Understanding Electric Handpieces

by Daniel Serrago

Almost every lab throughout the U.S. owns at least one electric handpiece system, making it one of the most common pieces of equipment found in today's dental lab. The applications for this handpiece system can vary greatly from lab to lab, but what is common to all is that each application places a strain, or load, of one kind or another on the internal workings of the handpiece that eventually leads to failure. This article will help you to understand the workings of your electric handpiece and show you ways to extend its life before major repairs are required. I will discuss maintenance and operational tips to help reduce the failure rate of certain components of your electric handpiece. Like the tires on your car, even with proper air pressure, rotation and moderate driving habits, they will eventually wear out and need replacing: so will the various components inside your electric handpiece need replacing.

First, it is important to remind you that **not all electric handpieces are created equal**. There is a great difference to be seen in RPM's, output power, and construction from the lower-priced models to the higher end. My experience has been *"you get what you pay for"*- Matching up the quality of the handpiece system to the task required is a critical factor to a longer life expectancy. Buying a $175.00 system and using it to cut, grind, and polish metals is probably not a good combination. Therefore, it is important to know what you will be using the handpiece for to help set your minimum system specifications.

After the overview below, I will familiarize you with the various components of an electric handpiece and then give you the information required to quickly diagnose problems to help reduce repair costs. At the end of this article I will provide you with information that can help extend the life of your handpiece's various components.

General Overview

The three important ratings of an electric handpiece is **RPM's**, (how fast it spins), **torque**, (resistance to slowing down under a certain load) and **wattage** (the product of rpm's and torque as measured at the bur).

Electric handpieces, depending on the type and model, operate between 25,000 and 50,000 rpm's and have output wattage from 35 – 250 watts. Torque, the resistance to slowing down under load, for electric handpieces can be expressed in several different units of measure. The most common is Newtons per cm^2. Higher end handpieces can generate upwards of 25 – 30 N/cm^2 at 50,000 rpm (the equivalent of 1/3 horsepower at the bur). *For the purposes of this guide it is not important to memorize these numbers, but to understand that different makes & models of handpieces have greater torque and spin faster than others.*

Electric handpieces come in 2 types "**Brushed**" and "**Brushless**". Brushed handpieces have 2 carbon composite brushes that bring "DC" electricity from the control box to the armature, which is the heart of the handpiece. Brushless handpieces utilize very sophisticated control electronics to generate strong electro-magnetic pulses to rotate a "rare-earth magnet rotor", or just rotor. Many of the brushless handpieces used in dental labs today generate close to 1/3 horsepower or 200 – 250 watts of power at the bur at 50,000 rpm's. Needless to say, these are the high-end handpieces that range in price from $1200 - $2000. In contrast, the low end brushed handpieces can be purchased for around $175 with control box & foot control. Their power at the bur under "no load" ranges from 35 watts to 120 watts at 25,000-35,000 rpm's, depending on the make and model.

As a general rule for labs, there are 2 main reasons for premature failure of electric handpiece components:

1. The handpiece not being used in a proper environment.
2. The handpiece being used on materials that stress the upper performance level of the handpiece.

These causes of failure will be discussed more thoroughly in a later section, but first I'll give you a brief explanation of the various parts of an electric handpiece.

Handpiece Components

I like to divide electric handpieces into 2 main sections. The front section, where the technician inserts the bur, I call the ***spindle section***. The back end where the power cord comes out from, I call the ***motor section***. Although there are other various spacers, wave washers, seals, and other parts that make up a complete electric handpiece, I will only be addressing the following main parts that help you diagnose the most common problems:

1. Ball Bearings
2. Brushes
3. Armature/ Rotor
4. Joint Delrin
5. Collet/ Chuck
6. Power Cord
7. Foot Pedal
8. Control/ Power Supply Box

Ball Bearings

Electric handpieces utilize ball bearings exclusively. I have yet to come across a bushing or sleeve-type bearing in an electric handpiece. Most electric handpieces will utilize 4 or 5 bearings. *Two bearings are in the motor section* and *two or three bearings in the spindle section*. Unlike the clinic high speed market that can repair the vast majority of high speeds with 8 – 10 types of bearings, the broad range of makes and models of electric handpieces requires an inventory of over 50 different types of bearings!

A bearing failure is the most common failure in an electric handpiece. A handpiece with good bearings turns smoothly. If this is not the case, it is most likely caused by 1 or more bearings failing. Also, there should be a low to moderate whirring sound coming from the handpiece when turning at slow rpm's. If there is a loud "hashy" sound, it usually means that 1 or more of the bearings has dried out and the balls have flat spots where they stopped turning for small periods of time.

