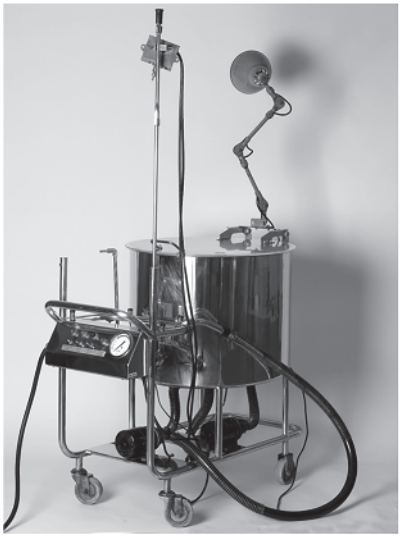
Figure 1.23 A modern syringe design.



(a)

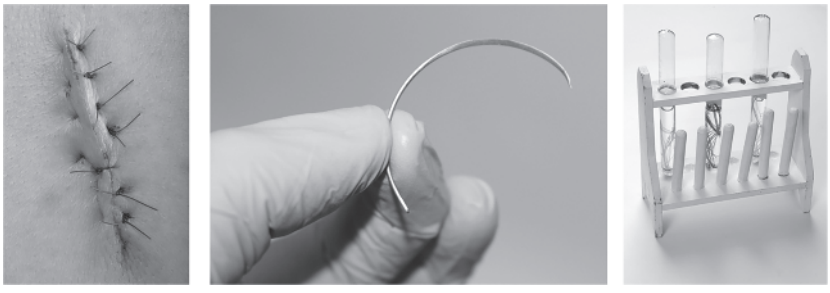
(b)

Figure 1.24 Artificial kidney equipment of 1960s (a) and 2020s (b).

adhesives are not used in this joint, the mechanism of adhesion is explored to ensure a strong and durable connection between the metallic and polymeric parts.

Artificial kidneys or dialysers are equipment used in haemodialysis or renal replacement therapies. Haemodialysis is a method for removing waste products (creatinine and urea), as well as free water from the bloodstream when the kidneys are unable to do so due to pathological causes. Modern dialysers typically consist of a cylindrical rigid casing enclosing hollow fibres, moulded or extruded from a polymeric material. Through the years, the construction of artificial kidneys was optimised, and biomaterial usage was increased, allowing to reduce the dimensions and improve efficiency (Figure 1.24).

For many decades, the default technique for re-joining tissues cut during surgery was to use stitches. However, this technique is strongly dependent on the skill of the medical professional that carries it out. In addition, some scarring due to the stitching remains visible after healing and can only be removed with plastic surgery. This technique ensures the correct position of the two parts to be joined with the tension applied in the line. However, it introduces stress concentrations in the hole created in the tissues, which can lead to failure. In such cases, the patient must return to the hospital to re-stitch the injured part, which can lead to delays in patient recovery and infections. Figure 1.25 shows the stitching technique that is used after surgery



(a) (b) (c)

Figure 1.25 Stitching technique (a), suture needle (b), and threads (c) dated from 1970.

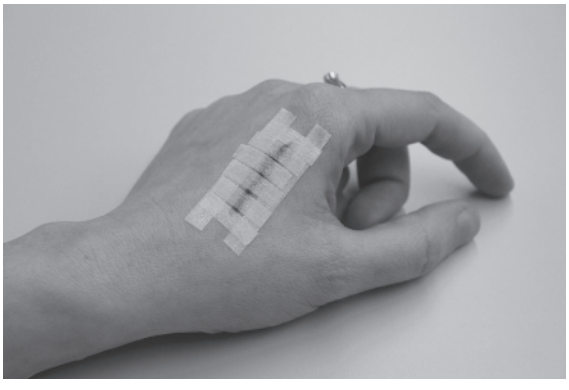


Figure 1.26 Application of an adhesive to join tissues.

and the scarring that remains visible after the tissues heal, which is not acceptable in most cases. In addition, this technique requires the sterilisation of both the wire and needle that are used to avoid infections.

As an alternative to stitching, special adhesives have been developed to join tissues. Using this technique, very little scarring occurs, and the continuously bonded area ensures a well-distributed contact between the joined tissues, drastically reducing the mechanical loads that are transferred to the tissues. The final aspect is not very dependent on the doctor's skill and does not leave any holes. In Figure 1.26, the process of application of an adhesive to join the tissues is shown, evidencing the fact that it not necessary to use any tool on the skin as is the case with stitching.

Some babies are born with defects in the septum of the heart, and their correction implies an invasive surgical intervention. To simplify this method, a team of researchers invented a new method that is much simpler, more effective, and less invasive: the application of an adhesive formed by a new biomaterial. Researchers developed a novel non-toxic adhesive with strong adhesion to the tissue where it is applied and can resist the constant pressure exerted by heartbeats and the presence of blood. It is applied through a small catheter and is quickly activated by light. Figure 1.27 shows an illustration of a defect in the septum of the heart, highlighting how a bio-adhesive can correct the defect. This is an example of a new and much less invasive methodology to correct defects, where adhesives play a key role.

