PRODUCTS CONTAINING PLASTICS

By A. G. Fishburn, F.P.S., F.R.I.C.

Department of Pharmacy, Imperial Chemical (Pharmaceuticals) Limited, Hexagon House, Blackley, Manchester, 9

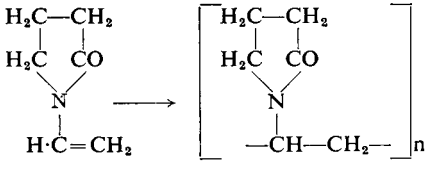
The introduction of plastic materials and chemically related polymers into medicine and surgery is largely a development of the Second World War and the post-war period. Before 1940, only a few semi-synthetic products such as nitrocellulose, celluloid and hardened rubber had been used in any medical connection. Of these, nitrocellulose formed the basis for medicated collodions, while celluloid and hardened rubber were the normal materials for dental plates, the artificial teeth themselves being of porcelain. Shortly before the war, an important advance in dentistry was made in Britain with the introduction of dental plates made of polymethyl methacrylate. By 1941 these were in regular use, although still with porcelain teeth, while in 1946 they were replaced by the now familiar "complete" acrylic denture. The war also provided a stimulus to the exploitation of plastics in several branches of medicine and surgery and led to, *inter alia*, numerous improvements in surgical instruments, a synthetic plasma substitute, and a simplified process for the manufacture of prostheses such as eyes, noses, ears or hands. After the war medical uses were found for newer polymers such as the silicones, while fresh outlets continue to be discovered for other plastics, particularly as they become available in a wider variety of physical forms. The total use of plastics for medical, dental, and related purposes is, of course, extremely small in comparison with that of other arts and industries, and with the possible exception of polyvinylpyrrolidone, no single polymer has its main outlet as a pharmaceutical product. The main advantages which plastics offer to the surgeon are that, in the solid state, they are light, easily worked and moulded, are not cold to the touch, and do not conduct electricity. Some have the additional advantage of transparency. They can usually remain implanted in living tissue for long periods without causing irritation. This has made possible many developments in which plastics have replaced metal and other materials in surgical instruments, in surgical repair and in the fabrication of prostheses. Much of this work is still at the experimental stage, however, and it may well take several years of further investigation before the safety and efficacy of the new materials are fully established. Their optical properties have permitted them to replace glass and have, for example, made practicable the "contact" lens. The fact that many polymers can be converted into mono-filaments of accurately controlled diameter has led to the partial replacement of animal and vegetable fibres in surgical sutures.

Plastics still suffer from certain disadvantages and one of the main difficulties from the pharmacist's viewpoint is that very few can be sterilised by autoclaving and none by dry heat. Comparatively few polymers have been used in medicine, either as active agents or excipients, and, as might be expected, their value lies chiefly in their chemical stability

coupled with a high molecular weight. These properties have been utilised in "slow-release" or "depot-dose" therapy. Numerous other medical uses have been suggested and some are now being explored in the laboratory. It may well be that the availability of non-toxic compounds of high molecular weight and controlled purity may provide in the near future some extremely interesting developments in both medicine and pharmacy.

