Ball history

The game of tennis (more properly known as lawn tennis) was developed in the 1870s from the game of royal or real tennis, which has been played for centuries. While both games are similar, in that they are both based on two or four players opposing each other from different sides of a net hitting a ball back and forth, the type and size of court, method of scoring, etc., are very different.

Real tennis balls have been traditionally made from a spherical stitched envelope of leather or cloth stuffed with rags, horsehair or similar material, while tennis balls have always been based on rubber.

From the beginning of lawn tennis in the 1870s, India rubber, made from a vulcanisation process invented by Charles Goodyear in the 1850s, was used to manufacture lawn tennis balls.

Originally tennis balls were made solely of rubber, but the wearing and playing properties of the balls were improved by covering them with flannel stitched around the rubber 'core'. The ball was quickly developed by making the core hollow and pressurising it with gas. Originally, core manufacture was based on the 'clover-leaf' principle whereby uncured rubber sheet was stamped into a shape resembling a three-leaf clover and this was assembled into a roughly spherical space by machinery adapted for the purpose. Chemicals generating pressurising gas were added prior to closing the assembly and these were activated on moulding the core to a spherical shape in heated cavities. The process was used for many years until the precision of the game demanded a higher degree of uniformity (particularly relating to wall thickness) than could be obtained with the clover-leaf method. Now it is usual to compression mould two separate 'half-shells' which are assembled together to produce a 'core'. The original flannel cloth was replaced by special 'melton' cloth made specifically for the purpose and the stitching has been replaced by a vulcanised rubber seam.

Historically, balls were either black or white in colour, depending on the background colour of the courts. In 1972 the ITF introduced yellow tennis balls into the rules of tennis, as research had shown these balls to be more visible to television viewers. Meanwhile Wimbledon continued to use the traditional white ball, but eventually adopted yellow balls in 1986.

Until high altitude balls were introduced into the rules in 1989, only one type of tennis ball was allowed. The Type 1 and Type 3 balls were introduced into the rules in 2002.

Other properties of the tennis ball have changed over time. The range of forward and return deformations - the change in the ball's diameter under an increasing and decreasing load of 8.165 kg - have varied over the years, reaching their current values in 1996.

Modern 'Real-tennis' ball featuring hand stiched seams

Traditional white 20th-century lawn tennis ball

Optic yellow cloth was introduced in the 1970's

Tennis court history

There are many theories as to the origins of tennis but many believe that the early form of tennis can be dated back to the 11th century when monks used to play hand ball around the cloisters of monasteries. The game gradually evolved to the game of Real Tennis, the precursor of the modern game, and became very popular with the French and British nobility. Henry VIII was a keen player and had the original Real Tennis court built at his Palace at Hampton Court but Charles II later re-modelled the court in the 17th century to the court that exists today which is the oldest in Britain.

Grass

Real Tennis was and still is played on hard surfaces, wood or

tury that "Field Tennis"
courts. It wasn't until
nnis as we know it
n Wingfield patented
of the court was
rking but the shape of

5 to today's design
n up by Marylebone
quet Club adopted the
name to the All
England Lawn Tennis & Croquet Club, home of the Wimbledon Championships.

Until the early 1970s, the majority of tennis tournaments were played on grass, including three out of the four Grand Slams – Wimbledon Championships, Australian Open and the US Open. Wimbledon is now the only Grand Slam event played on grass, whilst the majority of professional tennis events played on grass take place in England.

Clay

Clay courts are mainly found in Europe and South America and up until the 1980s, virtually all the courts in Spain and Italy were clay courts. The French Open championships at Roland Garros is the only Grand Slam event to be played on clay.

Acrylic/Asphalt/Concrete

These mateirals, traditionally used in civil engineering, can be porous or non-porous (impermeable). They utilise a wide variety of surface textures, colours and names. It was not until the 1940s that acrylic courts were used in official tournaments. Now, the Australian Open and US Open are both played on acrylic courts.

Carpet

'Carpet' is the term used for most synthetic indoor surfaces and the first carpet surface was called 'Sportsface'. In the 1970s, 'Supreme' became the first rubber mat surface to become widely accepted. Artificial grass is also a surface used in tennis as well as other sports such as hockey and football. The pace of the court can be varied by adding sand or rubber granular material.

Racket history

1100 AD – The Hand

The earliest known tennis racquet was the human hand. Historians tell us that monks played an archaic form of the game in the cloisters of French monasteries, using their hands to strike a ball made from animal skin.

Within a short period of time these tennis players started protecting their hands with gloves, using animal skin to absorb the impact of the ball. Before long, however, players began using wooden paddles to strike the ball, thereby eliminating the discomfort caused by hitting the ball with the hand.

