correlates with their resistance to macroscopic bone fractures, or, stated another way, their overall bone fracture risk. Indentation testing is already well-established as a powerful tool in characterizing mechanical properties of materials.*

Fundamental research has revealed that bone fractures begin when the organic matrix of the bone, or 'glue' holding mineralized collagen fibrils together, fails causing crack propagation. Preliminary results with the Reference Point Indentation instrument have shown that an individual's susceptibility to this fundamental failure mode can be measured by indentation tests in which bone is forced, on a microscopic scale, into the same types of failure – separation of mineralized collagen fibrils – that is the root event of bone fractures. Preliminary results with the Reference Point Indentation instrument have also shown that the necessary measurement can be performed on bone that is still covered with soft tissue (skin).

The great news for the future of our diagnosis system is that the probe is small and easy to use; small enough to be stored on a doctor's desktop, and, as such, has great potential to become incorporated into general use. I, for one, would be very happy to undergo a test such as this; it eliminates the need for exposure to ionizing radiation (X-rays and CT scans) and takes very little time. It could well become the future of accurate diagnostics and fracture risk assessment.

Chapter 2 summary

- Bone is made up of organic (protein) and inorganic (mineral) components.
- There are three types of active cells in the bone: those which build bone, those which break it down, and those which act as communicators.
- 'Bone glue' is a fascinating new discovery which could, in the future, give us an amazing insight into bone health and strength.
- DEXA scans have their limitations and might not be the best way in which to diagnose patients who are most at

risk of fractures. Recent developments in technology, such as the OsteoProbe, could pave the way for better diagnosis and earlier detection in the future.