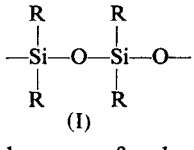
1. *Plastics in Medicine*

Polyvinylpyrrolidone (PVP). The use of this substance as a plasma substitute was developed in Germany during the Second World War, and it has since been introduced into several other countries under a variety of trade names (Periston, Subtosan, Plasmosan, PVP-Macrose, etc.). A comprehensive review of its properties and uses has recently been compiled by Reppe[1]. The chemical synthesis requires only simple starting materials (acetylene, formaldehyde, ammonia) and the final stage is the polymerisation of *N*-vinyl-α-pyrrolidone in aqueous solution. This yields a mixture of polymers covering a wide range of molecular weight, and fractionation is necessary to provide material of uniform properties suitable for medicinal use. The approximate molecular size of any given fraction is usually expressed as the "K value"[2], which is derived from measurement of viscosity of a PVP solution. A K-value of 16, for example, corresponds to a mean molecular weight of about 10,000. For use as a plasma substitute a fraction having K-value in the range 28 to 32 is preferred. A concentration of 3·5 per cent. w/v of this material gives a colloidal osmotic pressure approximating to that of whole blood. PVP itself is a stable, white powder which can be stored indefinitely. It is readily soluble in water and in many organic solvents, but is almost insoluble in ether. An aqueous solution can be sterilised by autoclaving, the only change being development of a slight yellow colour caused by fractions of low molecular weight. The solution is slightly acid in reaction (about *p*H 5) and this is usually neutralised by sodium bicarbonate when PVP is formulated for intravenous injection. There appears to be ample evidence that it is non-toxic to man; the usual dose is 500 to 1000 ml. of PVP-saline but, in extreme cases, doses of over 3 litres have been administered. Its ultimate fate in the body is not known, but excretion takes place via the kidneys and normally up to 75 per cent. can be recovered from the urine. In addition to its original war-time use as a plasma substitute, it has been tested extensively as a vehicle for "delayed-release" or "depot-dose" preparations. For this purpose, small volumes of 10 to 20 per cent. solutions containing fractions of K-value 50 and over have been used in conjunction with various drugs such as local anæsthetics, hormones, and antibiotics. This work has been carried out chiefly in France. Most workers report significant retarding effects but no satisfactory



theory has been advanced to explain the mechanism by which PVP operates. A third use arose from the observation that it showed the so-called "embathic effect" characteristic of serum, namely the ability to peptise coarsely dispersed dyes such as Congo Red. It was thereafter shown in experimental animals that PVP exerted a protective or detoxifying action by removing certain toxins and toxic dyestuffs, possibly by diverting them from the liver and causing excretion via the kidney. It is thought that fractions of low molecular weight are the most effective for this purpose. A recent innovation has been the introduction of a complex formed between PVP and iodine. It is claimed that combination with iodine renders the latter safe, even for internal use, without reducing its bactericidal power and that successful results have been obtained using "PVP-iodine" in the treatment of skin infection cases which had failed to respond to conventional treatment. Systemic infections have also shown rapid and marked improvement under this treatment, no harmful side effects being observed in any of the cases. Besides detoxifying the iodine PVP appears to give a longer duration of effect.

Silicones. There has been a recent revival of interest in the chemistry of silicon due to the discovery of a series of organic/inorganic polymers containing both carbon and silicon and having the essential structure of a substituted siloxane or "silicone," (I). The substituted organic groups, R, are commonly methyl or phenyl, and one of the best known series of fluid silicones is composed of polymerised dimethyl siloxane. These polydimethylsiloxanes comprise the silicones which have so far been used most extensively in pharmacy and medicine, and their use has recently been reviewed by Levin[3]. Individual silicones in the series are usually distinguished from one another by their viscosity, expressed in centistokes, and by a manufacturer's identifying number. Silicone polymers of different composition have been obtained as solids, e.g., as elastomers and resins, and have other industrial applications. The value of silicones lies in an almost unique combination of chemical and physical characteristics. In the first place they are extremely stable in the chemical sense, that is to say they are unaffected by water, acid, alkali or other common reagents, and are not decomposed by heat. Fluid silicones, for example, can safely be heated to temperatures at which hydrocarbons would char. As an additional sign of inertia, they are odourless and tasteless and appear to have no pharmacological action. Coupled with this high degree of stability they have several extremely valuable physical properties, notably water-repellancy, lubrication and anti-foaming action.



(I)

There have been a large number of investigations into the pharmacology of silicones. Independent clinical tests in several countries on unformulated silicone oils and on various barrier creams have shown that there is no danger of skin irritation, and even when rubbed into the eyes of experimental animals they only produce a transitory irritation of the conjunctiva with no permanent damage. Silicone oils have also been tested extensively by oral administration to laboratory animals; this has been done to ensure