A rebuild is usually recommended but not required at this point. *It is important to point out that a bearing failure is not far away*. There is no way to judge how much time there might be before a failure occurs. When a bearing does fail, I disassemble the handpiece, clean all parts and replace all bearings and seals- this is what constitutes a standard rebuild at Garland Dental Services.

Another common bearing failure is the broken or loose cage. This can be identified by either a subtle ticking sound in one of the bearings, which sometimes causes the speed to drop slightly, or an intermittent squealing sound as two of the ball bearings rub together. *What is difficult about this kind of failure is that the symptoms can be very short in duration and may not appear frequently*. Again, once diagnosed, a rebuild is required as soon as possible as a sudden lock-up of the damaged bearing can cause damage to other parts of the handpiece.

Brushes

Brushes are a carbon composite material that can be machined into various shapes and sizes. A multi-strand wire is connected to one end of the brush. This wire travels through the brush spring and is soldered to the mounting plate electrical hook-up. Brushes bring the current to the armature contacts, producing a magnetic field which turns the armature. As this involves a constant rubbing of the carbon material against the copper plates, the brushes will eventually wear down. *As a brush wears down to its stop the spring pressure drops to nothing, meaning the spring is fully extended and there is no additional pressure to push the brush against the armature. This allows the brush to bounce along the armature contacts which causes arcing*.

Arcing is the current jumping across a small gap like in arc welding. Arcing can pit and damage the armature. It produces lots of carbon dust, which causes the armature plates to short together, reducing motor power and makes the motor get very hot. The carbon dust also accumulates in the rear motor bearing causing premature bearing failure. I recommend that brushes be replaced if they are less than ½ their original length. Another common brush failure is the brush wire burning or breaking off. When this occurs, the current must pass through the brush spring to get to the brush. As this is usually a much thinner wire carrying the same current, it gets red-hot and loses its tension, thus letting the brush arc on the armature and give very poor output power. *Brushes are easily changeable by the lab tech and normally it isn't required to send the handpiece into the shop for repairs*.

Armature/ Rotor

The armature (rotor) is the heart of the electric handpiece. The armature receives the electrical current through the brushes onto the contacts, making the armature rotate. The rotor is used in brushless handpieces. Made from a very strong magnetic material, the rotor receives electro-magnetic pulses through the stator windings making it rotate. *As there are no field serviceable parts in the armature/ rotor, the only thing you can test for is vibration*. The armature can, over time and use, lose its balance- this causes the handpiece to vibrate. <u>While spinning the handpiece at high rpm's, if you feel a strong massaging effect while holding the handpiece it should be brought in for repair</u>. While it is possible that a bad bearing could be causing the vibration, an out of balance armature/ rotor is most probable and will dramatically shorten bearing life. <u>The most common cause of an out of balance armature is dropping the handpiece</u>.

Joint Delrin

As I mentioned earlier, an electric handpiece is made in two sections: the motor and spindle. Most electric handpieces unscrew at the center to divide the handpiece into its two distinct sub-assemblies. The joint delrin is a fairly inexpensive plastic piece that receives the power from the armature drive shaft and couples it to the spindle section. The joint delrin is normally pressed onto or inserted into the backend of the spindle shaft and is easily replaced in the field. <u>The most common indication of a bad joint delrin is when you can hear the motor section turning and the bur is not turning or can be stopped with very low pressure</u>.

Collet/ Chuck

As in high-speed handpieces, the chuck holds the bur. Chuck assemblies consist of 2 parts: the chuck itself and what I call the chuck receiver. Chucks are designed only to grip the bur at the front of the handpiece, which makes inspection for wear fairly easy. With a bur in the handpiece, look and the side slits or cuts in the chuck. As the chuck wears these slits or cuts get narrower. This means the rounded inner surface that holds the bur is wearing away. The chuck then seats deeper in the receiver and has less spring pressure to hold the burs with. Eventually the slits will touch and the fingers of the chuck can no longer squeeze tighter together. This is when your burs will begin slipping out. When you begin to see this slippage, it is time to replace the chuck.

The receiver on many electric handpieces has a precisely machined-out center to "receive" the back of the bur. This provides 2 points, front &

back, with which the bur is held, thus stabilizing it for a highly concentric spin. *Chucks, although fairly straight forward in concept, are not user-friendly to change, especially after being used for a couple of years. Some disassembly of the spindle section and special tooling is required to break free the chuck from the receiver*. NSK brushless handpieces come with tools to lock the shaft without disassembly, and Ram Products "Tech 2000" series handpieces have a locking feature to their spindles so that just the chuck tool is required to remove the chuck. For all other types it is my recommendation that the handpiece should be sent in for chuck replacement.