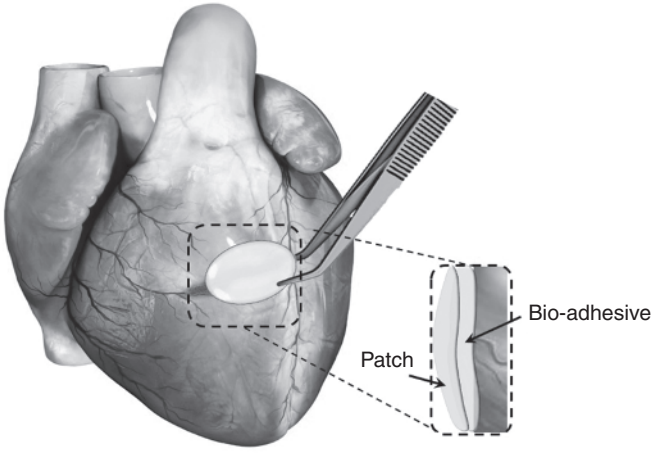


Figure 1.27 The use of bio-adhesive to correct the septum damage of the heart.

In summary, adhesive bonding techniques have been used and developed to create new medical products and techniques that simply would not be possible with traditional joining techniques. In medical applications, the use of the adhesive is growing, being used to simplify the intervention and avoiding the conventional intervention (e.g. organ transplantation), accelerating the healing process.

1.4.5 Electronic Devices

In electronic devices, adhesives are used for attaching and joining of components, allowing to combine many complex parts with different purposes. Electronic devices are constantly evolving to become smaller and more powerful, which is achieved by closely mounting several electronic components without gaps, something only possible with adhesive technology. The adhesives used for this purpose show good thermal conductivity to provide an efficient heat or electrical transfer between the components and high dielectric strength (that is, a high electrically insulating capacity) to avoid undesired current flows or short circuits. The use of adhesive permits greater flexibility in design and allows for a streamlined product assembly process. These are key aspects that have played a role in the development of mobile devices with powerful computational capabilities, improved efficiency while remaining relatively compact (Figure 1.28).

1.4.6 Sport Equipment

The use of adhesives is widespread in many different types of sport equipment, and this is especially true in sports where high performance and efficiency is of the utmost importance, demanding sporting equipment to be built with the lightest materials and manufactured using highly efficient joining techniques. Adhesive bonding again appears as the most suitable technique to join light materials. Sporting equipment is optimised according to the type of use or the

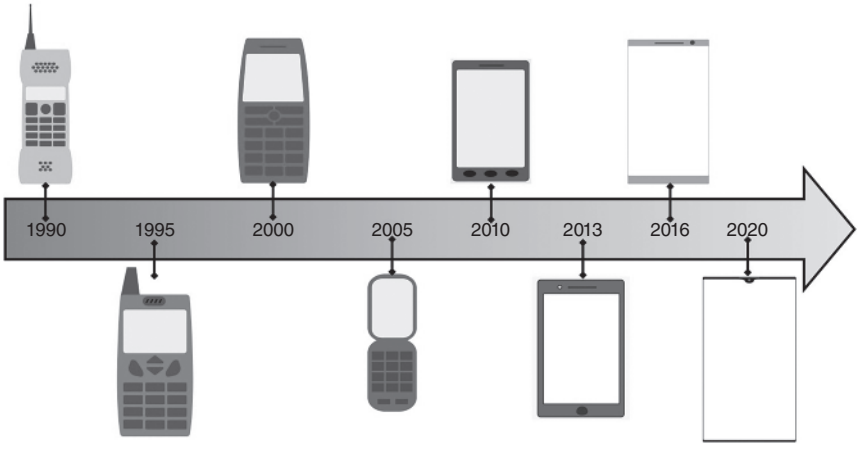


Figure 1.28 Evolution of mobile phones.

(a) (b)

Figure 1.29 Bicycle evolution, bicycle with metal frame (a) and with composite frame (b).

performance of the athlete who will use the equipment. One good example of a high-performance equipment that is only possible with the use of adhesives is bicycles, where aluminium, titanium, and fibre composites are combined in a single product. Adhesives are used to join these materials with highly dissimilar thermal coefficients leading to strong and stiff joints. In Figure 1.29, a comparison is made between a classic metal framed bicycle and a modern composite framed equivalent.

1.4.7 Footwear

The footwear industry is one the most important sectors of the Portuguese economy, as Portugal is one of three main shoe-manufacturing countries in the world. In the last 20 years, the footwear industry has completely changed from traditional methods of production (almost purely handmade) to much more modern methods of production (becoming almost fully automatized). In the traditional methods, the main materials used were limited to rubber and leather, joined by sewing processes (Figure 1.30). Nowadays, there is a much wider range of materials that are used in the shoe construction, such as textiles or foams, which have led to more comfortable

(a) (b)

Figure 1.30 Shoes manufacturing, (a) sewing technique and (b) bonding technique.

shoe designs. However, these softer, more compliant materials cannot be stitched, as they become easily damaged by the holes, which are essential to the stitching process. For these new materials, only adhesive joining can ensure a strong and durable joint. Adhesives are also used efficiently in more specific applications, such as baby shoes and fireman boots, maintaining the integrity, safety, and strength necessary in these conditions.