their safety in the food and confectionery industries, e.g., for glazing bread-baking tins and for coating paper on which confectionery is placed. Other laboratory tests have been made on the administration of silicones by intradermal, intraperitoneal and subcutaneous injection, and also by inhalation of vapour from the heated oils. The general conclusion seems to be that their toxicity is extremely low by all routes of administration, although their eventual disposal in the body is not yet fully known. The first feature to attract interest in pharmacy and medicine was water-repellancy, and this has led to the formulating of many types of barrier cream. It has been claimed that silicone fluids yield a water-repellent film, free from unpleasant greasiness, and that they are effective even when applied in an emulsified or "vanishing-cream" base. Quite apart from their use as "barriers," silicones have been studied as alternative excipients to paraffins or vegetable oils in various ointments, and in liniments. They appear to compare favourably in pharmaceutical properties with the more conventional formulæ but no outstanding advantages have been claimed. On account of their antifoaming action silicones are used in veterinary medicine as a remedy for "frothy bloat" (tympanites) of cattle. In this condition there is a persistent froth in the animal rumen due to saponins in grass and legumes; it is relieved by administering an antifoam preparation, either by mouth or directly into the rumen by canula. It has been suggested that silicone antifoaming preparations might also be used in human medicine to break the froth which develops in the lungs in extreme cases of lobar pneumonia. A clinical report has been published on the use of silicone aerosols in the treatment of pulmonary œdema. There has naturally been much speculation about the future of silicones in medicine, although many of the ideas put forward will require very careful clinical assessment. A favourite theme is the replacement of vegetable or mineral oils in preparations where these do not provide the ideal vehicle. Preliminary work has already been carried out using silicone oils as a depot-dose vehicle (i.e., as an alternative to arachis oil) but the release of drug was quite rapid. Another suggestion is that silicones should be used for infiltration in and about malignant growths, i.e., as vehicles for anti-carcinoma agents. In all probability the use of silicones as vehicles for drugs under conditions which do not require their specific water-repellent or defoaming properties, will be postponed until more is known of the effect of administering relatively large quantities by mouth or by injection.

Polyvinyl Alcohol. Like PVP, polyvinyl alcohol is not a precise chemical entity but is a mixture of polymers of different molecular weight. It is manufactured by controlled hydrolysis of polyvinyl acetate and is available commercially in several grades or fractions, each suited to a particular purpose. Essentially the grades differ in molecular size (the approximate molecular weight is 30,000 and upwards) and in the proportion of unchanged acetate which they contain (up to 20 per cent.). Polyvinyl alcohol is normally isolated as a white or cream-coloured powder which is soluble in water but insoluble in most organic solvents. The powder is hygroscopic and may absorb up to 10 per cent. of water on

prolonged exposure to an atmosphere corresponding to a relative humidity of 75 per cent. at normal room temperature. Aqueous solutions are neutral, or almost so, but those prepared from grades containing unchanged acetate may develop acidity on storage, particularly at high temperature. The solutions are viscous and mucilaginous and have hence found uses in pharmacy and cosmetics as thickeners, and as protective colloids to stabilise emulsions. Evaporation of an alcoholic or aqueous solution leaves a plastic film which may be used in the manner of a collodion to bring drugs into contact with the skin without the need of bandaging. A study of polyvinyl alcohol as an emulsifying agent has been made by Biehn and Ernsberger[4] who found that the most effective grades for this purpose were those of high viscosity, containing about 20 per cent. of unchanged polyvinyl acetate. The efficiency of polyvinyl alcohol was compared with that of common emulsifying agents such as sodium oleate, sodium dodecyl sulphate, sodium alginate and methyl cellulose, and it was found that polyvinyl alcohol at a final concentration of 1 per cent. showed good emulsifying properties but its value in relation to the "controls" varied considerably with the water-immiscible liquid used. Some work has also been done on the injection of polyvinyl alcohol, and Loubatières[5] has reported its use as a plasma substitute, both in experimental animals and human patients.

Polyvinyl acetate. In the preparation of polyvinyl acetate, vinyl acetate is first made by a catalysed interaction of acetylene and acetic acid in the vapour phase. The ester is then polymerised in the presence of a catalyst such as benzoyl peroxide or hydrogen peroxide. Polymerisation may be carried out in an aqueous dispersion or emulsion and the resultant emulsion containing 50 per cent. of polymer is one of the common forms in which polyvinyl acetate is commercially available. One of the most useful properties of this polymer is its ability to form a durable thermoplastic film of good clarity and, for this reason, it is used extensively in varnishes and adhesives, and as an interlayer in safety-glass. The film is also non-irritant and has therefore been tested as a flexible first-aid dressing. Until quite recently there was little or no interest in polyvinyl acetate in pharmacy or medicine, but in 1954 Piney[6] reported a significant prolongation of blood-level in drugs administered by mouth using polyvinyl acetate as excipient. Aspirin and sodium aminosalicylate were tested in this way and it was suggested that a "long-acting" aspirin tablet might be developed by combining "free" aspirin with aspirin intimately associated with polyvinyl acetate. This suggests interesting possibilities of various depot-dose formulations based on the polymer, but will obviously require considerable collaborative clinical and formulating work before any clear idea of its efficacy can be obtained.

