CUTTING AND ABRASION

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INTRODUCTION

A considerable proportion of our clinical time is expended in trimming and shaping the nailplate and reducing callus. After reduction of nails per nipper and use of the scalpel to pare away the gross excess of callus we naturally reach for our foot-sander or mechanical file. This article is aimed at saving labour and creating a better finish, whilst adding to the comfort and satisfaction level of the patient.

THE NEED

When working on nails we require to sculpt, remodel, thin and shape the plate in order to leave clean, continuous edges and smooth surfaces. The final shape will be that which can be achieved that most closely approximates the healthy nail unafflicted by pathology - the 'normal' nail - in extent and appearance. Early work in a large excess of tissue will need to be rapid. Later work at the same site will demand precision and greater attention to detail and surface texture.

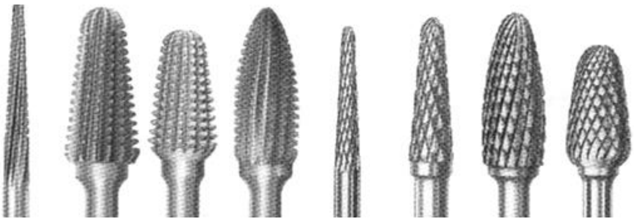
Work on the site of newly reduced callus may be directed towards blending of the edge of the area to match the flexibility of the surrounding skin, further reduction of the deeper elements of the lesion, or general smoothing of the area. Bearing in mind that skin is designed to be defensive against friction, this is no simple task.

THE ARMAMENTARIUM

The simple foot sander (a shaped board carrying a surface of abrasive grit) is a very efficient and potent instrument in the hands of a practiced and confident operator. It excels at rapid flattening and smoothing of skin surfaces, but is of no use whatsoever in the deeper regions of an irregularly floored callus. It is of limited value only in nail work. Foot sanders work entirely by abrasion.

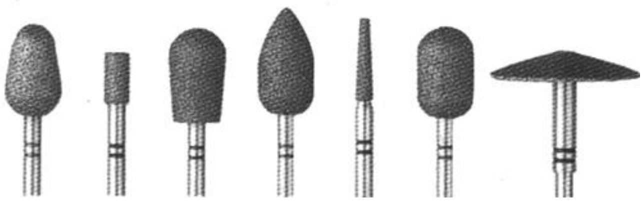
The mechanical file/handpiece motor is applicable to both nail and skin work. Wet drills are most versatile and are applicable to a wider range of cases and conditions, but a dry dust extraction drill used by a skilful clinician can be very effective indeed.

The drill is quite useless without some device fitted into the handpiece. Chosen intelligently with regard to its characteristic properties, it is this device (the bur), which will speed up our treatment and improve the comfort of the patient. It is this device that executes the work at the 'skinface'. The device may be a bur, a trimmer, an arbor band, cap, disc, umbrella, 'stone' or diamond. These tools are mostly produced for the dental trade and profession, from whom they are usually 'borrowed' by the foot health industry. A very wide range of handpiece bits are used in technical dentistry and in the dental surgery, and they are used in greater numbers and much more intensively than by the foot health professions. Only a very few designs are produced specifically for the podiatrist/foot health practitioner. The devices listed work either by 'cutting' or 'abrasion'. Burs and trimmers *cut*; stones, arbour bands, caps and diamonds *abrade*.



Above:
Examples of cross-cut steel trimmers.
Note the many different profiles available.

Below:
Examples of industrial diamond chip encrusted profiles (diamonds).
On the extreme right is an ‘umbrella’ that is coated only on the upper surface of the canopy.

