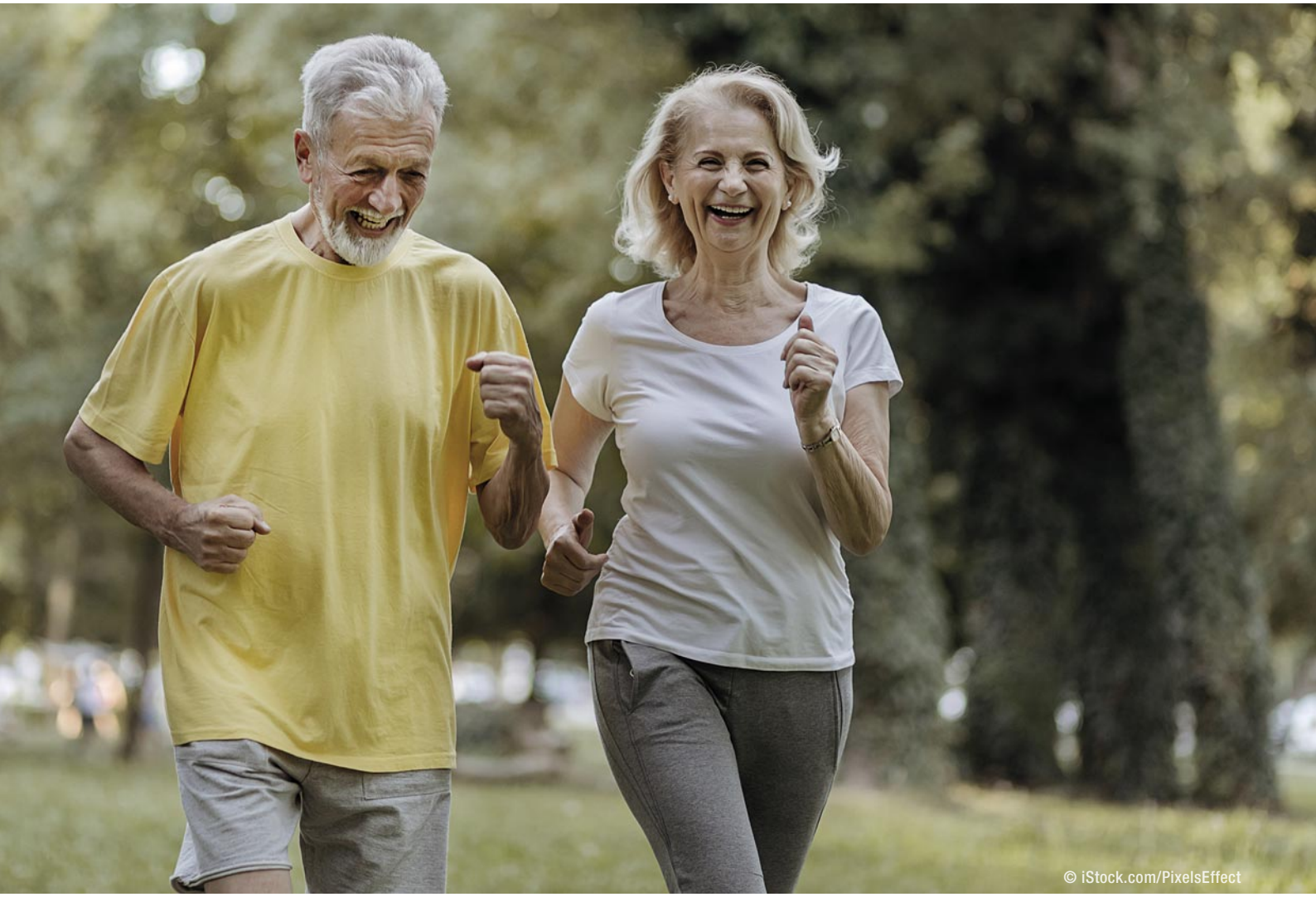
INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

The stent (r)evolution

When a blocked artery causes a heart attack, a tiny metal tube called a stent can restore blood flow. As these life-saving stents have become ever finer and more sophisticated, their materials have evolved too. Molybdenum has played a role throughout this evolution, from early stainless steel designs to some of today's most advanced stents.



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Heart disease is the world's leading cause of death, accounting for one in three lives lost each year. The heart pumps around 7,500 liters of blood through the body each day and depends on its coronary arteries for its own blood supply. These arteries can become narrowed by the buildup of fatty deposits, known as plaque. If the plaque ruptures, a blood clot can form and partially or completely block the artery, cutting off the flow of blood to the heart muscle. If blood flow is not restored quickly, the resulting damage to the muscle can lead to a heart attack.

Placing a stent

When a significant narrowing or blockage of an artery is suspected, a procedure called coronary angiography can reveal its location and severity. A catheter, usually inserted at the wrist or groin, delivers an iodine-based contrast agent that is visible under X-ray, allowing doctors to pinpoint the obstruction. If the artery needs to be reopened, a thin guidewire is passed through the narrowed area and a balloon catheter carrying the collapsed stent is advanced along the guidewire. When the balloon is inflated, it pushes the plaque against the artery wall and expands the stent, restoring the vessel to a sufficient diameter for blood to flow. The balloon is then deflated and removed, while the stent remains in place to support the artery.