2. *Plastics in Surgery*

(*a*) *Internal Use*

The search for materials suitable for use in surgical repair has been in progress for many years but the criteria for an ideal substance are extremely difficult to meet. Substitution for bone, for example, obviously

demands mechanical strength and, if a joint is involved, freedom of movement. Many metals are unsuitable on account of electrolytic reaction which they induce in presence of blood serum, and even stainless steel has the disadvantages of a high specific gravity coupled with the fact that it cannot be fashioned at the time of the operation. The use of synthetic materials is less than twenty years old but already it seems likely that they will go a long way towards replacing metals, and possibly also bone grafts. These and other possibilities have been discussed in several reviews[7,8]. The first point which had to be established was the freedom of plastic materials from any tendency to produce tissue reaction. The polymers themselves are extremely inert but dangers might result either from unchanged monomer or from various added substances such as plasticisers, lubricants, fillers, pigments and stabilisers. Another factor which must be taken into account is abrasion due to friction and the consequent release of fine particles which may produce tissue irritation due to their physical properties. The two plastics which have been used most frequently in surgical repair are polythene and polymethyl methacrylate the former for flexibility and the latter where mechanical strength and rigidity are required. In addition, nylon monofilament is used as a suture material on account of its high tensile strength and nylon tubing for ureteric and other catheters. "Pure" polythene, i.e., the polymer free from any added substance, appears to exert no harmful effect on living tissue even over long periods of contact. A variety of experiments have been carried out on laboratory animals in the course of which polythene has been in contact with brain, thoracic cavity, abdomen, blood vessels and other tissues without producing any inflammatory or foreign body response. On one occasion, polythene was found to produce a fibrous tissue reaction but this was later traced to a small percentage of dicetylphosphate introduced during manufacture of the polymer. The special properties of polythene containing this substance have since been used advantageously in the treatment of syphilitic aneurisms of the aorta[9]. Its normally inert nature has made flexible polythene tubing of value in common bile duct surgery, in urological surgery and as an aid to intravenous infusion of fluids or blood[10], particularly over long periods of time. Another interesting application of polythene is in thoracic surgery. In chronic pulmonary tuberculosis, cavities of varying size may be formed in the lung and will not heal until their walls are brought in apposition. This has been accomplished by artificial pneumothorax and by thoracoplasty. The latter is a painful operation which may require to be done in several stages, and a less drastic means of achieving collapse of the lung is by the polythene pack operation (polythene plombage)[11]. The procedure consists essentially of inserting a bag made of polythene sheet and stuffed with polythene ribbon so as to form a cushion between lung and ribs. A small quantity of iodised oil is added before the bag is sealed in order that its position may subsequently be verified by X-ray. Polythene has not been used extensively for replacement of bone but some examples of such use have been reported, such as the replacement of part of the shaft of the femur[12]. An extruded film 0·002 in. thick has been used to replace gaps.

in the dura mater in brain surgery and a thicker form is used to cover skull defects.

The main use of polymethyl methacrylate has been in replacement of bone, a well known example being arthroplasty of the hip joint, described by Judet[13]. For this purpose, a pylon of pure acrylic is made with a bulbous "mushroom" head and containing, for additional strength, a stainless steel shaft which is embedded before polymerisation. The same acrylic polymer has also been used in cranial surgery for the fabrication of plates to replace defective bone. It is non-irritant to brain tissue and has an advantage over vitallium in being transparent to X-rays. It has been used for thoracic implants in a manner similar to that already described for polythene, except that balls of 2·5 cm. diameter were used instead of tape. Artificial lenticuli of polymethyl methacrylate have been inserted after cataract extraction; the polymer is much preferred to glass for this purpose on account of its light weight. Nylon was the first plastic to be used extensively for surgical repair and was introduced as a suture material. It has since been used also as nylon mesh, nylon floss, and nylon tubing. Nylon filaments have a high tensile strength and are very tough; they are also of uniform diameter and are hence easily withdrawn. The filaments are prepared in a range of sizes from ·004 in. to ·020 in. in diameter, each having a distinctive colour. The repair of large herniæ by nylon mesh has been reported[14], while nylon floss has been used for herniæ and for closure of abdominal incisions[15].

