# THE POWER DRIVEN BUR IN TEMPORAL BONE SURGERY

By M. SPENCER HARRISON and G. T. HUTCHINSON (Lincoln)

MANY surgeons have now come to recognize that the power driven bur has considerable advantages over the gouge and chisel in almost all stages of the surgery of the temporal bone. There are still those who insist on using one method to the exclusion of the other, but most of us feel that both gouge and drill have their use, though as far as most bone cutting is concerned the bur is superior to the gouge even when large masses of sclerotic mastoid cortex must be removed, and especially when the access is limited. In many situations in practised hands, the bur gives greater nicety and less risk of damage to vital structures. It must be emphasized that the views expressed as to the value of the bur are tenable only if a constantly clear field is maintained, and the bur may become dangerous if used in any other way. The practice of working under a mess of blood and bone chips, until either the bur ceases to cut or the surgeon loses his bearings and has to wash out the cavity before proceeding, is quite crude and unsatisfactory. The skill required to obtain maximum advantage from the instrument is considerable and is best mastered before the bur is used on the living mastoid. Once the technique is acquired, the operation becomes cleaner and easier, the bleeding is less and it is easier to distinguish and remove the smaller cells. For fine work such as exposure of the facial nerve, or the opening up of the semicircular canal, the bur is now almost universally accepted.

The *dental motor* has advanced considerably since the treadle-driven foot-operated type, with which many of us commenced to use the bur, gave way to an electric instrument with a maximum speed of about 3,000 revolutions per minute, though the latest standard dental motor has a maximum speed of some 5,000–6,000 revolutions per minute. Nevertheless, it is possible to step up this rate by opening the shunt resistance of the motor circuit, to a speed of from 9,000–16,000 revolutions per minute, depending on the type of motor. Motors are said to tolerate increased speeds without excessive wear provided they have plastic insulation between the segments of the commutator instead of the old type mica insulation. Further bur speed can be gained in belt driven models by increasing the *diameter of the motor pulley*, speeds of up to 20,000 r.p.m. being possible with the motor modified as above using a pulley $2\frac{1}{2}$ in. or



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

$3\frac{1}{2}$ in. in diameter. Reduction of friction by use of *ball-bearing idler pulleys* may make a difference of 6,000 to 10,000 revolutions per minute in the speed (Brauer, 1957).

The work involved in an operation on the mastoid is considerably greater than that in preparing a tooth to insert a filling, and it is better to have a motor more powerful than that of the standard dental engine. The recently introduced *KaVo workshop motor* can easily be made spark-

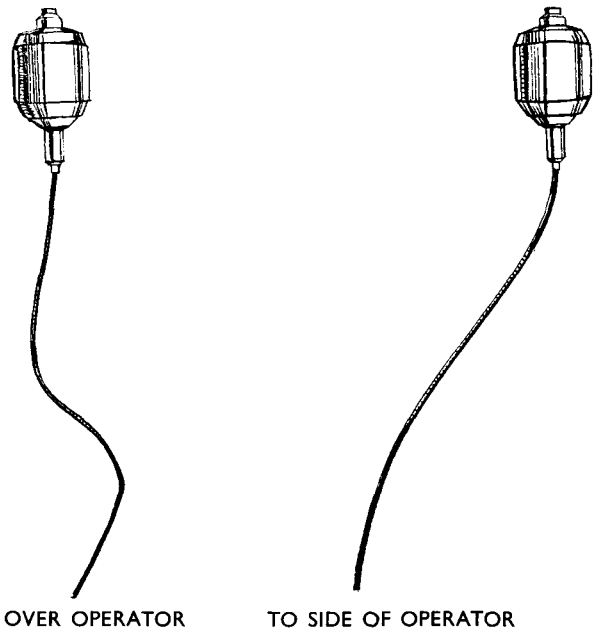



FIG. 1.

Diagram to illustrate siting of drill motor in relation to surgeon. If it is directly over the latter the shaft must be bent considerably.

proof and it gives the required robustness, is reasonably quiet and the cable drive fitted is reliable and durable. The speed of these motors is either 12,000 or 18,000 revolutions per minute. The latter has been found satisfactory, though in use a speed of considerably less than 18,000 revolutions per minute is obtained under the conditions normal in temporal bone surgery. The torque at the speeds obtained is very good. This model (18,000 r.p.m.) is designed for fine grinding of metal and is supplied only with foot control for five forward speeds. Opinions as to the value of the reversing mechanism vary; with a forward cutting bur, rotation in the opposite direction by burnishing instead of cutting, can be used to stop bleeding from the bone, while with diamond or carborundum points which will cut in either direction, a change of direc-



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

tion of rotation may increase the safety of the procedure by cutting away from such structures as the facial nerve or sharp spurs near the meatal flap. A reversing foot control is difficult to manipulate from the sitting position, usually requiring a second person to control it. An easy way of overcoming the difficulty is for the surgeon to have a press down pedal footswitch and for the reversing switch to be connected in the circuit but controlled by a member of the theatre staff away from the operating table.

*The drive* from the motor may be by cord to a pulley on the handpiece, by cord to a pulley attached to the proximal part of a flexible shaft, or straight from motor to handpiece by flexible shaft. The cord drive to the handpiece is favoured by the dental surgeon as it gives greater range of movement of the handpiece, but the distal pulley attachment is rather

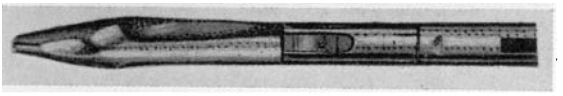


FIG. 2.
Handform handpiece, made to fit more comfortably between fingers.



FIG. 3.
Screwdriver in handpiece.

clumsy, especially when the bur is used under the microscope; the combined cord and shaft eliminates this objection, but it has been found that less trouble occurs with the flexible shaft alone than with either of the other forms of drive. A further advantage of this shaft drive is that the motor can easily be suspended from the ceiling or from the large operating lamp, so freeing valuable floor space in the operating theatre which is becoming over crowded during aural surgical procedures. Another advantage is the ease with which a sterile covering such as a Paul's rubber tube, can be slipped over the flexible shaft. No complications resulting from the shaft drive have been experienced over some twenty years of its use. The drive from the motor should be as straight as possible, because if the flexible shaft is curved the friction is increased and the speed of the motor falls. This increased friction is easily demonstrated with a treadle drive by curving the flexible cable. It is important thus to make sure the motor is not directly over the working area but a little behind and to the right of the right-handed surgeon (Fig. 1).