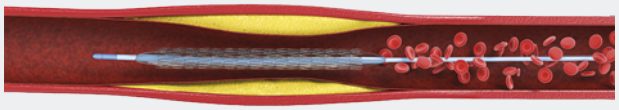
The evolution of stenting

A major breakthrough in treating narrowed coronary arteries came in Zürich in 1977, when cardiologist Andreas Grüntzig performed the first successful coronary balloon angioplasty procedure on a 38-year-old patient. Instead of opening the chest, Grüntzig guided a catheter carrying a small balloon through the patient's blood vessels to the narrowed artery. When inflated, the balloon pressed the plaque against the artery wall and restored blood flow. This procedure revolutionized treatment, but its benefits were not always lasting; after balloon angioplasty alone, the artery could recoil or gradually narrow again, a process known as restenosis.

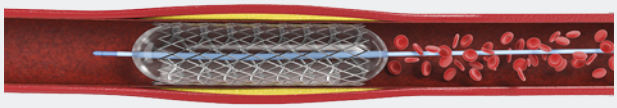
The next breakthrough came in 1986, when French cardiologist Jacques Puel and Swiss cardiologist Ulrich Sigwart implanted the first coronary stents. Unlike balloon angioplasty alone, the stent remained in the artery after the balloon was withdrawn, holding it open and reducing the frequency of restenosis by around half. Early stents were made primarily from Type 316L stainless steel.

Yet stenting presents another challenge. Implanting the stent injures the inner lining of the artery, and the resulting healing response can cause excessive tissue growth within the stent, again narrowing the passage. Drug-eluting stents were developed to reduce this risk. Their surface carries a drug that inhibits excessive cell proliferation and is gradually released into the surrounding tissue. Today, drug-eluting stents have largely replaced bare-metal stents in coronary interventions.

Sequence of stent placement



Closed stent positioned in the narrowed artery.



Stent expanded with a balloon catheter.



Expanded stent remains in place, allowing blood to flow freely.

Coronary stents are typically 2.25 – 4 mm in diameter and 8 – 38 mm long, while strut thickness has decreased from around 120 –140 µm in earlier stents to as little as 60 µm today.

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Why thinner struts matter

A stent must balance competing requirements: it needs to be strong enough to hold the artery open yet be flexible and thin enough to travel through narrow and often tortuous blood vessels. To achieve this balance, many stents are manufactured by precision laser cutting an intricate pattern into a little metal tube, leaving a flexible mesh of slender struts, some finer than a human hair.

The thinner these individual struts can be made, the more flexible the stent becomes, which makes it easier to insert. Thinner struts also cause less disturbance to blood flow and less injury to the vessel wall, reducing the risk of restenosis and clot reformation. But reducing strut thickness places greater demands on the material; it must provide the required strength with less metal, while the increasingly fine structure must still be clearly visible under X-ray during placement. These competing requirements have driven the development of ever more sophisticated stent alloys and designs.

Ever more effective alloys

Type 316L stainless steel was the material of choice for the first generations of coronary stents and is still used today. Its combination of strength, ductility, biocompatibility, and corrosion resistance makes it well suited to the demanding environment inside the human body. Its approximately 2.5% molybdenum content provides improved resistance to localized corrosion. The relatively modest strength of Type 316L, however, limited how far strut thickness could be reduced, encouraging the adoption of stronger alloys that could provide the required mechanical performance with less metal.

Two cobalt-based alloys have played important roles in coronary stents: L605, a cobalt-chromium-tungsten alloy containing essentially no molybdenum, and MP35N, a cobalt-nickel-chromium alloy containing around 10% molybdenum. Their higher strength enabled thinner struts than Type 316L while maintaining sufficient radial strength.

L605 remains widely used in current drug-eluting stents. MP35N was used in several generations of coronary stents and continues today in combination with other metals. For example, one modern stent uses a wire with an outer layer of molybdenum-containing MP35N surrounding a dense platinum-iridium core, combining the strength of the cobalt alloy with improved X-ray visibility.

Another approach is platinum-chromium (Pt-Cr), which combines high strength with good X-ray visibility. Platinum makes the stent easier to see under X-ray, while around 2.6% molybdenum enhances corrosion resistance and strength. Pt-Cr is used in major contemporary drug-eluting stent platforms.

A physician views the catheter as it moves through the vessels on a screen.



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Illustration of a modern coronary stent mounted on a balloon catheter before deployment.

A stent designed to disappear?

Stents support reopened arteries while they heal, but after recovery, the metal structure may no longer be necessary and can contribute to late complications. This has prompted research into bioresorbable materials that provide temporary support before gradually degrading in the body. One candidate is Mo-14Re, an alloy containing 86% molybdenum and 14% rhenium. Early research has shown a promising combination of mechanical properties and controlled degradation, making it a potential material for future bioresorbable stents.

From established stainless steels to high-strength cobalt alloys and newer platinum-containing designs, advances in materials have enabled ever finer stents. Molybdenum contributes to several of today's stent materials and may play an even greater role in future designs.

In less than half a century, coronary intervention has progressed from Grüntzig's pioneering balloon procedure to today's highly sophisticated drug-eluting stents. His breakthrough showed that a blocked coronary artery could be treated through a tiny incision rather than major surgery, while successive generations of stents have made treatment more durable, reducing restenosis and the need for repeat procedures. However, even the most sophisticated stent treats the consequences rather than the causes of heart disease. With up to 80% of heart disease considered preventable, a healthy diet, regular exercise, avoiding smoking, and other preventive measures remain as important as advances in treatment. After all, no matter how effective stents become, the best option is always a healthy artery. (Thierry Pierard)