The sterilisation of plastics before surgical use is still a problem. None can be sterilised by dry heat at 150° C. and only nylon will withstand autoclaving. Polythene can be boiled, but tubing and other fabricated articles will undergo deformation unless supported mechanically while hot. Colker and Norman[16] have described a method for sterilising polythene canulæ by enclosing them in glass tubes and autoclaving at 104° C. for 30 minutes. Immersion in solutions of antiseptics, such as quaternary ammonium salts, has been recommended by Farquhar and Lewis[10] but these authors also point out that polythene will increase in weight after prolonged immersion in solution of chloroxylenol, presumably due to absorption of certain constituents of the antiseptic.

(*b*) *Surgical Dressings*

Nylon film. Although conventional dressings of bandage, gauze, and cotton wool will, when dry, prevent infection of a wound, in practice it is difficult to avoid wetting the dressing either from external contact with water or as a result of exudation from the wound. Under such conditions, infection will rapidly penetrate from outside. A completely waterproof dressing is not the answer to this problem since it causes an accumulation of condensed skin perspiration. Human perspiration proceeds at the approximate rate of 15 g./sq. metre/hour, and a suitable dressing material would thus be one which permitted passage of water vapour at this rate but, at the same time, acted as a barrier to liquid water and to micro-organisms. It has been found that a nylon film of thickness 2/1000 in. meets this requirement, and this material has been used in a

variety of ways, including gauntlets for the protection of burns of the hand and arms. The progress of the wound can be followed visually by the surgeon without changing dressings, and much lighter protective dressings can be used.

Paints and sprays. Synthetic polymers have led to several improvements on the original nitrocellulose collodions. Acrylic polymers are most suited to this method of presentation since they are soluble in a range of organic solvents. The first product of this type to be introduced was a solution of an acrylic resin in a mixture of acetic esters which, on evaporation, left an elastic transparent film. Like nylon film, this prevented the entry of micro-organisms but allowed free passage of air and of water vapour. Its use for covering clean surgical wounds has been described by Rob and Eastcott[17]. More recently, a solution of similar properties based on a different polymer has been made available as an aerosol dispenser or "bomb." It is claimed that a burn covering half of the body area can be treated in 5 minutes using spray dressings, compared with the 60 minutes which would be required for applying ointment and bandage. In emergencies, the spray dressings can be applied by semi-skilled persons.

(*c*) *Splints and Orthopædic Appliances*

The use of plastics in this field has been reviewed by Scales[18]. Their chief advantages lie in their ease and speed of manipulation, lightness, durability and resistance to chemicals. As an alternative to plaster of Paris for arm and leg splints, a knitted bandage has been developed containing 1 part of glass fibre and 4 parts of cellulose acetate. This is immersed before use in a setting fluid consisting of a mixture of volatile organic solvents in which the cellulose acetate is partly soluble. The damp bandage is then wound around the limb and after "setting," forms a light, porous water-impermeable splint which is also radio-translucent. Polythene is useful where a semi-rigid support is required such as in forearm splints, cervical collars, and spinal jackets. It can be obtained in sheet form, and on heating to 120° C. this becomes semi-viscous and can be applied to a plaster cast. If allowed to cool slowly on the case over about ¾ hour it will harden without wrinkling and thus provides a light and easily cleaned support which is much easier to make than a similar appliance from moulded leather or cellulose acetate reinforced with steel. Polymethyl methacrylate may be used in a similar manner but requires a higher temperature for moulding; it is less pliable than polythene and is therefore used for smaller splints and in simpler shapes. An interesting recent development in this field is the use of plastic appliances moulded direct to the patient and hence eliminating the need for a previously prepared plaster cast. This has been accomplished by using polythene together with polyurethane; polythene sheet reinforced by polythene strip provides rigidity while polyurethane supplies a heat-insulating layer during moulding and afterwards forms a comfortable padding. The technique has been described by Brennan[19].