It will be shown later that correct adjustment of equipment and lubrication of moving parts have considerable influence on the final



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

instrument speed, though due to friction and other losses, the speed rarely increases by the calculated amount. If a cord drive is used it should be run at the point of slipping, the loss of motor speed is considerable if the cord is tighter than this. This applies also to the new elastic cord drive, which is not suitable for high speed drives. Adjustment of the cord tension should be done whilst listening to the pitch of the rotating handpiece. Fiddlers rosin used on the cord will lessen the tendency to slip. Cords should



FIG. 4.
Angled KaVo handpiece.

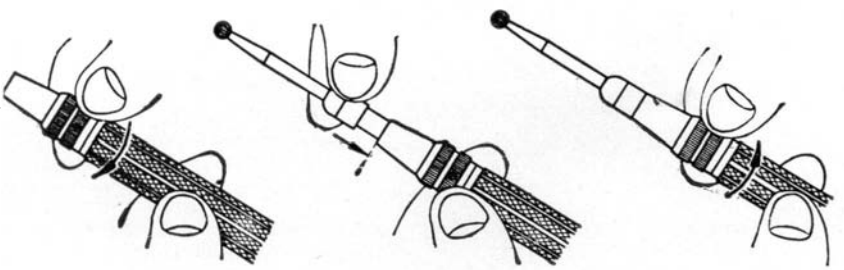


FIG. 5.
Way to open above.

be washed in a detergent each month and allowed to dry thoroughly before use.

*The handpiece*. Care in the choice and upkeep of a handpiece is well rewarded, particularly now that motor speeds have increased. The modern handpiece which is made so that the working parts are removed easily from the sheath is more suitable for aural surgery, and an outer cover shaped so that it fits comfortably into the fingers is useful (Fig. 2). A small screwdriver which fits into the bur tray is supplied with certain types of hand piece so that if the bur is found to be slipping, adjustments may be made by the surgeon during an operation (Fig. 3).

Straight, angled, right-angled and contra-angled handpieces are available. The latter have been little used in the surgery of the temporal bone.



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

The *angled handpiece* is useful when work is being done under magnification because it has less tendency to interfere with vision, but it is more difficult to control the bur accurately in this handpiece. A right-angled handpiece for temporal bone surgery has been introduced by Zollner, but many operators find a KaVo instrument, angled at 20° some $\frac{7}{8}$ in. from its distal end, more easily controlled, and it is also less expensive (Figs. 4 and 5).

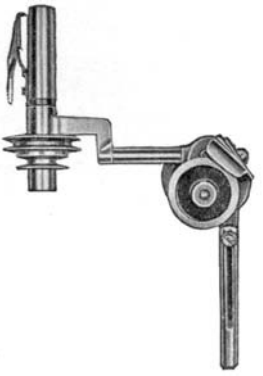


FIG. 6.
Wrist slip joint.

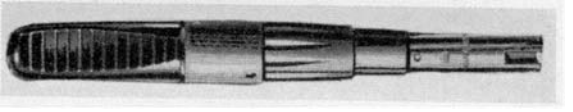


FIG. 7.
Workshop handpiece. Plastic sheath is heat resistant and air space between this and moving parts is greater than in the usual dental handpiece.

The most important brake on the speed which can be used is the handpiece; the *standard handpiece*, even if well maintained, will only run satisfactorily at speeds of up to 6,000 revolutions per minute for the time usually required for mastoidectomy.

*High speed handpieces* of standard size are manufactured with ball or sapphire bearings (the latter are not so efficient) which will run at 20,000 or even 25,000 r.p.m. for short periods (Kaltenbach and Voight, KaVo). To obtain a speed of 20,000 to 25,000 r.p.m. at the handpiece the wear and tear on the motor and driving mechanism is considerable, but this may be eased, if a cord drive is used, by attaching the handpiece to a *speed-increasing* wrist slip joint, which will give an increased bur speed of from three to four fold the speed of the motor. This slip joint is efficient as long as the small rubber inner wheel is kept free of oil, but this is not easy, and failure means loss of torque and speed. It is therefore possible with this mechanism



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

to reach speeds in the range of 40,000 to 50,000 r.p.m., but if much work is done at this speed the *special workshop handpiece* (Fig. 7) must then be used. This is larger than usual with double ball bearings, and has an insulated cover giving a cavity between outer shell and shaft to absorb the heat generated as a result of the high speed. The difficulty with this handpiece, apart from its size, from the otologist's point of view is sterilization. The ball bearings are packed with grease and it is necessary to sterilize the handpiece chemically, preferably in formalin vapour. The collet chuck, which is removable and can be sterilized separately, gives a much surer grip on the shaft of the bur than do the standard dental handpieces.

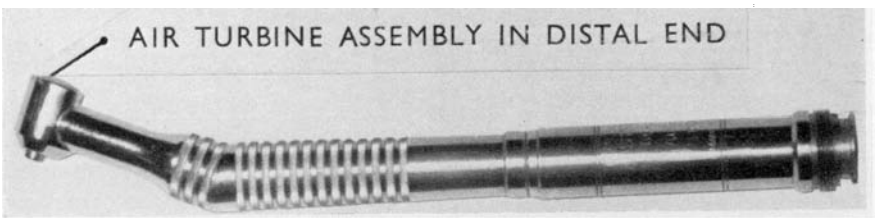



FIG. 8.
Air turbine handpiece.



FIG. 9.
Dentalair machine.

There is a rapidly growing tendency in dentistry to use ultra high speed drills driven by an air or water turbine instead of an electric motor (Fig. 8). Speeds of up to 350,000 r.p.m. may be reached, which promise the great advantage of absolutely smooth and rapid cutting without the tendency to snatch in the cut as with the standard form of drill. When such speeds are used, the response of the tissues to heat generated becomes a serious problem. Other disadvantages associated with high speeds are the need for special practice, the lack of tactile guidance to cutting and the greater care required, the need for exacting instrument maintenance and the relatively short life of the bearings. Certain further disadvantages render them unfit for temporal bone surgery as yet: sterilization is difficult, an exhaust of air, water, or oil may be ejected into the wound, a lot of water is needed to keep the bur point cool during cutting, the torque is much too low and for technical reasons only a contra-angled handpiece is available. It is claimed



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

that many of the above difficulties have been eliminated by a separate small turbine driving a shaft in the handpiece (*Dentalair of Atlas CopCo.*) (Figs. 9 and 10). The speed obtained then is 50,000 r.p.m. and the torque good, but sterilization is not easy and the handpiece difficult to control, which appears to be caused by the larger turbine attached to the proximal part of the handpiece having a gyroscopic action. To overcome this action it is not only necessary to keep the drill vertical, but to avoid any rotatory movement in the plane of its axis.

