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Anatomy of a Handpiece: Understanding Handpiece Maintenance and Repairs

A Peer-Reviewed Publication

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Figure 4. Air-driven high-speed handpieces

Water Delivery: All high-speed handpieces incorporate a water spray as a coolant; the latest innovation is a multiport spray emanating from the face of the handpiece. This provides even distribution of coolant water over the entire surface of the tooth and prevents the water spray from being blocked when cutting is performed on the distal surface of a tooth.

Fiber Optics: Fiber optics enhance operator visibility. Cellular optics have been introduced that are made from one solid glass rod instead of a collection of optic fibers. The newest innovation in optics is an LED lightbulb that generates a brighter, whiter light. Most existing systems are retrofittable to an LED lightbulb.

Autoclavability: Handpiece manufacturers are constantly seeking improvement in their handpiece designs to better withstand the harmful effects of the autoclave. Materials from bearing retainers to O-rings have evolved through several generations to higher-temperature heat-resistant components. New materials such as titanium are used for the handpiece body or shell, or special coatings are applied to help preserve the handpiece's external finish.

Electric Handpieces

The single biggest difference in comparing an electric handpiece to an air-driven handpiece is its constant speed. With an electric handpiece, there is <u>no</u> difference between free-running speed and active speed, due to the amount of power generated by the electric motor driving the handpiece, and no power is lost while cutting tooth structure. Another advantage of the new electric handpieces is that they are significantly quieter than air-driven handpieces. An electric handpiece consists of an entire system. A control box must be mounted on the delivery unit, and a conventional delivery tubing plugs into the box, which provides signal air and water, enabling the motor to be operated from the foot control already in use. The control box has digital settings so the operator can literally dial in the exact speed at which he or she would like the bur to rotate. Lightweight tubing extends from the control box to the motor. Electric motors look and feel like cylindrical low-speed air motors and produce a very quiet hum as opposed to the high-pitched whine of an air-driven high-speed handpiece. Fiber optics and multiport water spray are delivered through the attachments.[7]

Figure 5. Electric handpiece unit and attachment examples

Any number of attachments with various gearing combinations will connect onto an electric motor. The most commonly used attachment for operative dentistry is a 1:5 step-up referred to as a "high speed" attachment. Most electric motors operate at 40,000 rpm; adding a 1:5 speed-increasing attachment provides 200,000 rpm at the bur. This speed remains constant no matter how aggressively the clinician is cutting, and the advantage is much faster preparation time. There is a learning curve associated with mastering this increased power. Electric attachments are generally universal, meaning that any brand will work with any motor. One exception is the new Comfort Drive® by Kavo, a more compact design.

There are a few trade-offs to be aware of with electric handpieces. Together, the attachment and the motor are similar to working with a low-speed handpiece in your hand, versus the shorter and lighter high-speed air-driven devices. This may be of particular concern to operators with a smaller hand size. On the other hand, many users report that since the actual cutting time is reduced, this offsets any limitations based on size and weight. Electric handpieces have been found to be more efficient than air-driven high-speed handpieces.[8] Head size is also typically larger than with the average high-speed air-driven handpiece. A major investment is associated with equipping an office with electric technology, with the cost for a complete system beginning at around $3,500, and there are additional costs for each attachment required for sterilization redundancy. Electric handpieces consist of several complex parts – the attachment is more similar to a gear-driven low-speed than to an air-driven high-speed handpiece. A series of drive shafts and transmissions increase the rpm of the handpiece from 40,000 where it connects to the motor up to 200,000 in the head. This intricate array of gears and bearings makes repair more costly than for air-driven high-speed handpieces.

Body or Shell

Brass is the most common material used in handpiece manufacturing; it is a relatively inexpensive material and easy to machine, although it is soft and susceptible to denting. Cosmetic protective plating is applied over the brass but can discolor or flake off over time as a result of sterilization. Stainless steel is another material commonly used to make handpiece bodies. Steel is lighter and stronger than brass, but its use results in higher manufacturing costs, so the prices are generally higher. The current state-of-the-art in handpiece construction is titanium, which is 40 percent lighter than stainless steel and stronger and more resistant to the corrosive effects of autoclaving.