(*d*) *Instruments*

The optical properties of polymethyl methacrylate have led to improvements in the design of diagnostic instruments such as the sigmoidoscope and laryngoscope. Owing to the high degree of internal reflection from the polished surface it is possible to direct "cold" concentrated light from a distance at any point or angle without risk of explosion from inflammable vapour or of tissue damage through burning. The construction of transparent instruments to various designs was made possible by the introduction in 1940 of methacrylate polymer in block form, from which the required shape can be cut without necessity of heat-moulding. Due to the "memory" of the polymer, a heat-moulded article tends to revert to its original shape when reheated, and instruments made in this way would thus become deformed when sterilised by boiling. The newer instruments made from "block" are free from this defect and can be sterilised repeatedly. Their introduction has greatly increased the safety of many surgical operations, particularly on the brain, due to elimination of heat. On account of its heat resistance and mechanical strength, nylon has been used to replace glass in the manufacture of syringes. These are now available in capacities up to 20 ml. and the plungers and barrels of each size are interchangeable, which facilitates reassembly after sterilisation. The syringe is virtually indestructible under ordinary conditions of use and can be sterilised by autoclaving up to 120° C.

3. *Plastic Prostheses*

Dental uses. Modern dentures are made entirely of polymethyl methacrylate since this possesses a suitable mechanical strength combined with ease of moulding and ability to take up inorganic pigments for colouring. The absence of any gap between teeth and plate makes the "complete" acrylic denture more hygienic than its precursor which had porcelain teeth on an acrylic plate. To prepare the denture the powdered polymer is mixed with a suitable amount of liquid monomer to produce a "dough," which is then transferred to a plaster mould contained in a metal flask. The latter is sealed and heated to a suitable temperature to cause complete polymerisation. The acrylic polymer is clean and easy to work with and seems to meet nearly all the requirements of both dental mechanic and patient. During the war, however, it was found that it would not resist mechanical shock of the severity experienced by paratroopers on landing, and nylon is therefore being investigated as an alternative of increased toughness.

Eyes. The making of artificial eyes was originally the secret of a small number of European glass-blowers. Their skill lay mainly in the blending of coloured glass to form the iris, and no attempt was made to fit the individual socket with any degree of accuracy. The first step in the use of plastics, during the early part of World War II, was to fit a glass iris on an acrylic eyeball. The modern method is to print irises on paper patterns and to insert these into complete acrylic eyes. An impression is first taken of the patient's socket and then transferred to a two-part plaster mould. The mould is used for the preparation of a wax

eye which is checked for ease of fitting and then inscribed with the position of the pupil and the size of the iris. Using the wax model, a second plaster mould is prepared in a dental flask and an artificial acrylic eye is prepared in the same manner as a dental plate. The final stage is the cementing in of the iris, previously painted or printed on paper or cellulose acetate film.

Facial and other restorations. In spite of the considerable advances which have been made in plastic surgery there is still a demand for a material which can be fabricated into prostheses, either for temporary use during a protracted series of surgical operations, or as a permanency if inoperable. Polyvinyl chloride is suitable for this purpose, since it is easily moulded and tinted, is not cold to the touch and has a texture not unlike that of natural soft tissue. For theatrical and film use it has the special advantage of not melting as wax may under strong artificial light. For facial and other repairs an impression of the injured area is first taken, using either plaster of Paris or dental impression material, and this is used to build a model. The missing part is made up in wax or plasticine and, when satisfactory, is impressed in plaster of Paris in a dental flask. A pourable cream is then made by addition of a plasticiser (e.g., phthalic esters) to polyvinyl chloride, and "foundation" colouring by inorganic pigments is also carried out at this stage. The coloured plastic cream is then poured into the dental flask mould and heated at 150° C. for one hour. After removal, it is trimmed and finally tinted, using organic dyes dissolved in liquid plasticiser.