Damage to neighbouring soft tissues is an important consideration in high speed cutting. Disorganization of cell structure is known to develop at frequencies of $10^6$ cycles a second and at 250,000 r.p.m. harmonics may be generated which might rise to this frequency. It is now recognized that large portions of dental enamel may disintegrate during treatment at these speeds (250,000 r.p.m.).

The possibility has been voiced that prolonged exposure to the high-pitched note of the air turbine may cause damage to the receptor mechanism of the ears of the surgeon, though no such finding has been reported. Kazantzis (1960) states that a fundamental vibration of 4,400 cycles per second is generated at an off-load turbine speed of 260,000 r.p.m. There is some distortion, but not enough to suggest the presence of a high percentage of harmonics and the main sound emission can be expected at this frequency. The sound level at the 4,000 cycles per second level varies between 50 and 70 decibels with different 250,000 r.p.m. turbine drills tested by ourselves. This level is insufficient with normal use seriously to affect the hearing of the operator.

Some dental surgeons have experienced irritation of the eyes and respiratory tract following the use of the air turbine drill, but the most serious complication described by Scott-Samuel (1960) is surgical emphysema of the soft tissues due to exhaust air being driven into the tissues.

Thus of the conventional handpieces none of the standard pattern, whether straight or angled, should be run at much over 5,000 r.p.m.; the high speed handpiece with special bearings is available for speeds of 5,000 to 25,000 r.p.m. and for speeds up to 40,000 to 50,000 r.p.m., the heavy workshop handpiece is best used.

Portmann (1957) has described a curved microdrill expecially designed for stapedial surgery; this instrument may now be obtained modified for the standard dental handpiece.

Handpieces with motor attached are being developed in some centres. J. D. Gray of Sheffield has developed two small handpieces; one is driven by a small electric motor and the second by an air turbine fitted into the proximal part of the handpiece (Fig. 11 and 12s.) Both these instruments are designed to drill at an angle of 45° to the shaft so that it is possible with them to cut the annulus round the stapes, cutting a groove as well as drilling into the bone. Gray found that the small bur cut unsatisfactorily



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

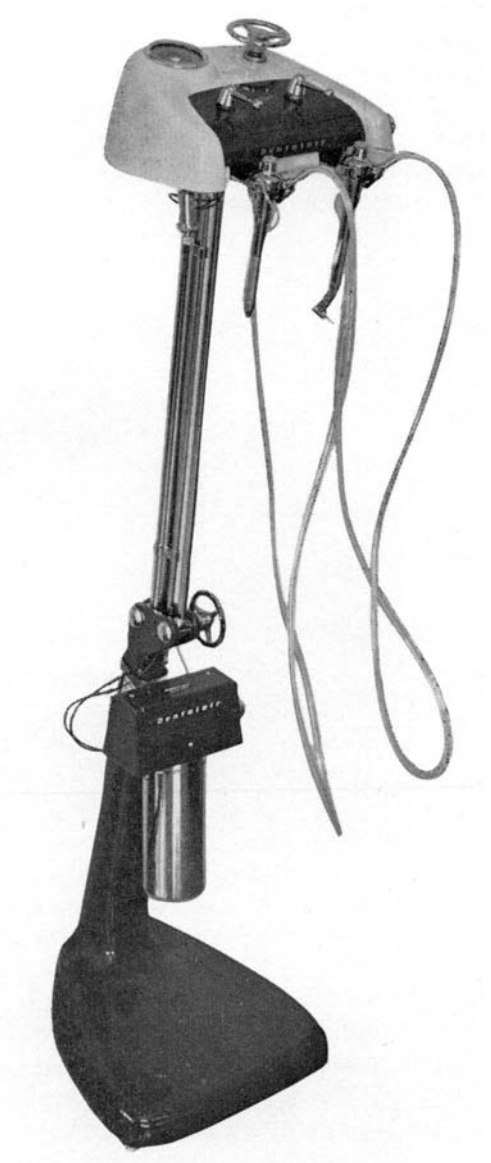


FIG. 10.
Dentalair handpiece.



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

owing to chattering at 10,000 revolutions per minute the speed of the electrically driven handpiece, though drilling was entirely satisfactory, and that it was necessary to use speeds in excess of 20,000 revolutions per minute for side cutting. The air turbine reaches 30,000 revolutions per minute using air at 20 lb. pressure per square inch. The whole equipment including the silicone rubber pressure tube can be sterilized in the hot air oven. The low torque is, of course, not a handicap for the fine surgery for which instruments such as this are designed. The gyroscopic effect of the small motor is not important unless rapid movements are made, but Gray

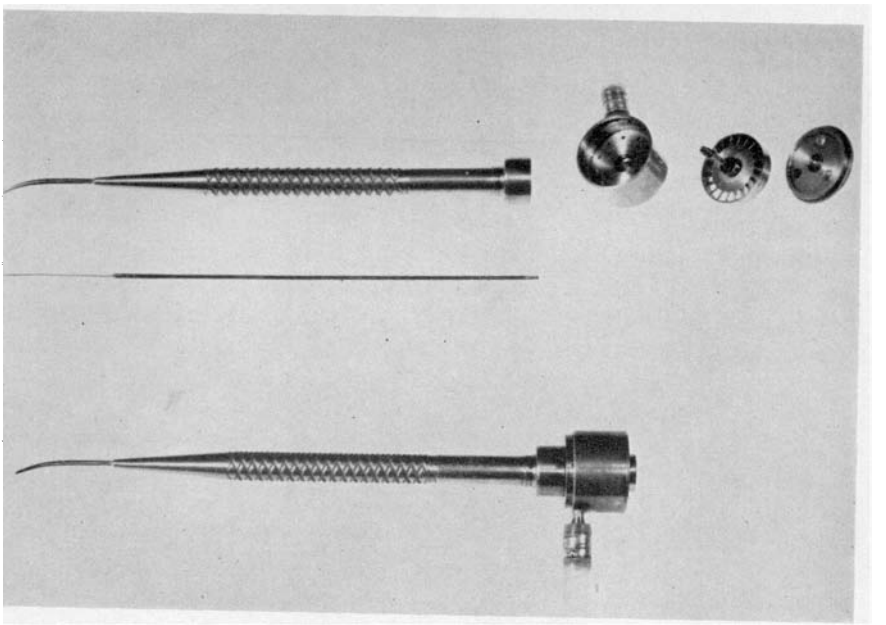


FIG. 11.

Gray's turbine drill. Exploded view showing air turbine parts, the drive shaft ending in the flexible drill, the housing ends in a curve to give a 45° angle to the drill.

is anxious lest acoustic energy delivered to the cochlea may be of dangerous intensity during side cutting near the stapes, though so far it has not proved to be so. With instruments so small and delicate as these the care and maintenance required are very considerable and unless a highly trained technician is available frequent faults are likely.