Figure 8. Body or shell

Figure 9. Corrosive effects of sterilization

The body shell of most handpieces comprises two parts: the head that houses the turbine and an outer sheath. Problems have been experienced with the heads separating from the outer shell as a result of heat processing, and various methods have been employed in the past to join these two parts together. However, the joint is a weak area, and further stress is introduced with pushbutton-type bur changing. The joint between the head and body can loosen, and the head can become too dented and affect the turbine operation.

Older-generation handpieces contain bundles of tiny light-transmitting glass fibers held together with adhesive; these bundle optics degrade and darken over time with repeated sterilization. Most new handpiece models employ cellular, or fused-rod, optics. Manufacturers claim that virtually no degradation occurs with cellular optics and back their claims with a five-year warranty. However, cellular optics are more fragile and will not survive a severe drop without fracturing.

Air and water are delivered through the body to the handpiece head. This includes drive air (used to rotate the turbine), coolant water, and chip air (often used to atomize the water spray). After the drive air is passed through the turbine, it is exhausted through the hollow body of the handpiece and down the handpiece tubing. A major problem associated with handpiece sterilization is the continual buildup of rust and corrosion that naturally occur in the steam-saturated environment of the autoclave. One way internal corrosive buildup negatively impacts handpiece performance is a gradual closing off of the handpiece exhaust ports, leading to increased backpressure around the turbine. This results in loss of turbine speed and power. Air and water lines are more prone to clogging as a result of sedimentary buildup in the recirculated water of older sterilizer models utilizing a reservoir. Newer sterilizer designs provide a fresh charge of distilled water for every steam cycle, greatly reducing the susceptibility to clogging. The latest handpiece models feature a multi-port water spray that disperses water evenly around the work area. These systems, however, incorporate tiny O-rings that break down with repeated sterilization.

The Air-Driven High-Speed Handpiece Turbine

The component that fails most often on a high-speed air-driven handpiece is the turbine; as this degrades, the handpiece exhibits signs of impending failure that are all too familiar to the dental team.

Figure 10. High-speed turbine

Figure 11. Effects of wear and sterilization

Turbines rotate at speeds ranging from 380,000 to 450,000 rpm, faster than anything else on the planet. Turbine speed can be categorized as free speed and active speed.[12] Free speed is the maximum rpm with no load. Active speed is the actual speed the turbine is reduced to when the cutting instrument engages the tooth structure. Most high-speed handpieces have an active speed in the range of 180,000 to 200,000 rpm. This extremely high speed allows the clinician to cut through hardened tooth structure with ease, leaving a smooth, clean margin, with reduced trauma to the surrounding structure and tissue. As the turbine bearings wear, speed decreases. Clinically, this results in longer preparation times with slower cutting and rougher margins. Power, also referred to as "torque," is the measure of the handpiece's ability to remove tooth structure and is expressed as watts of energy, while torque is measured in oz/inch. Handpieces used to generate 10 to 13 watts, while newer handpiece models produce 15 to 18 watts and have smaller head sizes. The greater the power available to operate the cutting instrument, the less physical demand is placed on the operator's hand and wrist, which means less fatigue and reduced risk of long-term injury.

Concentricity can be defined as the ability of the handpiece to produce a cutline consistent with the diameter of the bur. The more concentrically a handpiece operates, the smoother the bur cuts, with less perceptible vibration and greater comfort for the patient. The International Standards

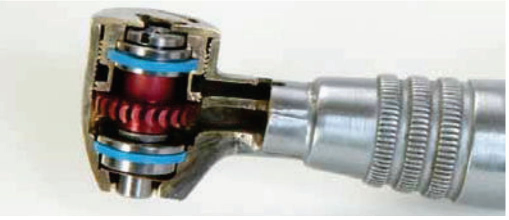
Organization (ISO) specifications[13] allow up to 0.03 mm of eccentricity, commonly referred to as "run out" or "bur wobble." Concentricity – one of the most critical features of handpiece performance – diminishes as the turbine deteriorates, and a pronounced lack of concentricity can be visible to the eye. Bur retention is another critical feature of today's automatic chucking mechanisms. Sterilization affects autochucks in different ways. Autoclaving causes accelerated chuck failure when heat causes the springs that provide gripping force to lose their temper and strength, while corrosion dulls the sharp edges used to grip bur shanks. Clinically, autochuck failure is manifested as the bur working out of the chuck during use, which creates a very dangerous situation.