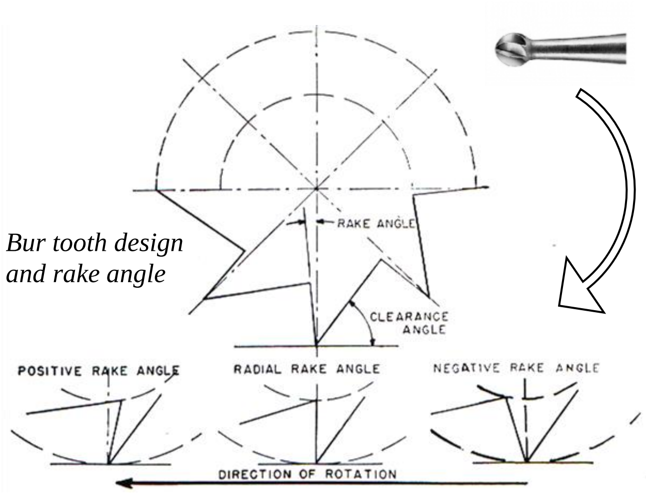


CUTTING

When a rotating bur or trimmer turns, the blades of the tool remove a part of the surface by means of a shearing action, the edge of each tiny blade working essentially as the blade of a hand-held knife or chisel. The design of the working edge has great influence on the efficiency with which the cutting takes place in the material to be cut. Any given cutting edge will work differently upon a hard material compared to a soft material. The characteristics of the cutting edge are 'designed-in' to a bur or trimmer by the manufacturer who produces the tool with a specific end use in mind. Burs and trimmers are produced from hypereutectoid steel with hardening agents added, usually referred to as *carbon steel*. Cut from blank stock, they are cut by a rotating cutter that cuts in line with the axis of the bur. The bur is then hardened and tempered. They may also be produced in *tungsten steel* for extended working life. Sometimes only the head of a tungsten steel bur is made of tungsten steel. The head is made by the process of powder metallurgy: tungsten carbide powder is mixed with cobalt powder in the proportion of 90 parts to 10 parts respectively. This mix is placed under pressure in a vacuum and heated to approximately 1,350º C. A partial alloying, or sintering of the metals take place. The head is machined using diamond cutters and is then electrically butt-welded to a steel shaft. Burs are industrial milling cutters in miniature, but instead of the work being fed to the cutter at a predictable and constant rate, the bur is applied to the work by the variable hand pressure of the operator. Trimmers are designed primarily for carving hard plastic, in particular methyl methacrylate resin as used in denture bases and removable orthodontic appliance baseplates.

THE MECHANICS OF CUTTING

The mechanics of how an edge cuts are highly complex. The following diagram should be examined:



Bur tooth design and rake angle

Note that in the diagram the bur is turning clockwise. The diagram shows a portion of the bur in cross-section with the teeth shown in outline. A cutting edge is shown in contact with the surface to be worked upon (the work). The side of the bur tooth which precedes is the *tooth face*: the following surface behind the cutting edge is the back, or *flank* of the tooth.

The face of the bur tooth is at an angle to the radial line from the centre of the bur head to the cutting edge. This angle is known as the *rake angle*. The rake angle is referred to as a positive rake angle if the tooth face follows the edge, or a negative rake angle if the face precedes the edge. A zero rake angle occurs if the face of the tooth lies along the radial line. The angle between the back of the tooth and the work surface is the *clearance angle*. Wherever possible a positive rake angle is used. The greater the positive rake angle, the more eager will be the bur to cut - but the less controllable it will be. Positive rake angles cause less stress (and hence less heat) within the work as the tooth bites. Cut shavings curl away into the space between the successive teeth, the *flute*, as the edge removes the surface by a shearing action.

Negative rake angles are employed in many bur designs intended for cutting hard materials with precision, since the work substance then fragments into small particles in front of the edge and is readily washed from the flute as dust or grit. However, more stress is caused within the work and more heat is generated.

If the clearance angle is steep the cutting edge will be delicate, unsupported, and will wear quickly and damage easily. Conversely, if the clearance angle is low, the tooth edge is better supported and therefore more robust and durable. The clearance angle is created to reduce the amount of contact with the work and thus reduce friction that would otherwise accompany the turning of the bur and generate heat. The steeper the clearance angle, the more vulnerable is the cutting edge.

OTHER FACTORS

The cutting edges of trimmers and burs may be straight-cut or spiral-cut since the angle of the cutting edge to the work affects the 'bite' or 'attack'; in other words how aggressive the action is. Flute design is important to the way the debris is cleared from the cutting edge and discharged from the bur. If debris clearance is not efficient, the bur will clog and cease to cut.

The number of teeth on a bur seems to make little difference to the speed of cut, but if two or more teeth engage with the work at the same time, vibration is reduced. However, the more teeth working, the less each individual tooth does. Faster rotation of the bur will not remove more substance unless pressure is increased. If this is done there will be more friction and more heat generated.

The majority of bur designs carry six or eight cutting edges. If those edges are cross-cut the bur usually becomes more efficient since the debris is fragmented with greater rapidity and removed from the flute more readily. But cross-cut burs wear more rapidly because the length of the cutting edge is reduced by the collective width of the cross-cuts. Cross-cut burs have reduced cutting edge and more fluting.