*Care of handpiece.* With the advent of increased drill speeds the problems of care and maintenance of the handpiece become of more significance. Though one of the most important of these problems is lubrication, proper care of the handpiece also involves cleaning, sterilization and correct adjustment. Neglected handpieces quickly loose their fine adjustment, wear rapidly and show more tendency to heat up during



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

the operation. Regular dismantling and oiling are especially important if water is used during the drilling, as the tendency to corrosion is greatly increased.

The handpiece may be cleaned by slowly running it in white spirit, a useful non-corrosive solvent of used oil, and this will also clean out the bearings of bits of foreign material. Crowley (1959) then suggests the handpiece, to lessen corrosion, is coated with AC10 oil just before *autocalving*. AC10 is a mineral oil, supplied by the Amalgamated Dental Company, which easily emulsifies in a boiling solution of sodium carbonate. After autoclaving the handpiece should be dismantled and sparingly lubricated.

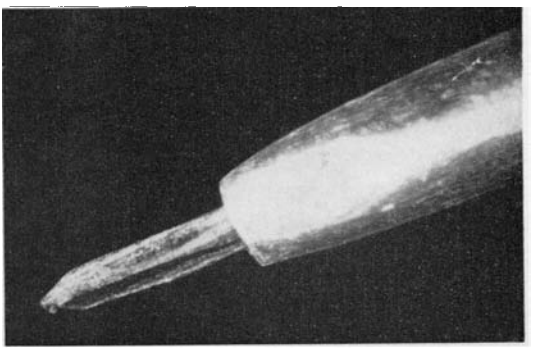


FIG. 12.
Gray's turbine drill × 25. Drill point protruding from housing.

Charbeneau (1957) suggests the following technique for cleaning and sterilizing. After use the handpieces are run for a short time in a solution of a detergent to clean them. They are then run in the following emulsion to coat the internal surfaces—(20 ml. Prorex C, 3 ml. Span 80, 20 ml. Tween 80, 5 gm. sodium benzoate U.S.P., and water to make 1,000 ml). The handpieces are then dismantled as far as is easily done, this is important and allows for better drainage of excess emulsion, better steam penetration to accomplish sterilization and easier lubrication without the danger of overlubrication. After this handling the dismantled instruments are dipped in the emulsion again, and after draining, should be autoclaved within fifteen minutes. Hand-cutting instruments, scissors, burs and diamonds may be dealt with in a similar manner. After the normal autoclave cycle the handpiece is sparingly lubricated with a light oil prior to reassembly. Instruments previously subjected to other forms of sterilization or disinfection and lubrication should be well cleaned by running in a spirit solvent before putting in the emulsion, and in any case the instruments should be well cleansed in this solvent at intervals, depending on the amount of use.



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

Burs may be cleaned after use by brushing with a bundle of fine brass wires, which cleans the debris between the flutes, but diamond stones are best "drilled" a few times into a typists ink eraser. If either type is boiled in one of the above alkaline emulsions cleaning is very much easier.

Some designs of rotating instruments should not be autoclaved. This limitation arises especially with some high-speed instruments, because of (1) the damaging of non-metallic parts by the temperature employed, (2) the use of factory-lubricated bearings with subsequent loss of lubricant due to the high temperature, and (3) inability to get emulsion to all parts of the instruments.

An additional advantage in the use of the oil-in-water emulsion is that after clinical use, all instruments may be scrubbed with water and detergent and those to be protected by the emulsion may be immersed in this solution until autoclaving is convenient, whether it be one hour, overnight, or over a week end. The emulsion is continually effective as a corrosion preventive when completely covering the instruments.

The emulsion should be discarded whenever debris becomes evident, since this debris will cling to instruments during the precoating procedure. Filtering of the emulsion is undesirable because of the possible absorption of some oil on the filter, thus reducing oil concentration below an effective limit.

Some authorities state that *hot air* sterilization is also a good method (320°F for one to one and a half hours), the working parts being lubricated with oil and assembled before being placed in the oven, but some manufacturers state that the temperature in a hot air sterilizer is too high for rotating instruments.

The handpiece may be *boiled* in a slightly alkaline solution (0·25 per cent. sodium hydroxide) placed in 95 per cent. alcohol for ten minutes to remove all traces of moisture and then dried and lubricated. One of the *silicone oils* at 300° F for ten minutes will sterilize the instrument, but as the viscosity is high the lubricating properties are not good. *Boiling in 1–2 per cent. AC10* in alkaline aqueous solution also protects against corrosion and lubricates. The solution of AC10 may be used several times, but after five boilings the handpiece should be soaked in neat AC10 oil for a few minutes and then reboiled in the emulsion.

The flexible drill shaft can be sterilized in the hot air oven at 300°F without distortion provided it is kept straight (e.g. inside an open ended, perforated brass tube) though more care must be taken over lubrication.

*Lubricants* have been the subject of much work (Charbeneau, 1957); important considerations are their viscosity, stability under heat and their practicability in a straight handpiece. That viscosity affects the efficiency of a lubricant is shown by the difference in the temperature rise when using fluids of different viscosities. These temperature changes are probably of the greatest practical interest to the aural surgeon as temperature



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

changes in the handpiece are only too easily detected during an operation and are of importance as regards the life of the instruments. The effectiveness of a lubricant varies with the mechanical design and the material used in the construction of the dental handpiece. Differences may even exist between two handpieces made by the same manufacturer and each handpiece will also vary in its performance due to difference in care and use. Difficulties from over-lubrication appear to be greater than those from under-lubrication, excessive heat generation, rapid deterioration of lubricant and leakage from the instrument will occur. When a handpiece is removed from a sterilizing fluid and the excess drained off, leaving the residual oil as the lubricant, the temperature rise during use is somewhat higher than when the handpiece is cleaned and lightly lubricated with the same fluid with an applicator. The greater the amount of residual oil removed from the handpiece, the less the temperature rise of the bearings. If the handpiece is over-lubricated trouble may at times be experienced with *oil trickling down the bur shaft* towards the cutting head; this is partly overcome in certain patterns of bur (Meissinger) by the use of a cupshaped attachment to the bur shaft, but these attachments not infrequently work loose and a good substitute is the hollow rubber cap from a glass local anæsthetic cartridge. *Certosept* is a good sterile oil and it is useful to have a little of this available on the instrument trolley, with a penfiller, during the operation.