In spite of significant technological advancements in handpiece design over the last ten years, dental professionals continue to experience recurring handpiece problems resulting from sterilization. Misconceptions abound throughout the dental field about exactly what goes wrong when a handpiece turbine fails. Closer examination of the turbine may shed light on just what is happening inside your handpiece.

The Handpiece Turbine Assembly

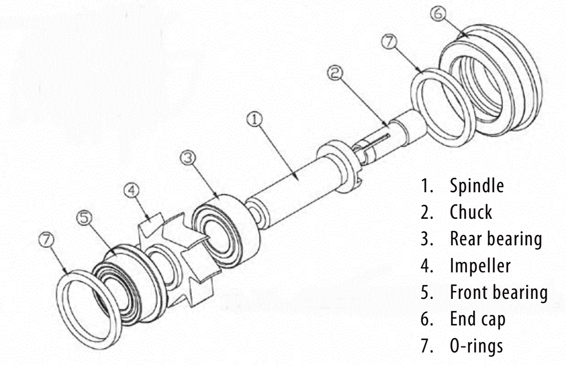
As the only moving part inside a high-speed handpiece, the turbine is the most common source of problems. A high-speed turbine contains two components: a chucking mechanism to hold the cutting instrument and a rotary system that spins the bur at speeds up to 6,000 times per second when air pressure is supplied.

Figure 12. Handpiece turbine assembly



The rotary system consists of an impeller, or rotor, which "catches" drive air (similar to a water wheel), mounted on a spindle. The spindle rotates clockwise at high speeds, supported by two precision bearings and two suspension O-rings.

Figure 13. High-speed air-driven turbine components



1. Spindle
2. Chuck
3. Rear bearing
4. Impeller
5. Front bearing
6. End cap
7. O-rings

These miniature bearings are the heart of the turbine. As reported in the 1993 DIS study, "… handpieces do not fail gradually because of decreased speed and power but, rather, fail as a result of catastrophic failure of the turbine bearings." The most critical element of these bearings is the retainer, or cage, that secures the ball bearings within the raceways. This becomes brittle as it is subjected to harsh sterilization environments; upon failure, the bearing cage disintegrates and the turbine will no longer rotate or generate power. You will most often see evidence of this final degradation when "black stuff" is expelled from the handpiece head during use or lubrication procedures. The dentist may also note that the bur will "stall out" when applied to tooth structure. Other symptoms of bearing failure include the bur no longer spinning concentrically, unacceptable vibration when the handpiece is activated, or unusually loud sounds emanating from the turbine.[14]

Figure 14. Bearing retainer showing stages of degradation

Improved cage materials and manufacturing processes have extended handpiece life since the advent of routine sterilization, as evidenced by the longer warranties prevalent today. Other design improvements offer the clinician the choice of maintenance-free ("lube-free") handpieces. This is accomplished by saturating the bearing cage with a food-grade, autoclavable grease that gradually releases onto the ball bearings over time through use and sterilization. The bearings are not really "lubrication free." They are "maintenance free," however, as it is no longer necessary for the staff to apply lubricant. One of the latest innovations in dental bearing applications is a bearing cage coated with a layer of pure silver. According to a leading bearing manufacturer, the new silver composite retainers combine the lubricating capabilities of metallic silver with strength and the ability to withstand repetitive autoclave cycles.