These early origins of the tennis racquet are preserved in its name, which is derived from the Arabic word for the palm of the hand - rakhat.

1300 AD – The Palla

It took two centuries for the primitive paddles used to play tennis with to evolve into the forerunners of the modern tennis racquet. The Italians are credited with this step in the evolution of the tennis racquet, which they achieved by introducing the use of animal gut strung across wooden frames.

This new design was a quantum leap forward in the evolution of the tennis racquet, increasing the shock absorbent properties of the racquet whilst also allowing for more powerful strokes, as well as a greater variety of shots.

Despite similarities in construction, the palla looked very different from the modern racquet, having had a long handle and a small head.

The Traditional Wooden Racket

Rackets for Tennis (or Lawn Tennis as it was originally called when first introduced in the 1870's) were developed from those used for Real or Royal Tennis played for centuries previously. These rackets were made from wood fashioned and glued into many variations of the now familiar key-hole shape. They were individually crafted in the early years and this led to a multiplicity of ideas regarding general form, strength, weight and stringing arrangements, many of which were covered by patents.

In 1874 Major Walter Clopton Wingfield formalised the rules of modern tennis, giving the game the unwieldy name of 'Sphairistike'. Keen to cash in on his initiative, Wingfield also took it upon himself to market the equipment required to play the game.

While Wingfield's somewhat cynical attempts to patent the game of tennis proved unsuccessful, he did meet with modest success in his efforts to sell tennis equipment. The racquet sold by Wingfield had a larger head and shorter handle than the palla, and would remain unchanged for the next century.

While racket frames were originally made mainly from ash because of its good specific strength, its toughness and its ability to be bent to the required shape, it was early recognised that metal tubing could also be used for the purpose but problems were experienced with the incompatibility of tensioned strings with the sharp edges of holes drilled in the tubing. This was not a problem with wooden frames and successful metal frames had to wait until this was overcome and, importantly, until improved metal alloys were produced. The later development of composite frames became possible only because of the development of carbon fibre and associated manufacturing techniques in the 1960's.

Wooden Frames

Initially these were made from one or more sticks of ash bent to the required shape and glued with 'animal glues'. Mechanisation in the 1940's allowed a larger number of thinner 'veneers', bonded with urea-formaldehyde adhesives, to be used so that a multiplicity of layers could be incorporated which could be more easily bent to shape and so that the natural variability in wood could be 'averaged out'. In addition to ash, other wood types including maple, sycamore and hornbeam have been used in the main frame member to provide desirable strength and stiffness properties; hickory, for wear resistance in the outer layer; beech and mahogany for throat and handle cosmetics and obeche as a lightweight filler in the shaft.

Selection of wooden rackets from the 1960's

Over many years of evolution, the shape, size and resulting weight (a compromise to give satisfactory durability) became largely standardised across the industry and limiting parameters were not specified by the controlling authority, the International Tennis Federation, until 1979, when the introduction of new materials made this necessary. The wooden tennis racket was manufactured in quantity until the early 1980's when metal and later composites took over.

Metal Frames

The problem of stringing metal rackets was not satisfactorily solved until a method was devised and patented by Lacoste in 1953 in which the racket strings were made to pass around metal wires looped to the frame. The result was the first commercially successful non-wood racket and this was subsequently marketed as the Wilson T2000 and successfully used by Jimmy Connors over many years, notably in winning the Wimbledon Singles title in 1974 and 1981.

Examples of typical 'I-beam' metal rackets of the 1970's. Note that the bridge is screwed to the frame

The commercial success of this racket in the early 1970's encouraged competitors to develop other types – some based on hollow aluminium-alloy extrusions and very stiff frames using carbon-steel. The use of metal tubing determined that the racket frames invariably had twin shafts unlike the single shafted wooden frame. This meant that a 'bridge' member had to be incorporated between the shafts to complete the head loop which had to be welded-in but in some cases a plastic moulding positioned with screws was used for simplicity. Plastic 'grommets' were developed to insulate the strings from sharp hole edges and such developments together produced successful rackets which began to erode the market for wooden rackets. In the longer term, aluminium rather than steel rackets have been made in larger numbers because their simpler process of manufacture has made them commercially more competitive.

In the mid 70's, the increased stiffness and strength offered by metals led one manufacturer, Prince, to develop and patent a racket with a larger than normal or 'oversize' head and this was subsequently followed by other manufacturers making rackets with a variety of head sizes. At that time, no limit on head size was specified by the International Tennis Federation, but a limit was subsequently imposed in 1979. While this allowed the stringing area to be increased by up to around 100% compared with the standard wooden racket of the time, rackets of head size limited to some 30 to 50% larger have subsequently been favoured.