Power Cord

The simplest of all components, the handpiece power cord provides an electrical connection from the control box to the handpiece. They are available in straight and curly form. The most common failure is for one of the wires at the handpiece end to break inside the connector, usually caused by the cord being pulled at an extreme angle for long periods of time. A simple test is to turn the handpiece on at a moderate speed than push in and wiggle the cord where it enters the connector at the back of the handpiece. A bad cord will show intermittent operation of the handpiece. Power cords are easily replaceable in the field.

Foot Pedal

The foot pedal or foot control of a handpiece system allows the user to turn the handpiece on and off and to vary the output speed. The most common failure is having one of the wires break where the wire harness enters the foot control housing. Another common failure is the rheostat, or variable resistor. This tells the control box how fast to run the handpiece. Foot pedals cost around $120.00 plus new, so it is cost-effective to repair the foot pedal up to the $55 - $65 range. *There are no field serviceable parts in a foot pedal.*

Control/ Power Supply Box

The final main component to be discussed is the control box. This unit takes the 120Vac, converts it to 35 – 55Vdc and, through various electronic circuits, delivers a variable DC voltage from 0-50Vdc (depending on the type of supply). This voltage varies the speed of the handpiece.

On most units the speed control knob located on the front panel varies the speed of the handpiece. Controlling the speed in this manner is called hand mode. By moving a switch from hand to foot allows the variable speed to be controlled by the foot pedal, also known as foot mode. The last control commonly found on a control box is the directional switch. As the name implies, this switch changes the direction of spin of the bur. Control boxes for Brushless handpieces have control panel layouts similar to the brushed control box and are operated identically. Except for a circuit breaker or fuse, there are no field serviceable parts inside either control box. Systems with suspected control box issues should be sent in for repairs.

The Dental Lab Environment & Electric Handpiece Failures

In the overview I mentioned that there were 2 main reasons for electric handpiece failure. The first reason is the environment in which they work. Dental labs use a wide variety of chemical compounds, materials and metals in making the various crowns, implants, bridges, partials and dentures. ***Working with all the various materials can produce a lot of very fine dust. This dust, which in some cases is no longer than 1 - 2 microns, is the main cause for electric handpiece failure***.

Many dental labs that I have been to are quite dusty from the materials used. This fine dust collects over everything over time. To help combat this dust, and provide a clean breathing environment many labs use a dust collector, suction unit to suck in this dust. <u>While working with the electric handpiece, the dental tech should be no more than 3" from the vacuum opening</u>.

However, reality is that many techs do not get close enough for the vacuum to have much effect. This allows the vacuum generated by the spinning of the bur and associated spindle parts to draw particles into the nose of the handpiece. Over several months this dust works its way through the dust shields and into the upper spindle bearings and causes them to fail. Dust also gets into the handpiece through the motor section. Brushed armatures utilize a fan to circulate air to help cool the armature down. This also allows for the dust to be sucked in. Both motor bearings are susceptible to this failure.

Also as discussed earlier, carbon dust from the brushes will cause the rear motor bearing to fail. Trimming models with an electric handpiece is especially deadly as a very fine plaster dust is created. In many cases the model material is not completely dry and when not used near a vacuum source this very fine dust mixes with moisture to create a corrosive combination in the spindle of the handpiece, which usually causes rapid bearing failure and rust in the upper spindle components. This is a more expensive rebuild, having to clean up all the surface rust on the various parts in the spindle. *I believe that it is not a good idea to trim models with an electric handpiece. Use a model trimmer instead. They were designed for the job. If you are using an electric handpiece be sure to use a suction unit as well.*

The 2nd main cause of electric handpiece failure is using the handpiece beyond its capabilities. Handpieces are capable of delivering only so much torque at a given rpm. As a general rule, the cheaper the handpiece, the lower the output power. Materials such as non-precious and semi-precious metal and acrylic require fairly high torque and a sustained higher rpm to cut or grind through. With brushed handpieces, the more load you place on it, the slower it will go. Even with power boost circuitry, dc brushed handpieces will slow down as you increase the load, or pressure. This increased lateral pressure is absorbed by the upper spindle bearings very similar to the way the pressure is absorbed in high speed handpieces. The extra pressure generates heat in the upper spindle bearings. This creates a downward spiral as shown in the following example.

A handpiece does not have the power to maintain speed while cutting non-precious metal sprues, so the rpm's slow down, the tech presses harder to retrieve the cutting power. This in turn decreases the speed even more. While this happens, it is generating more and more heat in the bearings. This heat eventually cooks off the bearings' grease and causes bearing failures.

Another side effect of greater pressure and slower rpm's is the effect on the armature and brushes. The slower an electric motor goes due to resistance/ load, the more power it must draw from the control box. This will cause the armature to get hotter along with the brushes. As the cycle increases, more heat keeps being generated. In the end the brush wire fails causing the brush spring to over heat and fail. The brush will not seat to the armature properly, which causes arcing, bringing about its associated failures as mentioned earlier.