4. *Miscellaneous Products of Some Interest to Pharmacists*

Spectacle frames and lenses. The "horn-rims" which were introduced about 1920 were celluloid and had the drawback of inflammability; they were later replaced by cellulose acetate frames of similar appearance, which were non-inflammable but less tough. An important post-World War II development was the frame made from polymethyl methacrylate, either by moulding or by cutting from sheet. This material is particularly suitable for the more decorative type of frame. Cheaper frames, such as those used in sunglasses, are still made of cellulose acetate. Another development has been the use of nylon, which is extremely tough, for sturdier articles such as safety goggles. Plastic lenses are almost entirely a post-war feature. Acrylic polymers are used and are either injection-moulded or roughly machined and then stamped out to give the correct curvature. Their main advantage over glass is that they are non-splintering; they are thus useful in sports or under any conditions where there is risk of breakage and hence damage to the eyes. Bifocal lenses are easier to fabricate in plastic than in glass, while contact lenses are really only practicable in plastic material. The latter are moulded to fit the patient's eye in a manner similar to that used for dentures.

Tooth brushes. Tufts are now usually made of nylon while the handle may be polymethyl methacrylate, polystyrene, or cellulose acetate. The brush should not be placed in hot water since this softens the cavity in which the tufts are embedded and thereafter allows them to splay out.

Unlike natural bristle, nylon does not soften when wet and the user should therefore be advised to start with a relatively soft nylon tuft to avoid damaging dental enamel. Having no central channel or cavity, nylon is more hygienic than natural bristle.

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DISCUSSION

MR. R. L. STEPHENS (Brighton) asked Dr. Child where the field of plastics ended and resin chemistry started. An interesting application referred to in the *Lancet* recently was a combination of melamine resin with plaster of Paris, to give a plaster cast which was strong, light and completely waterproof. Was the absorption of chemicals likely by plastic apparatus, with the possibility of contamination of one material with another when a change was made?

MR. W. H. STEPHENSON (Nottingham) asked whether the authors had any comment to make on the future development of the newer plastics for wound protection.

MR. T. D. WHITTET (London) said that some surgical dressings of the older type had almost entirely been replaced by plastic ones in his hospital. Jaconet and battiste were no longer employed, and the theatre staff found plastics particularly useful for covering couches and for aprons. Polyvinyl alcohol was used in buffered gels, but difficulty was experienced in obtaining a standard product. He understood plastic eye drop bottles were used in America. Tests had been carried out with nylon syringes and it was found that they had distinct advantages from the point of view of breakage. Unfortunately they were jerky in use and after repeated sterilisation they became opaque and dirty brown in colour.

MR. N. J. VAN ABBÉ (Loughborough) said he was particularly interested in the possibilities of polyvinylpyrrolidone dissolved in chloroform or alcohol for preparing tablet granules of readily hydrolysable substances. It did not prolong the disintegration time of the tablets. The non-sticking properties of P.T.F.E. suggested that if it could be bonded to

the surface of tablet punches it might assist in overcoming sticking problems.

MR. J. D. KULKARNI (Nottingham) said that soon after the war plastic watch straps were very popular in India, but the wearers suffered from skin diseases. Could the authors explain this occurrence?

MR. R. W. GILLHAM (Leeds) said that the use of flexible plastic wash bottles in the laboratory was accepted practice. It would be of great advantage if a plastic were developed which could stand up to sterilisation at 150° C., for use in packing sterile powders, such as cord powder.

MR. A. R. ROGERS (Brighton) said it would be interesting to know whether any of the plastics were good transmitters of ultra-violet light.

DR. K. R. CAPPER (London) stressed the necessity for plastic and other containers to be tested with the particular solution which it was intended to pack in them to ensure the constituents were not adversely affected.

MR. J. A. FREEMAN (Hounslow) pleaded for closer tolerances of the necks of glass bottles which were to be sealed with plastic plugs. How could such plugs be sterilised? There were plastic caps which were satisfactory in this country and others which were satisfactory in the tropics, but he had not found one which was satisfactory under both conditions.

MISS M. J. HINCKS (Slough) said it was often very difficult to remove plastic stoppers from bottles.

MR. D. STEPHENSON (Dartford) in commenting on the statement that plastics could not be sterilised by dry heat, said that some types of nylon could be heated to 180° C. without any deformation and with only slight shrinkage. Would not such heat treatment sterilise the nylon and was it not rather the shrinkage that occurred which rendered such nylon apparatus unsatisfactory.