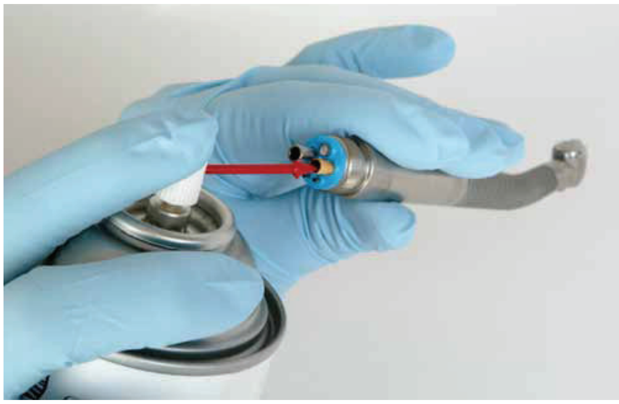
Prolonging Handpiece Life Through Proper Use and Maintenance

Much can be done to prolong handpiece life by understanding the importance of variables that can be controlled within the practice and by understanding and adhering to some basic handpiece maintenance.

Proper Air Supply

One of the most frequent causes of premature bearing failure is excessive air pressure entering the handpiece. Every handpiece head has a specific capacity for exhausting air. Additional air tends to accumulate around the turbine and may reduce speed. An accurate reading for handpiece air pressure can be obtained only by using an in-line air gauge

Figure 15. Proper lubrication of handpiece



Air-Driven Low-Speed Motors and Attachments

CDC guidelines indicate that "only the portion of the attachment that comes in contact with patient tissue" is required to be sterilized, or disposed of. It is not necessary to sterilize the motor if a barrier is used. If you are not autoclaving motors, make sure they are removed from the tubing and lubricated at least once a week. Not removing motors at some interval leads to the accumulated disinfectant corroding the threads onto the tubing permanently. Motors, especially rotary vane models, do not require much oil. Dental motors and attachments require higher viscosity oil than a high-speed spray. One or two drops of oil in the drive air line are all that is necessary. Run the motor to distribute the oil. Also apply some oil as a preventative measure to forward/reverse valves, shift rings, and sheath attachment points. Wipe away excess oil with a paper towel. Most straight attachments do not require lubrication. Perform an external cleaning with a brush under running water prior to bagging the sheath or nose cone for sterilization.

Figure 16. Low-speed attachments

It is very important to take latch angles apart for proper lubrication. If you are processing angles routinely, at least once a day unscrew the head from the sheath and remove the transmission gear for cleaning and oiling (try doing this first thing in the morning as part of the opening routine). Apply a drop of oil under each gear on the transmission gear as well as in the center hole. Apply several drops of oil to the exposed cartridge while the transmission gear is removed.

Figure 17. Latch head components

Handpiece Lubricants

During the initial warranty period, you should always follow the manufacturer's suggested maintenance procedures and use the approved lubricant supplied with a new handpiece. It is important to follow these instructions to the letter to avoid any disputed warranty claims should your handpiece fail under warranty. The same is true when you purchase or have a new original manufacturer's turbine installed in your handpiece. Manufacturers reserve the right to void your warranty if you are not using their brand of lubricant. Once your handpiece is out of the warranty period, or if you choose a different source for handpiece repair than the original manufacturer, then you are free to use any lubricant you wish. There are a myriad of choices on the market, sporting all sorts of claims. Some are advertised as a cleaner and lubricant in one, some are synthetic, and some advocate the use of a separate cleaner and oil. That you consistently employ a good-quality oil matters more than which brand of oil you choose.

Automatic Lubrication Stations

Many manufacturers offer an automatic clean and lube station to minimize staff time and take the guesswork out of the maintenance process. These units vary in cost, depending on features. One incentive to purchase an automatic lubrication station would be that some manufacturers will significantly extend their handpiece warranties if their respective automatic stations are used to maintain the handpieces.