Composite Frames

Using technology first used in ski manufacturing, Head combined the use of metal and plastic to develop the first composite racket in 1969 which was marketed under the name 'Arthur Ashe Competition'

The recognised success of metal rackets in the early 1970's led to experimentation with other non-traditional materials, particularly glass fibre and the newly developed carbon fibre (usually referred to as 'graphite' in the sports industry). Although very expensive, carbon fibre was preferred as it had greater specific stiffness and strength, in fact several times that of steel, and so offered significant prospects for further racket frame development.

Fibrous materials, by their nature, have uni-directional strength properties and so have to be used in a form where this can be properly utilised. This is done by alternatively weaving tows of fibres into a fabric which is subsequently impregnated with a thermo-setting 'epoxy' resin, or by using such a resin to coat fibre tows and aligning them to form a 'warp sheet' in which the resin holds the tows together in sheet form. Several sheets of the impregnated fabric and/or warp sheet (now termed a 'composite material') are then layered together with their tow alignments angled to provide subsequent multi-directional strength properties.

The process of making a racket frame from such laminated sheet material involves forming it first into tubular form by rolling it around a plastic tube capable of subsequently being pressurised with air. Local areas are reinforced with extra material and the whole assembly is fitted into a mould of the appropriate shape and cross-section to form the main keyhole-shaped structure of the frame. An extra 'bridge' component is added of similar material to complete the loop of the head and the assembly is moulded under heat and applied internal air-pressure to cure and so harden the resin. This procedure has been developed by many manufacturers to become recognised as the basic method for making composite racket frames. In some cases the internal pressurisation is obtained by the heat-expansion of a plastic-foam core instead of pressurised air in an inflation tube.

While the manufacture of such a frame requires much handwork, one advantage is that specific areas of the frame can be individually strengthened, as noted above, prior to moulding. This allows just sufficient strength and stiffness to be created were necessary so that the overall structure is as light as possible. Metal rackets using uniform drawn or extruded metal tubing are at a disadvantage in this respect.

Many variations have been developed on the basic method described. One is where the tubular assembly is made up from a concentric assembly of tubular braids made with carbon fibre to which are assembled onto the inflation tube and then arranged in the mould. The mould is closed and the resin then injected prior to internal pressurisation and heating. Another is where the hollow tube is formed from two separate mouldings of 'C' cross-section are joined together by adhesive bonding to form the 'O' section of the tube.

Other variations involve using a thermoplastic matrix rather than a thermosetting type. One such method involves combining thermoplastic filaments, usually nylon, with the carbon fibre filaments in the tows when using the tubular braiding method above. On heating and subsequent cooling, the nylon melts and fuses the carbon fibres together to form a rigid structure.

A method based on a thermoplastic matrix departs radically from any of the foregoing. In this method, to reduce hand-work involved in manufacture, 'chopped' carbon fibres a few millimetres in length are mixed into a nylon matrix and the resulting compound injected into a mould the shape of a tennis racket where it solidifies. To form a hollow moulding, a 'core' of a fusible metal alloy is placed in the mould prior to injection and this becomes sheathed in the carbon fibre-reinforced nylon. The core is subsequently melted-out and a hollow frame results. This method, while used to produce rackets by Dunlop in the 10-year period 1980-1990 and successfully used to win Wimbledon Championships in this time, could not be adapted to make the larger headed, lighter frames subsequently becoming available using conventional manufacturing techniques.

In general, the use of carbon composites has allowed rackets to be made larger in head size, stiffer and lighter in weight than the most up-to-date wooden rackets of the 1980's. Larger heads allow larger 'sweet-spots' (i.e. a larger contact area where higher ball velocity can be developed) and better control of off-centre ball contact. Increased stiffness reduces energy absorbed by the frame on ball contact and so increases applied ball velocity. While light weight is not in itself an unconditional virtue, in combination with a larger head and greater stiffness the composite racket of today provides a player with distinct advantage over its wooden fore-runner. A current composite racket can have a 40% larger head, be 3 times stiffer and 30% lighter than the most highly developed wooden version.

To provide a variety of playing characteristics, rackets have been developed successfully with a variety of special features; for instance, with the ultimate in stiffness by grossly increasing shaft cross-section, with special combinations of weight, stiffness and balance and by the incorporation of special shock and vibration absorbing elements.

The Future?