*The bur* is identical in its action with the engineer's milling cutter. A number of teeth round the periphery are successively presented to the material being cut during each revolution, and each individual tooth acts as a wedge shaped chisel and cuts out its own fragment. (Fig. 13.) These teeth are all pointing in one direction, and therefore cutting only takes place with the bur rotating one particular way—this is always clockwise—looking from the shank end. It is obvious that the more acute the angle of the edge of each individual tooth the less pressure is required to force it into the material to be cut, but on the other hand the weaker and less rigid is the cutting edge. Conversely a more obtuse angled edge will resist deformation better, but will require more pressure to enable it to cut into the material. This compromise raises difficulties where substances of varying degree of hardness are to be cut, but bone is relatively soft and any design of bur, as used in dentistry or industry, should be satisfactory on the softer material-bone.

Perhaps more important than the shape of the cutting edge is the number of blades round the circumference of the bur. If absolutely dry bone were to be cut, the cut particles would be in the form of a powder, and would easily clear from between the blades. As soon, however, as any blood or moisture is present the debris forms with it a thick paste, which wedges solidly between the blades and effectively prevents further cutting. This means that the more teeth there are, i.e., the less the space between



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

them, the more easily this jamming with debris occurs. However, even with closely set teeth this clogging can be prevented by cutting under a copious flow of water which washes away the cut particles as quickly as they are produced. The number of teeth depends on the diameter of the

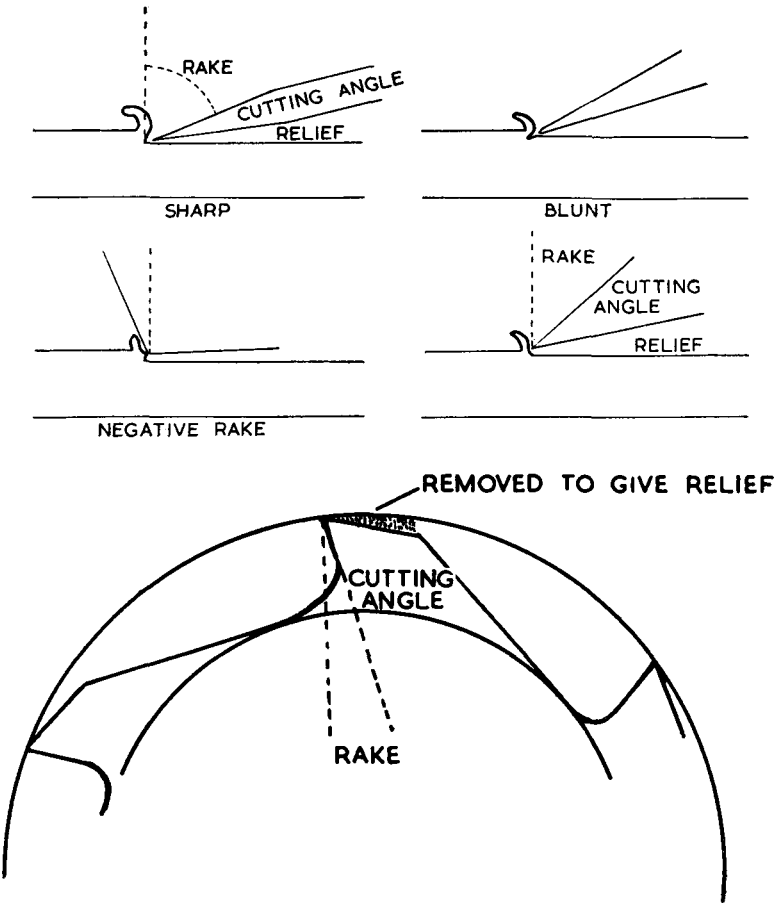



FIG. 13.
Sketches illustrating action of bur.

cutter, for instance an $\frac{1}{8}$ in. diameter round head bur usually has ten teeth. Too few teeth cause difficulty in cutting by greatly increasing the vibration and "chatter".

Standard dental burs are made of heat treated carbon steel, and wear reasonably satisfactorily. Any localized heating of the fine blade edges, as produced by the lack of water cooling, will quickly "draw" the temper and blunting of the edge rapidly occurs. The more expensive tungsten



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

carbide burs will retain this sharpness indefinitely, although the extremely hard edges are rather brittle and easily chipped.

*Stones.* Under this heading are those cutters which consist of minute pieces of diamond, carborundum or tungsten carbide cemented together. Each particle which projects from the cementing matrix acts as a cutting-edge, all arranged haphazardly, which explains why stones cut equally well in either direction of rotation. The very large number of cutting-edges and therefore the much increased tendency to clogging, means that a copious stream of water to clear the debris is essential.

It is important with any rotating cutting tool to move it in the correct direction over the surface to be cut. It must always be drawn *against* the direction of rotation, as if allowed to move in the direction of its rotation, it will climb to the top of the cut and run over the surface, creating havoc on the way. This tendency increases as the number of teeth diminishes, and it is very slight with stones, with their innumerable teeth. This "snatching" in the cut is more aggravated if there is any play in the handpiece bearings. One of the greatest advantages of the higher speeds (over 20,000 r.p.m.) is the increased smoothness of cutting and diminution of chatter.

The bone may be removed by being ground away piecemeal, or a series of parallel grooves may be cut, and the intervening bone lifted out, or again an area of bone may be outlined by a peripheral cut and removed in a piece when the cut is deep enough. The bur should be applied to the bone at an angle of about 45°—it will cut or drill a hole if applied end on—but much less efficiently, as there is only one effective cutting tooth on the end of a rose-head bur.

In temporal bone surgery the bur head is usually ranging from 2 mm. to 6 mm. in diameter. Conical burs may be used to expose the antrum, but these offer little advantage in the hands of most surgeons and it is probably better to have a selection of spherical burs in a convenient bur container so that the surgeon may choose the size he requires. The standard length of bur for the straight handpiece is $1\frac{5}{8}$ in., but specially long shank burs ($2\frac{1}{2}$ in.) are made for temporal bone surgery. It is often better to use a short bur for the earlier stages of the operation as the long shanks are rather fragile, and may snap off if too much pressure is applied.

*The temperature rise* at the bur point associated with bone cutting at constant speed, is proportional to the frictional surface, the larger the bur the higher the total heat (Henschel, 1944), though slipping of the engine belt or slowing of the motor are greater the larger the bur. Thus with a weak dental motor, or a slipping belt, it is doubtful whether large burs generate more heat than much smaller ones.

Other factors of importance in the heat rises are:

1. Speed of instruments in revolutions per minute.
2. Pressure applied by the surgeon.
3. Duration of cutting.



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

4. Character of bur—as already mentioned, the bur must be quite sharp (Fig. 14). The number of teeth, the nature of the surface, diamond, steel or stone, all play a part. Tungsten carbide burs produce less rise in temperature than do steel burs of the same pattern.