Figure 18. Lubrication stations

The simplest lubricator design holds only one handpiece, and the operator must remain at the station to hold the button down during the entire process. This ensures a complete cycle of lubrication and flushing, but there is no time savings for staff. Fully automatic designs will hold more than one handpiece, including low-speed attachments. Similar to using an autoclave, the operator loads the machine, closes the door, and presses a button. This begins the maintenance cycle, and the machine will dispense the correct amount of lubricant and then operate each handpiece at the correct running speed. During operation the staff member is free to complete other duties while the machine runs multiple handpieces through the maintenance cycle. While the automatic machines initially cost more, there is absolute consistency of operation, which may result in longer handpiece life and reduced repair costs. Additional savings may accrue while the staff member completes normal between-patient tasks and does not need to use valuable time performing routine handpiece maintenance procedures. One area of concern that is not often addressed is chuck maintenance. According to a handpiece manufacturer product manager, "Ninety-five percent of all turbine or attachment problems are found in the head of the handpiece. Everyone always seems to lubricate the back end, maybe purge, but do not address the head of the handpiece or the chuck."[15] When a handpiece is in operation, the air is being expelled outward. Once the clinician takes his or her foot off the rheostat the physics reverse, which can bring contaminants and tooth dust back into the head of the handpiece. If these particles are not purged, they bake onto the internal components and will cause premature failure. By shooting lubricant and compressed air into the chuck, this will help dislodge the debris or at least loosen it up. Once you run a purge cycle by attaching it to the tubing or maintenance system, the particles are much more likely to be expelled from the handpiece, extending longevity.

Common Handpiece Maintenance Mistakes

There are a number of common maintenance mistakes that should be avoided:

1. Using a chemical wipe-down on a handpiece before sterilizing: this is not only redundant, it may multiply harmful reactions when the handpiece is subjected to heat.
2. Using an ultrasonic cleaner or solution: except for immersion in a cleaning solution offered by the handpiece manufacturer, handpieces should never be immersed in any fluids.
3. Lubricating in the wrong hole – The drive air line leads directly to the turbine; other orifices such as exhaust and water do not. If you are using a liquid oil applicator on a swivel-type handpiece, it is critical that you deliver oil to the correct internal opening.
4. Using an incorrect lube applicator – Make sure the spray tip fits the handpiece quick-disconnect correctly. Some models depend on a pressurized fit to flush out debris.
5. Not applying enough lubricant – Sometimes the staff is directed not to overspray oil into the handpiece, to reduce excess residue; however, it is important to ensure that oil is getting to the bearings, by seeing oil leave the head.
6. Not running the handpiece prior to autoclaving – Failing to operate the handpiece following lubrication will gum up the turbine as excess oil gets baked into the bearings; an undesirable clinical effect is expelling oil into the operating field after not properly running out the excess.
7. Not cleaning the fiber-optic bundles – Failing to keep the fiber-optic bundle surfaces clean will lead to a buildup of oil and debris, affecting the ability to transmit light.
8. Leaving the bur in the chuck during autoclaving – When a bur is held in an autochuck, the springs are compressed. Subjecting any spring to heat and corrosion under tension will weaken it and shorten the life. Leaving a bur in a manual chuck leads to buildup of debris in the chuck and increased difficulty of operation.
9. Leaving levers open during autoclaving – When a lever chuck is actuated, about eight pounds of force is exerted onto the front O-ring of the turbine. During normal operation this force is momentary as the bur is changed. Leaving the chuck open during the autoclave cycle means compressing the O-ring while subjecting it to heat for 30 minutes. This will dramatically accelerate turbine failure.
10. Failing to maintain autoclaves – If the autoclave is not properly cleaned, buildup can occur that contaminates the entire system, including the handpieces.

Handpiece Repair Options

Historically, the most conventional method of restoring a handpiece to service was to replace the old turbine with a new one. With replacement intervals measured in years, cost was no great concern. As the rate of repair increased once handpieces required sterilization, cost became a consideration. Options available for handpiece repair include replacing or rebuilding the turbine, either doing this in-office or sending the handpiece to the original equipment manufacturer or an independent repair service.

Turbine Replacement

Handpiece turbine repair options include returning the handpiece to the original equipment manufacturer, purchasing a new turbine from the original manufacturer and installing it yourself, or purchasing a new "aftermarket" or generic turbine and installing it yourself. Before 1992, standard procedure was simply to order a new turbine from the original manufacturer or send the handpiece back to the manufacturer for repair (who may or may not charge a significant labor fee for installing a new turbine).