The tennis racquet has rolled onto an evolutionary plateau. While small modifications to the weight, graphite composition and the aerodynamic properties of racquets will continue, these modifications are unlikely to result in substantial changes to racquet performance.

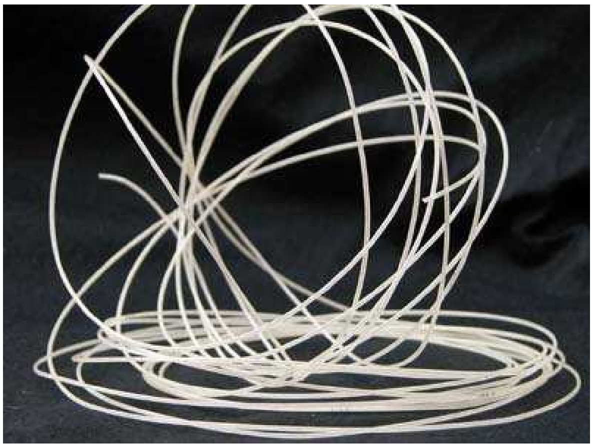
The next step in the evolution of the tennis racquet is likely to take advantage of advances made in the field of micro electronics. The focus at present is the contact area of the racquet and ensuring that the racquet responds optimally to contact by converting impact energy into electric energy, and then using this energy to strengthen the frame at the moment of impact.

Rackets on Display:

1920-75 (Borg) 1970-1999

McEnroe 1978-2010 Juniors' rackets 2000-2010

Strings



The interlaced pattern of string makes contact with the ball and the frame acts as a vehicle to position this hitting surface at the required velocity and time.

During a typical serve the strings impact the ball with such force that both deform extensively, yet within 5 milliseconds (5 thousanths of a second) they both recover their original shape.

In fact, the collision is not perfectly elastic and some energy is lost in the process as heat and sound. Most of this energy is lost through deformation of the ball, because the strings are much more elastic. Looser strings deform the ball less so less energy is lost and exit ball velocity is increased.

In the 1920s, the average tension of the strings was 20 kgf (44 lbs). Nowadays the tension has increased to over 25 kgf (55 lbs), with some professionals using tensions approaching 35 kgf (77 lbs). Many of the older, wooden rackets warped under the load of the strings, but the strings themselves are also subject to creep and lose tension over time.

Natural gut

The first lawn tennis rackets, used in 1874, were strung with the stretchy, outer skin of sheep intestine, known as serosa. Indeed, sheep gut is remarkably well suited to the job of providing outstanding flexibility, elasticity and retention of tension. However, a shortage of sheep gut following World War II forced manufacturers to look for other natural gut alternatives. Cow gut was eventually adopted after several years of experiments with pig and horse innards. The number of animals that were needed to make a set of strings was halved by this change (from 6 sheep to approximately 3 cows), as was the number of strings per racket. Between 11 and 12.2 metres of string is needed to string a tennis racket. Sheep intestines are typically less than 8 metres long, so conventionally two strings were needed per racket. Longer cow gut permitted single-string rackets to be produced from natural gut for the first time. This enabled faster stringing times, although two strings allow hybrid combinations (different strings for main and cross strings) and normally longer lifetimes.

The initial stage of natural gut production involves soaking the entrails in a chemical bath to remove contaminants. They are usually bleached to give a perfectly clear string, although some manufactures prefer not to decolour their strings. The strands are spun and slowly dried, and the resulting fibres are polished to smooth out any defects and achieve the required diameter. The final step is to apply a protective polyurethane coating.

Synthetic strings

Two main drawbacks of natural gut have encouraged the development of man-made materials for strings. Although animals are not reared specifically for their serosa (it is collected as a by-product from the abattoir) the cost of natural gut is comparatively high. Additionally, durability in terms of wear and moisture resistence is mediocre.

Synthetic strings are made primarily from nylon, polyester or Kevlar (either individually or in combination), using a single solid strand or up to hundreds of small filaments. The fibres are made by a process of extrusion. Molten polymer is drawn out of a die with small holes (bushings) called a spinnerette. The fibre solidifies as it exits the spinnerette and is stretched to align the tangle of molecules in the polymer, greatly improving its strength.

The fibres are twisted together in a 'wrapping' process. An outer wrap of thinner fibres is usually added to protect the core of the string and improve durability (solid core, single wrap). In some string constructions, the core is replaced entirely by smaller filaments twisted together in an attempt to recreate spun natural gut (multifilament).

Regardless of construction, synthetic strings do not possess the low dynamic stiffness or 'feel' of natural gut. Nylon is the most favoured of the man-made materials, but polyester and kevlar are used to increase durability