5. Relation between heat production and rate of cooling.

6. Thermal conductivity of medium beneath the instrument.

7. Dry or moist field. A moist field causes clogging of the instrument and lowers its cutting efficiency.

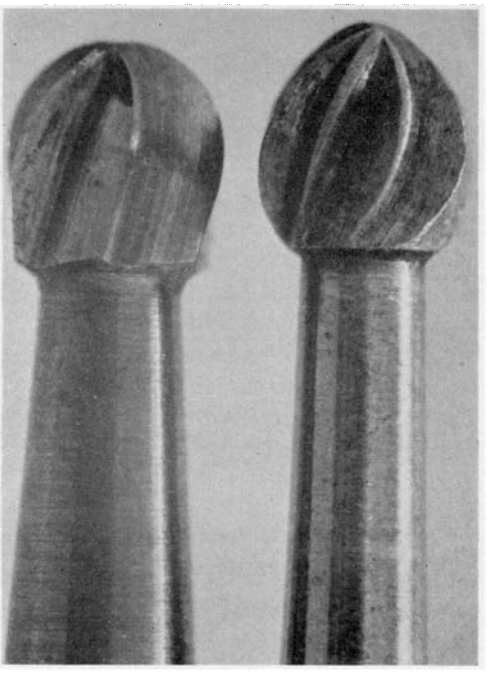


FIG. 14.
Tungsten Carbide and Steel bur after similar period of use.

The efficiency may be taken as the amount of bone which can be removed for a given rise of temperature and improves as the speed rises. A diamond bur for a given temperature rise cuts 3·9 times as fast (Walsh, 1949) at 6,000 revolutions per minute as at 3,000 revolutions per minute. The light pressure which can be used with high speed machines reduces frictional effects and increases the efficiency of the instrument (Fig. 15). High speed and low pressure are four times as efficient as low speed and high pressure. The hand pressure of 2 lb. necessary when using a standard drill can be reduced to less than half an ounce at 150,000 revolutions per minute. The light touch needed at higher speeds gives greater ease of



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

control with less danger of running or slipping. The temperatures attained by a bur at any one standard pressure have been shown to approach near to a maximum at a speed of 6,000 revolutions per minute (Hudson, 1953) (Fig. 16). As the speed increases beyond this point there is little change in temperature. Steel and carbide burs cut faster as speed of rotation increases up to about 20,000 revolutions per minute (Fig. 17), but Hudson does not consider there is any great advantage as far as rate of cutting is concerned, in increasing speeds of rotation above some 12,000 revolutions per minute. Above 20,000 revolutions per minute the gain is in smoothness and absence of vibration, which is of the greatest importance to the

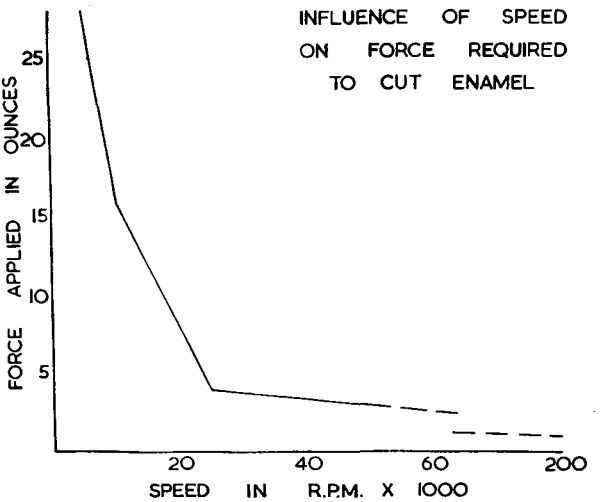



FIG. 15.
Chart of pressure and speed.

conscious patient in the dental chair. Shovelton (1958) and other authors consider that a true speed of 20,000 to 25,000 revolutions per minute at the handpiece is the most useful generally. At speeds in the region of 40,000 steel burs are not very effective, but carbide burs and diamond stones maintain their efficiency. A more important consideration than revolutions per minute is peripheral speed of instruments. Diamonds are most effective in the 5,000 to 9,000 feet per minute range (American Standards Association) ($\frac{1}{8}$ inch diamond bur has a rim speed of 1,000 feet per minute at 30,000 revolutions per minute, therefore it is most efficient at 150,000 revolutions per minute).

There appears to be little doubt that bone is damaged by the heat of burring and thin sequestra may at times separate before healing occurs. Hudack (1932) states that tissue changes begin at 160°F and that the



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

changes may become irrevocable at 110°F. Starling states that a rise of 15° to 20°F. causes damage to protoplasm. Lindeman (1956) has described facial palsy after diathermy coagulation of the vestibule during destruction of the labyrinth, and has shown that a temperature rise of 20°C. may

Temperatures developed at various speeds and applied forces (557 steel bur) (Peyton, 1957)

| Speed r.p.m. | Temperature °F. at forces | | | |
|---|---|---|---|---|
| | 0·5 lb. | 1·0 lb. | 1·5 lb. | 2·0 lb. |
| 2,000 | 30 | 40 | 50 | 60 |
| 4,000 | 38 | 59 | 78 | 100 |
| 6,000 | 43 | 75 | 95 | 125 |
| 8,000 | 48 | 88 | 110 | — |
| 10,000 | 52 | 102 | 121 | — |

FIG. 16.

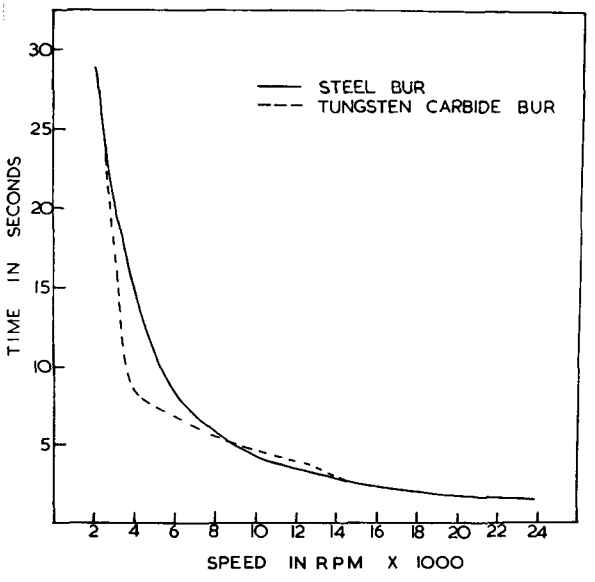



FIG. 17.
Cutting time and speed.

be recorded within the facial canal during burring of the lateral semicircular canal. The temperature of a bur cutting bone may rise to 130°C. (Henschel, 1943) or even as high as 370°C. (Lisanti, 1952).