It is important to keep a clean work environment and be sure to use the handpiece for the materials that it was intended: Most mid range and upper grade electric handpieces will work fine for all porcelain work, polishing and light metal work. If you want to do the heavy stuff, you should be using a brushless handpiece. Their advanced electronic circuitry enables the bur to maintain the set rpm under varying loads thus breaking the downward spiral of greater pressure, slower speeds and more heat.

Maintenance Tips
to help prolong the life of your handpiece

These tips can extend the life of your handpiece until its next rebuild.

First, **never** use compressed air to blow out dust around the front spindle & motor areas. It will only serve to force some of the dirt into the bearings. The power cord cover can be removed and excess dirt brushed away, also the spindle section can be removed from its housing and dusted off.

Check brushes a couple of times per year. If they are showing too much wear, change them out. Brushes should last for a year or more under normal use. If brushes are lasting much less than a year it could be and indicator of a bad armature. If the armature plates have worn unevenly or the armature has been overheated allowing the plates to move out of alignment, it can cause the brushes to bounce or vibrate.

As I had mentioned earlier, the chucks are not normally user friendly, it would be very difficult for most techs to remove the chuck and clean out the dirt build up in bottom of the chuck receiver. Normally burs extend out no further than ½ inch in a clean receiver. Do not use a handpiece where the bur extends more than ¼" further than it should. If the bur does stick out to far it means the chuck receiver is filled with dirt and cannot seat the bur properly. This will increase the loading of the front bearings. Try using a carbide bur of equal or narrower diameter and use it to drill out the compacted dirt. This can help reduce the build up and allow you to keep using your handpiece without causing to much loading to your bearings. Examine the shank of your burs. You should be looking for a shiny band or an obvious wearing of metal at the point where the chuck grips the bur. This is an indicator the shank is worn or way under tolerance, to thin, and should be discarded. Continued use will shorten the life of the chuck.

Last, always keep a bur locked in the handpiece when not in use. If the handpiece is left open and the foot pedal is accidentally pressed on, the handpiece will not be able to turn. This will cause the armature and brushes to overheat to the point of melting. It can also cause damage to the control box, depending on how the armature & brushes fail.

Electric Handpieces in the Dental Clinic

In the last 5 years or so, companies like KaVo, Bien Air, W&H and NSK have introduced electric motors and attachments to replace the air driven high speed. I am told that in Europe, 90% of the dentists use electric systems at the chair instead of air and that the U.S., Canada and 3rd world countries are the hold-outs to the move. Whether the U.S. will ever make the move to electric, I don't know; however, there are enough out there for us to be interested in, and to have some knowledge of, this type of handpiece.

The electric handpiece motors are predominately brushed. KaVo, Bien Air and W&H have a brushless model, but they are very expensive. It is believed the extra torque will not be utilized as it would in the lab.
The motors are designed to spin at 40,000 rpm's. The contra-angle attachments gear up the speed to 160,000 rpm's for the 1:4 contra-angle and 200,000 rpm's for the 1:5 contra-angle, thus crossing of the optimum cutting rpm of the air drive handpiece under load.

Maintenance on these motors and attachments is limited, but there are a couple of common sense do's and don'ts that, if followed, will give longer life and can reduce costs when they are required.

Except for the Bien Air, changing the brushes is not user friendly. The KaVo motor even requires a special tool set just to unscrew the brushes if the doctor is interested in changing his own. The following will allow the doctor to utilize his electric handpiece system more fully:

1. Do not spray or put oil into the motor section of the handpiece. The bearings are greased and do not need oil. Also the oil collects by the brushes and armature contacts. The brush dust mixes with the oil and produces a black paste that coats everything. It is time consuming to clean and will collect in the spaces between the contact plates. This paste is highly conductive and it will short out segments of the armature making the motor loose power & rpm's.

2. Do not autoclave the motor and power cord unless absolutely necessary. If autoclaving is required, do not bag the handpiece and cord. Place it in one of the upper trays to avoid water collecting inside the motor. When the handpiece is removed, the high heat still in the handpiece will help to dry out any moisture inside.

3. Spray cleaner and lubricant through the attachment after each use and be sure to let the cleaner go through the head until it looks clean. This is especially true for surgical attachments. When using the lubricant, use a 1 to 2 second spray to make sure spray comes out the head where the bearing are. I also advocate not bagging the attachments for the same reasons. Try to allow the excess oil to drain from the lower portion of the attachment using absorbent paper towels. This will help to keep oil from running down into the motor.

4. Finally, when any sounds of failure start coming from the attachments or motor, **STOP** using them immediately and send off for repair. Contrary to air handpieces, running electrics until they grind to a halt will double or triple the repair costs.