As a bur is utilised, it may at first appear to improve with use. It may be that it was not truly concentric, or that some of the teeth were 'higher' than others. When all teeth are worn to the same level and true concentricity is attained, the bur will be at its best.

RUN-OUT

This is the eccentricity or maximal displacement of the bur head from its axis of rotation as the bur turns. Run-out may be due to discrepancies within the bur itself, or due to wear and misalignment within the handpiece mechanism. If the collet of the handpiece allows any wobble, the effect is magnified at the bur head in proportion to the length of the bur shaft protruding. This will affect the efficiency of the cut. If pressure upon a bur exhibiting run-out is increased, vibration will be set up as the eccentricity first drives the bur into the work. At the next half-turn the bur will escape from the work, only to strike the surface again after another half turn. This will prove very disagreeable to our patient. A vibrating bur will appear to remove a greater amount of tissue, but this will be by a process of 'shattering', not by cutting. Control will be poor and heat will be generated.

THE INFLUENCE OF ROTATION SPEED AND LOAD UPON THE BUR

The energy exerted in pressing the bur into the work surface will depend upon the contact area of the bur, the hardness of the work, the speed of rotation of the bur, the design of the teeth and the material of which the bur head is manufactured. Greater pressure generates more friction and therefore more heat. In practice, the worker will vary the pressure as required for optimal performance. The higher the rotation speed, the less requirement there will be for exertion of heavy pressure (because there are more cuts in any specified time interval and thus more material will be removed). At any rotational speed there is a minimal load that is necessary to induce the edges to cut. As the first tooth contacts the work the induced stress must be sufficient to overcome the elastic limit of the material. If the force at the cutting edge exceeds the elastic limit of the material, permanent deformation and cutting/fracture will occur, and the work surface will be removed.

COOLANTS

If a coolant water spray can be applied at the interface, heat will be reduced and the pressure can be increased to remove more material. Some slight heat will remain with a water spray (a water stream is even more efficient at heat dissipation), but for most clinical applications upon the foot the water spray is quite sufficient. Applying coolant increases the cutting rate noticeably. The tooth edges are washed clean, the cut material washed from the surface and flushed from the bur flutes, and the friction resisting rotation is reduced. The work surface is also somewhat softened by the coolant making it easier for the cutting edge to penetrate and cut. Intermittent cutting at brief intervals is preferable to sustained effort in one place. Momentary lifting of the bur from the surface prevents such build up of heat as would prove uncomfortable to the patient.

ABRASION

Abrasion is the removal of a surface of a by a series of multiple scratches made by a substance harder than the target material. Abrasion is a much more random process than cutting, and the depth of each scratch varies according to the set of the particle that created it. Deep scratches made by large particles are replaced by more superficial shallow scratches as the level of the surface is improved.
The abrasive substance is usually granular, gritty and sharp. An ideal abrasive presents irregular angular facets with sharp edges. Good abrasive substances have a grit which is hard enough to resist itself being abraded and dulled by the work it passes over, and yet the individual grains must occasionally fracture to present new sharp cutting edges. These occasional fractures will shed any retained swarf and restore the cutting ability of the grit. Particles of an abrasive present sharp cutting edges and points, randomly aligned. As they pass over and through the softer work surface they may cut, gouge or scratch, according to the angle and set of the individual grain.
Sand consists mainly of particles of silica. Silica is potentially a good abrasive substance, but if taken off a beach the grains will have been reduced by wind and wave action and the particle edges will have been dulled by mutual tumbling. Sand from this source actually makes a poor abrasive.
Grits of volcanic origin are useful. Crushed mineral substances furnish alternative materials. Emery is primarily a natural oxide of aluminium called corundum. This is usually accompanied by various impurities such as iron oxide, itself an abrasive. Pure aluminium oxide is manufactured from bauxite, an impure form of aluminium oxide. It can be produced in various grain sizes and is very commonly used in abrasive dental stone manufacture.
Garnet includes a number of different minerals that have similar physical properties and crystalline form. The minerals comprise the silicates of any combinations of aluminium, cobalt, magnesium, iron and manganese. Garnet is often presented bound to a paper disc by glue or shellac, for mounting on a mandrel.
Industrial diamond chippings are the hardest abrasive of all, and are the most effective but most expensive substance.

HARDNESS OF GRITS

Hardness may be measured by *indentation*, *shear* and *elastic deformation before fracture* tests. There are several tests - each performed on a different machine. Hardness is expressed as a numerical figure of Brinell hardness, Rockwell, Vickers or Knoop hardness.