It should be possible to remove a considerable part of the bone in a mastoidectomy with a bur in a very short time compared with that taken for the whole operation, but this can only be done safely if a suitable means of keeping the heat produced down to a reasonable level is used.



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

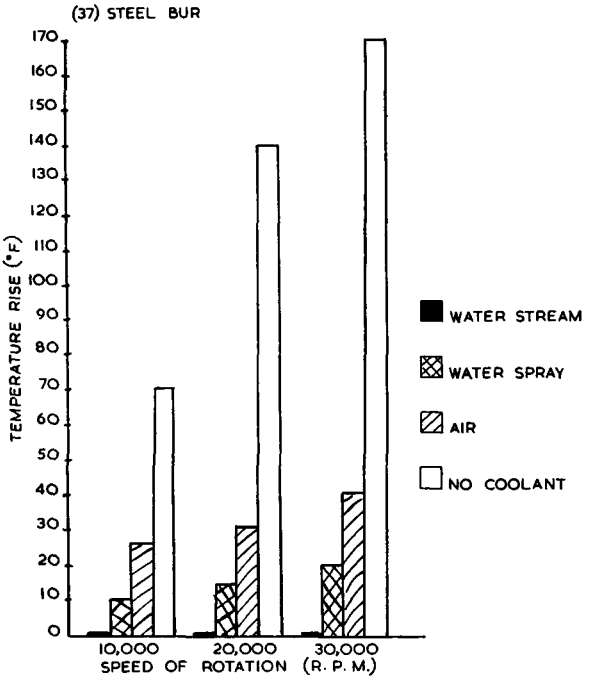



FIG. 18.
(Peyton, 1958) Temperature rise with various coolants.

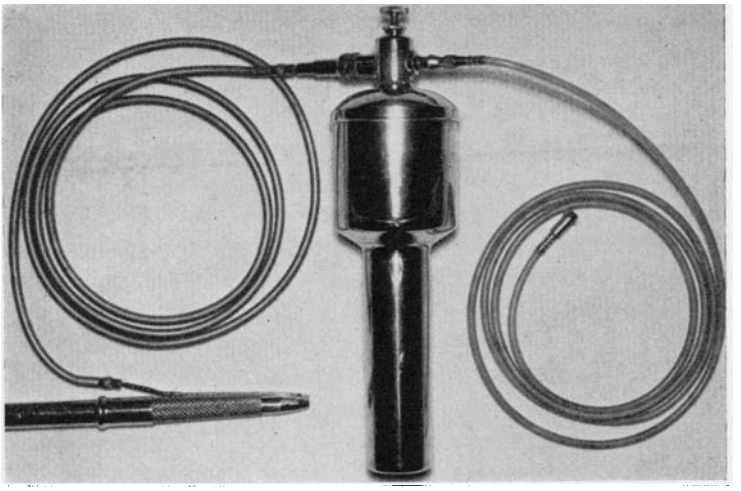


FIG. 19.
Air water spray equipment.



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

*The bur may be cooled* (Fig. 18) by a stream of air, water, saline with 1 c.c. adrenaline per litre (or Lampe's solution (1952) during later stages of fenestration), or a combination of air and water as a spray (Fig. 19).

*Water* cooling has the advantage that its temperature is easily stabilized and dessication does not occur. Water is the best heat sponge known, and properly applied will prevent thermal trauma even during the most violent bone work. With a standard dental drill and medium bur 8 c.c. of water per minute keeps the temperature rise down to 14°F., well within the zone of "temperature tolerance" (Henschel, 1944). A rate of at least 20 c.c. per minute is recommended in mastoid surgery. It is remarkable how much the life of the bur is lengthened by this means. *Air* is a poor heat sponge, with negligible specific heat, and dessication may result from its use, but

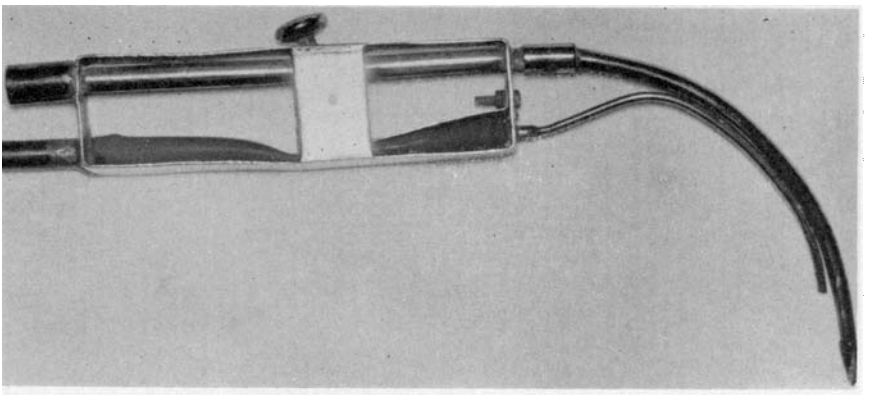


FIG. 20.
Modified Venker's sucker and irrigator.

a stream of air directed onto the bur point from a large suction end-piece at a pressure sufficient to blow the debris clear of the cavity is very useful in the initial stages of the operation, as long as the bone remains dry. By this method the working area is kept clean and better visualization of the whole area is obtained than by any other method. As soon as bleeding occurs the teeth of the bur may become clogged and a change should be made at this stage to water cooling, and the cavity walls may be run over by the bur again to remove a superficial layer of bone. At speeds of 20,000 revolutions per minute and over the greatest cooling effect is said to be obtained by an air-water spray which is better in this respect than water alone (Peyton, 1957) but the disadvantages in mastoid surgery will be mentioned. Proper washing is required for maximum efficiency of cutting tools, for then each cutting facet of the tool comes into contact with the bone instead of continuing to grind up the debris already cut away. At 250,000 r.p.m. it is very necessary to use large quantities of water



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

to avoid all frictional heat damage which may rule out these speeds for temporal bone surgery.