MR. N. BRUDNEY (London) asked whether the transfer of carbon dioxide through polythene was sufficiently great to vitiate the storage of standard alkali solutions in polythene containers.

MR. W. P. LEGGETT (Liverpool) enquired whether there was any move afoot to introduce standards for plastics used in pharmacy and to standardise their nomenclature.

DR. C. L. CHILD, in reply, said that the ill-effects arising from plastic watch straps were due to polyvinyl chloride which had been plasticised, stabilised and lubricated for use in insulating cables, being employed. The material which was now sold for watch straps was suitable for that purpose. It was almost impossible to define plastics and ion exchange resins could be considered as coming within their range. With regard to the absorption of chemicals into plastic tubing, it was always necessary to ensure that the material was suitable for the particular purpose in view. As to the difficulty of obtaining a standard polyvinyl alcohol, it had hitherto been imported into this country and only recently had British manufacture of industrial grades commenced. The point that repeated sterilisation of nylon syringes resulted in discoloration did not surprise him. Grades of nylon varied. They had a melting point range from 180° C. to 264° C., but if heated in air at about 150° C.

there was fairly rapid oxidation. He would expect oxidation accompanied by discoloration and embrittlement to occur over a fairly short period at 120° C. On the question of bonding P.T.F.E. on to tablet punches, work had been done with only partial success. One of the difficulties was that P.T.F.E. did not stick to anything very easily. As to the prospect of transparent plastic bags withstanding sterilisation at 150° C., that might happen in the near future but it was not possible at the moment. He had no figures for the transmission of ultra-violet light through plastics. He agreed with the desirability of making full tests on containers against the contents to be placed in them, though a certain amount of generalisation was possible. It was surprising to hear that some stoppers had been found to be suitable in this country but not in the tropics and vice versa. If they were satisfactory in the tropics one would have expected them to be satisfactory in this country. On the question of heating nylon at temperatures of 180°, it was not just the dimensions which changed at that temperature; oxidation occurred accompanied by discoloration and embrittlement. The effect of the carbon dioxide transmitted on alkali solutions stored in polythene containers depended on the vapour pressure difference, the wall thickness and the length of time it was left in those particular conditions. He agreed that the standardisation of nomenclature was long overdue.

MR. A. W. BULL, in reply, emphasised that each product must be tested specificially for its use in the container which was proposed. In the case of eye drops, for example, there was a possibility that gases might pass through the polythene into the bottle. It was fundamental to the process by which glass bottles were made that it was impossible to work to extremely fine limits, and it was for that reason he had mentioned polystyrene containers which could be made to much finer limits than glass. But it must be remembered that with polystyrene there were water vapour transmission and other effects so that again it was necessary to test the product in the proposed container. With regard to possible absorption of carbon dioxide by alkali in polythene bottles the volume of atmosphere over the solution was an important factor. The less solution there was in the bottle the more the likelihood of absorption. One could visualise a closure not proving satisfactory in the tropics, but it was difficult to visualise a closure which was satisfactory in the tropics but unsatisfactory in this country. Dimensional changes could be appreciable and this could cause a loosening of the stopper. There was also the susceptibility of some plastics to alkaline preparations, and again temperature was a factor which would accelerate the production of defects.

MR. A. G. FISHBURN, in reply, said that collodion was one of the first plastic wound dressings. It was now claimed that in the case, for example, of extensive burns, rapid protection could be given by a sprayed on plastic dressing. A second advance in plastic wound dressings was by using their water vapour transmission properties to improve on the rather heavy cotton wool pads. A third advance was the incorporation of several different plastics in a first-aid dressing. The general problem

of how to sterilise the plastic normally arose in the sterlisation of the fabricated plastic article. To the best of his knowledge nylon was the most heat resistant and could be autoclaved. Polythene could be sterilised by boiling either alone or with chemicals, but the article required mechanical support against deformation. The sterilisation of plastic material by bactericidal gases had also been suggested. He agreed that a transparent plastic material which could be repeatedly sterilised at 150° C. would be a great advantage. P.V.P. certainly had many interesting possibilities. A monograph for a plastic would not be easy to write because of the difficulty of defining the mixed polymers, but the job would have to be done sooner or later and at the same time an approved name would have to be coined.