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.

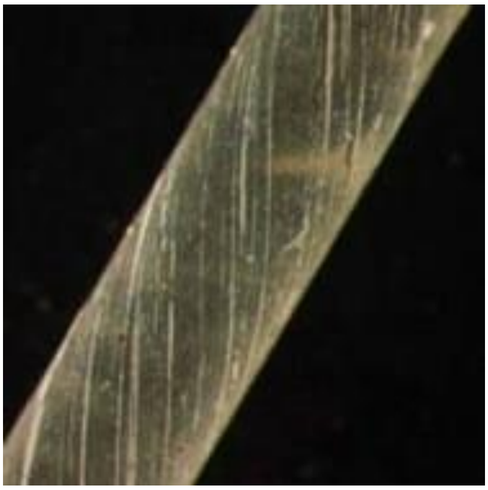
During a typical serve the strings impact the ball with such force that both deform extensively, yet within 5 milliseconds (5 thousandths of a second) they both recover their original shape.

However, 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 lbf). Nowadays the tension has increased to over 25 kgf (55 lbf), with some professionals using tensions approaching 35 kgf (77 lbf). 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.

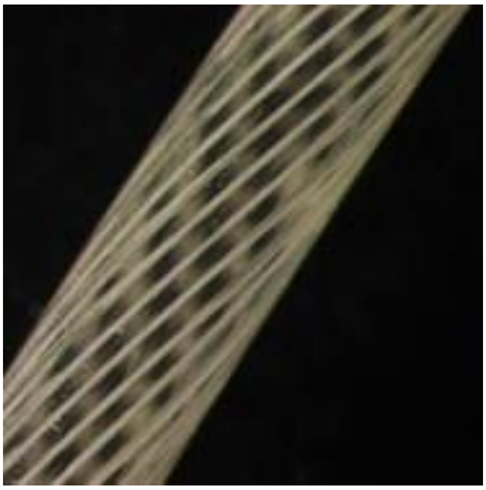


However, a shortage of sheep gut following World War II forced manufacturers to look for other natural gut alternatives. Cow gut was eventually adopted after several years of experiments with pig and horse innards.

The number of animals that were needed to make a set of strings was halved by this change (from six sheep to approximately three cows), as was the number of strings per racket. Between 11 and 12 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 resistance 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.

String Area Properties

Reducing the tension in the strings can produce a more flexible string area or lower stringbed stiffness. For a groundstroke, a 25% decrease in tension corresponds to a 2% increase in speed, a serve profits from just a 1% increase.

The stiffness of the stringbed is also affected by the arrangement of the strings. If the space between strings is increased the face becomes more flexible. Similarly, increasing the length of the strings, by enlarging the head for example, lowers the stiffness of the stringbed.

Several reasons have been proposed to explain that reducing the stiffness of the string area is detrimental to control:

1. The hitting surface distorts more during impact, increasing the range of angles at which the ball may fly off.
2. The ball deforms less, so the size of the contact area, which helps to direct the ball, is diminished.
3. The dwell time is extended, so the racket can rotate further during impact, which reduces the control the player has over the racket.

A benefit of the increased dwell time is that a smaller force is spread over a longer period, resulting in reduced shock on impact.

String gauge

The diameter of a string is more commonly referred to as its gauge. The more popular gauges lie between 1 and 1.5 mm, or 15 to 18 on the American scale (see Table 1).

A thinner gauge makes the string more flexible, but also reduces its durability. Minute movements between the strings tend to abrade them until they eventually snap at the point of intersection. Although thinner strings are believed to impart more spin on the ball, there is little empirical evidence to support this theory. There is also no appreciable difference in spin produced by rough or smooth, low- or high-tension strings.

European gauge	US gauge	Inches	Milimeters
12	13	0.065 – 0.071	1.65 – 1.80
11	14	0.059 – 0.065	1.50 – 1.65
9.5	15	0.056 – 0.059	1.41 – 1.49
9	15L	0.052 – 0.056	1.33 – 1.41
8.5	16	0.050 – 0.053	1.26 – 1.34
8	16L	0.048 – 0.051	1.22 – 1.30
7.5	17	0.046 – 0.049	1.16 – 1.24
7	18	0.042 – 0.046	1.06 – 1.16
4	19	0.035 – 0.042	0.90 – 1.06
3.5	20	0.031 – 0.035	0.80 – 0.90
3	21	0.028 – 0.031	0.70 – 0.80
2.5	22	0.024 – 0.028	0.60 – 0.70

Table 1. A comparison of European and US string gauges

Stringing Systems

The Rules of Tennis state, "the hitting surface of the racket shall be flat and consist of a pattern of crossed strings connected to a frame and alternately interlaced or bonded where they cross" (rule 4a). This tends to limit the movement between strings and, thus, the spin imparted to the ball. This rule was introduced in 1978 in response to a stringing system patented the previous year (US Patent 4273331, 8 December 1977) which could generate almost twice as much spin as a conventionally-strung racket, dubbed 'spaghetti' stringing.

Spaghetti stringing is illegal because the main and cross strings are not interlaced (or bonded). Instead, the strings lie on parallel planes and are able to move with the aid of tubular sleeves, which act as bearings, see below.

The freedom of movement allows the strings to deflect within the plane of the hitting surface and so rotate the ball as they recoil. The result is that players can produce extreme spin with minimal effort.