The earliest recorded cooling device was a nozzle for the handpiece worked by a rubber bulb. Anderson (1942) found that when a jet of water impinged directly on the bur the rise in temperature was eliminated for however long the drill remained in contact with the bone unless the diameter of the cavity were similar to that of the bur, and then the jet was not so effective. In this case the temperature rose up to 25 per cent. of what it would have done had there been no jet; it is thus important to keep the cavity reasonably open. The later designs of spray for attachment

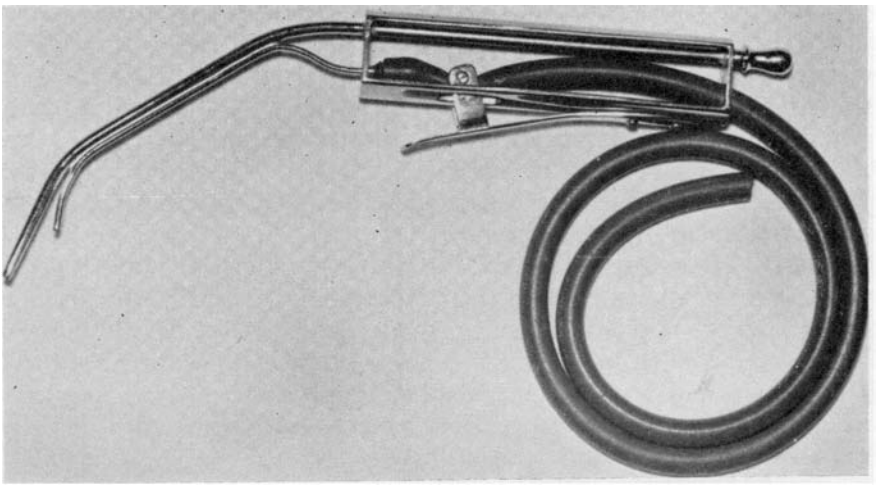


FIG. 21.
Wulstein's sucker and irrigator.

to the handpiece work well (Fig. 19), but in aural surgery it is at times inconvenient to have water playing on to the large bur head as considerable spray is formed which reduces visibility in the cavity, making finer work difficult. A separate irrigator is usually more acceptable and may then be used for other purposes such as washing the cavity when the drill is not being used. Spray cooling cannot be used with burs of over 3 mm. diameter as centrifugal force at the periphery of large instruments throws off the coolant before it reaches the bone so that overheating occurs.

During the use of water cooling it is important to understand that moist burs will clog, but that a really wet bur bathed in a constant stream of water will remain constantly quite clean. Sufficient water should enter the cavity to cool the bur, keep it clean and wash away debris and blood from the track of the bur. A sucker handpiece held in the left hand and the drill handpiece in the right (knife and fork-like), clears away from the excess



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

fluid and helps protect vital structures. Several methods of introducing water into the working area have been tried, one of the most convenient is the combined sucker and irrigator *introduced by Venker* (Fig. 20). The suction part of this instrument should be tapered ($\frac{1}{4}$ in. lumen down to about $\frac{1}{10}$ in. at its distal end); this lessens the tendency for debris to lodge in the tube. Narrow suction tubes of constant lumen are blocked easily, are particularly difficult to clean if the curve is acute, and once they have been boiled accidentally with blood in the lumen may only with great trouble be made to work effectively again. The irrigation tube may be placed above or below the suction tube, but the last half inch should be well separated from the suction tube or the water is picked up by the suction before it can reach the working area. The distal end of the suction tube may be worn away by touching the bur and small half-inch tips which screw on to this end of the tube have been found useful—they are easily removed when blocked and are disposed of when worn. The switch for the irrigation fluid of Venker's instrument switches the fluid on when required and is designed to remain in the "on" or "off" position without further attention. This arrangement is usually very satisfactory, but the adjustment is fine and if the switch becomes misaligned it is difficult to re-adjust. Wulstein has described a modified method of turning on the fluid by pressure on a metal spring beneath the handle (Fig. 21). This method is more certain than the original one, but it is better to be able to leave the water control on and so to concentrate attention on the drill in the right hand.

When drilling beneath the microscope it is convenient to employ a fixed sucker and irrigator such as Shambaugh's or Huggill's (1952) together with a second fine sucker in the left hand.

## Summary

In most instances rotatory cutting of bone in temporal bone surgery is to be preferred; propulsion may be electrical, hydraulic or pneumatic. First came a means to increase the speed from 4,000 revolutions per minute progressively up to 50,000 revolutions per minute by altering resistance coils and changing the ratio of pulley sizes. Existing handpieces wore out more quickly under these accelerated speeds, which also increased temperatures more quickly. New wear-resisting handpieces were thus developed with better steel and with ball-bearings to resist friction wear. A description of the use, care and maintenance of the drill is given.

## Acknowledgements

The authors are indebted to Mr. J. D. Gray for his valuable advice and help and for permission to publish (Figs. 11 and 12) his drill photographs and to Miss M. I. Burgess for a great deal of secretarial help.



https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press

# Power Driven Bur in Temporal Bone Surgery

## REFERENCES


ANDERSON, D. J., and VAN PRAAGH, G. (1942) *Brit. dent. J.*, **73,** 62.
BRAUER, F. J. (1957) *U.S. Forces med. J.*, **8,** 1291.
CHARBENEAU, G. T., and PEYTON, F. A. (1957) *J. dent. Res.*, **36,** 479.
CROWLEY, M. C., CHARBENEAU, G. T., and APONTE, A. J. (1959) *J. Amer. dent. Assoc.*, **58,** 45.
HENSCHEL, C. J. (1943) *J. dent. Res.*, **22,** 323.
——— (1944) *J. Amer. dent. Ass.*, **31,** 895.
HUDACK, S., and MCMASTER, P. B. (1932) *J. exp. Med.*, **55,** 431.
HUDSON, D. C., and SWEENEY, W. T. (1953) U.S. Nat Bureau of Standards Report, 2283.
HUGGILL, P. H. (1952), *Brit. med. J.*, **2,** 441.
KAZANTZIS, G., and KING, E. (1960) *Lancet*, **6,** II, 1960. p. 336.
LINDEMAN, H. (1956) *J. Oslo City Hosp.*, **6,** 17.
LISANTI, V. F., and ZANDER, H. A. (1952) *J. dent. Res.*, **31,** 548.
PEYTON, F. A. (1957) *New York J. Dent.*, **28,** 262.
——— (1958) *J. Amer. dent. Ass.*, **56,** 664.
PORTMANN, M. and CLAVERIE, G. (1957) *Ann. Otol. (St. Louis)*, **66,** 49.
SCOTT-SAMUEL, C. A. (1960) *Brit. dent. J.*, **108,** 131.
SHOVELTON, D. S. (1958) *Brit. dent. J.*, **104,** 310.
WALSH, J. P., and SYMMONS, H. F. (1949) *N. Z. dent. J.*, **45,** 28.



The Elms,
Market Rasen,
Lincs.




https://doi.org/10.1017/S0022215100057194 Published online by Cambridge University Press