KNOOP HARDNESS VALUES (HK) OF COMMON ABRASIVES

SUBSTANCE	HK
Sand	800
Emery	2000
Silicone carbide	2500
Boron Carbide	2800
Diamond	>7000

Many of the manufactured stones and discs are made from grit masses held together with a binder which is usually a ceramic substance, or the binder might be shellac or rubber in the 'soft grade' presentations. As the binder wears away, further particles are exposed upon the surface. These abrasive devices work equally well in clockwise and anti-clockwise rotation.

'Diamonds' are different in that they have a surface layer only of diamond chips adhered to an aluminium or steel form by an electroplating or electrodeposition process. This locks each diamond particle rigidly in position, where it will remain until the particle fractures or is dislodged. Diamond profiles are usually thrown away because the shaft is accidentally bent. They rarely survive long enough to wear out.

Open grits with regular spacing of particles have lots of space between the sharp protrusions. These burs and stones are more efficient because the removed material is quickly and easily dispersed from the grit. Tight packed, randomly dispersed grits clog easily and the swarf may remain, condense, and fill up the clearance spaces. Wet drills are more efficient because they constantly wash the bur, irrigating the working surfaces and ensuring maximal exposure and optimal value of the sharp edges.

PARTICLE SPEED

The speed at which a particle passes over the work surface is known as its *linear speed*. The linear speed of a particle is related to the diameter of the disc or stone and to its rate of rotation. If a particle on the outer surface of a stone undergoes one complete rotation of the stone, the particle travels the length of the circumference of the stone or π times the diameter of the stone. This, multiplied by its number of rotations per minute (rpm) gives the linear speed *(v)*. - Linear speed is related to rotational speed as follows:

$$v = \pi dn$$

where d = the diameter of the profile
and n = revolutions per minute
v = linear speed

So particles on the largest diameter of a profile or on the outer edge of a disc travel further and faster than do particles near the pole or towards the centre. Thus maximum removal of a surface will occur when the greater diameter is employed - greater control or precision comes from using the lesser diameter of a profile, nearer to the axis. From this we might design a rule: *the smaller the diameter, the faster must be the rotation speed* to deliver the same efficiency. It also follows that: *larger diameter devices must be used at lower speeds* to be safely controllable and comfortable for our patients.

CUTTING AND ABRASION PRODUCTS

Generally, cutting trimmers and burs produce larger particles of swarf that are heavy and unlikely to enter the respiratory tract. Abrading tools produce smaller particles and it is these that cause concern for the wellbeing of operator and patient. The health of the operator is the greater concern due to the frequency and duration of occupational exposure to organic dusts that may contain dermatophytic elements. Particles of 5µ and smaller (86% of the dust) can be inspired deep into the alveolar sacs and allergic sensitisation (raised serum IgE levels - presence of antibodies associated with a low-grade inflammatory response) is known to occur in foot health workers. Dust control measures are therefore vitally important to safe clinical practice.

SUMMARY

Understanding of the mechanisms of cutting and abrasion is important to good clinical practice and technical expertise. Appropriate choice and skillful application of bur, trimmer, stone or diamond results in efficient working with optimal outcome. By application of the principles herein discussed, treatment can be delivered with comfort and safety for the patient and with due regard to the health of the operator.

ALLIANCE PROFESSIONAL DEVELOPMENT

CUTTING AND ABRASION

Answers should be submitted on A4 paper and should be of sufficient length to demonstrate full understanding of the topic. Single word answers are not permissible. Try to answer in one or two short paragraphs, generally not more than ⅓rd page per answer.

Q1. How do trimmers and burs reduce skin and nail masses?

Q2. By what mechanism do stones and diamonds reduce tissues?

Q3. Draw a cross-section of a bur and label *i)the tooth face, ii)the tooth flank, iii)the clearance angle*

Q4. Explain *rake angle*. What is the effect of a negative rake angle?

Q5. Define the process of *abrasion*. How is a surface levelled and improved?

Q6. What characteristics would a good abrasive substance have?

Q7. What is the purpose of *fluting*?

Q8. What effect does *cross-cutting* have upon the action of a bur or trimmer?

Q9. How does a *stone* differ in its manufacture from a *diamond*?

Q10. What is meant by *run-out*?

Return this page with the administration fee (see website CPD Download page) and your answers to: Alliance CPD Dept, Plas Eirias Business Centre, Colwyn Bay, Conwy, N Wales LL29 8BF. A CPD certificate will be issued for 10 CPD points on successful completion.

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