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RESEARCH ARTICLE

EVOLUTION AND MECHANISM OF DENTAL HANDPIECES- AN OVERVIEW

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ABSTRACT

The dental handpiece is a sophisticated combination of precision parts moving in perfect synchronization at extremely high speed. The handpiece is a device that requires diligent maintenance protocol to keep it running properly and safely. Handpiece delivers a smooth powerful cut that allows the clinician to remove tooth structure in an efficient manner with little discomfort in contrast to earlier days which was done with hand cutting instruments and electric belt driven instruments with top rotational speeds of 50000 rpm. The leap from belt driven to air driven hand piece was a major breakthrough because it overcame slow speed, time spent on tooth preparation, pressure and vibration of belt driven handpieces. The selection of an appropriate handpiece and appropriate burs is the key for safe and effective removal of dental hard tissues and caries in an efficient manner. The overall goal of this article is to provide information on the evolution, internal parts, mechanism of belt and air driven handpieces and classification of air driven handpieces.

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INTRODUCTION

Human tooth contains enamel which is the hardest tissue in the body. Nature has provided teeth with this form of tissue so that it can withstand massive occlusal forces and protect the innermost part of the tooth. The removal and shaping of both diseased and sound tooth structure is an essential part of restorative dentistry, initially this was a difficult process accomplished entirely by the use of hand instruments, bulky chisels and excavators. As this trend has become apparent, it has become equally obvious that the efficacy of operative dentistry and the quality of work performed can only be improved if the technology applied becomes more sophisticated. The introduction of rotary, powered cutting equipment was one of the truly major advances in dentistry. [1, 2] The term rotary instruments in dentistry refers to a group of instruments that turn on an axis to perform a work such as cutting, abrading, burnishing, finishing or polishing tooth tissues or a restoration.[3,4] A hand piece is a device for holding rotating instruments, transmitting power to them and for positioning them intra orally. Dental handpiece of today is a sophisticated combination of precision parts moving in perfect synchronization at extremely high speed. In this review article we discuss about the evolution, classification and mechanics, of handpiece.[4, 5, 6]

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Evolution of handpiece

Although there is archeological evidence of dental treatment as early as 5000 BC little is known about the equipment and methodsused. Mayan people who lived between 2500 BC to 900 AD used round, hard tube similar in shape to a drinking straw, made in early times of jade and later of copper, was spun between the hands or in a rope drill, with slurry of powdered quartz in water as abrasive, cutting a perfectly round hole through the enamel.[1, 5, 6] Fauchard designed his own bow drill to cut into the enamel of natural tooth.In the early 1800's mechanical hand drills were invented, however their capabilities were minimal and the drills could only reach 15 rotations per minute. One of the first great advancements came in 1864 by British dentist George Harrington. He invented the clockwork dental drill named the Erado. It was relatively faster than previous drills but also much noisier. The noise has been and still continues to be a major disadvantage for mechanically driven dental drills.[6, 7, 8] The first electric dental drill was patented in 1875 by Dr. George F.Green.James BeallMorrison, revolutionized the practice of dentistry in 1870 by inventing Foot-Treadle drill. In 1883, the electric dental engine was linked to the handpiece by a flexible cable arm. This is the first time cutting was made from a power source other than human hand and feet. In1887 Dr.C.EdmundKells patented electric control panel to which a motor driven hand piece can be attached.[1, 6,9] Belt driven hand piece on a jointed engine arm became available in 1910. The modern form of the dental drill is the air turbine handpiece, developed by John Patrick Walsh.A belt driven angle handpiece called the Page-Chayes became available in 1955 at successful speeds of 100,000 rpm powered by electric motor.In 1956 the first clinically successful air-driven turbine hand piece became available with speeds of approximately 300,000 rpm. It was introduced by Dr. John Borden.Contemporary air turbine handpiece was introduced in year 1994.[6, 10, 11] Most of what we now take for granted as restorative dentistry was made possible because of the advancing technology of the air driven handpieces, the latest being the fibre optic handpieces. Evolution is given in tabular column with their speeds. (Table 1)[6, 11]

Table 1. Evolution of Handpiece with Speed

Date	Instrument	Speed (rpm)
1728	Hand rotated instrument	300
1871	Foot engine	700
1874	Electric engine	1000
1914	Dental unit	5000
1942	Diamond cutting instruments	5000
1946	Old units converted to increase speed	10000
1947	Tungsten carbide bur	12000
1953	Ball bearings handpieces	25000
1955	Water turbine angle handpiece	50000
1955	Belt driven angle handpiece (Page-Chayes)	150000
1957	Air turbine angle handpiece	250000
1961	Air turbine straight handpiece	25000
1962	Experimental air bearing handpiece	800000
1994	Contemporary air turbine handpiece	300000

Classification of dental handpieces [6, 11]

1. Dental hand pieces classified according to driving mechanism
   - Gear driven hand piece
   - Water driven hand piece
   - Belt driven hand piece
   - Air driven hand piece
2. Depending upon angulations
   - Straight
   - Contra angled
   - Right angled
3. Depending on speed

   Sturdevant classification:
   - Low or slow speeds (less than 12,000rpm)
   - Medium or intermediate speeds (12,000 – 20,000 rpm)
   - High or ultra high speeds (more than 200,000 rpm)

   Marzouk classification
   - Ultra low speed - 300 -3000 rpm
   - Low or slow speed- 3000 -6000 rpm
   - Medium or intermediate speed - 20,000 – 45,000 rpm
   - High speed- 45,000 – 1,00,000 rpm
   - Ultra high speed – more than 1,00,000 rpm
4. Based on head design
   - Standard
   - Mini
   - Torque
5. Based on bur holding type
   - screw type chuck
   - airmatic bur changer
   - ultrapush system
6. Based on motor
   - AIRTURBINE
   - AIR MOTOR
7. Based on colour coding ring
   - Blue–no change in speed
   - Green-speed reduction
   - Red –speed increase
8. Handpieces used in endodontic
   - Giromatic hand pieces
   - Reciprocating hand pieces
   - Sonic and ultra sonic hand pieces
   - Torque control gear reduction hand pieces

Basic Characteristics of Rotary Instrument

Speed: Speed is defined as the number of revolution per minute (RPM) or the number of times a rotating instrument, such as a bur, will make a full turn during a minute, higher the (RPM), faster the speed of hand piece. Speed refers not only to the revolutions per minute, but also to the Surface feet per unit time of contact that the tool has with the work to be cut.

Pressure (P): Pressure is a resultant effect of two factors under the control of the dentist:

- Force (f) the gripping of the hand piece and its positioning and application to the tooth.
- Area (a) the amount of surface area of the cutting tool in contact with the tooth surface during a cutting operation
- Pressure relates as follows
  $P=F/A$

Heat Production

Heat is directly proportional to

- Pressure
- RPM
- Area of tooth in contact with the tool

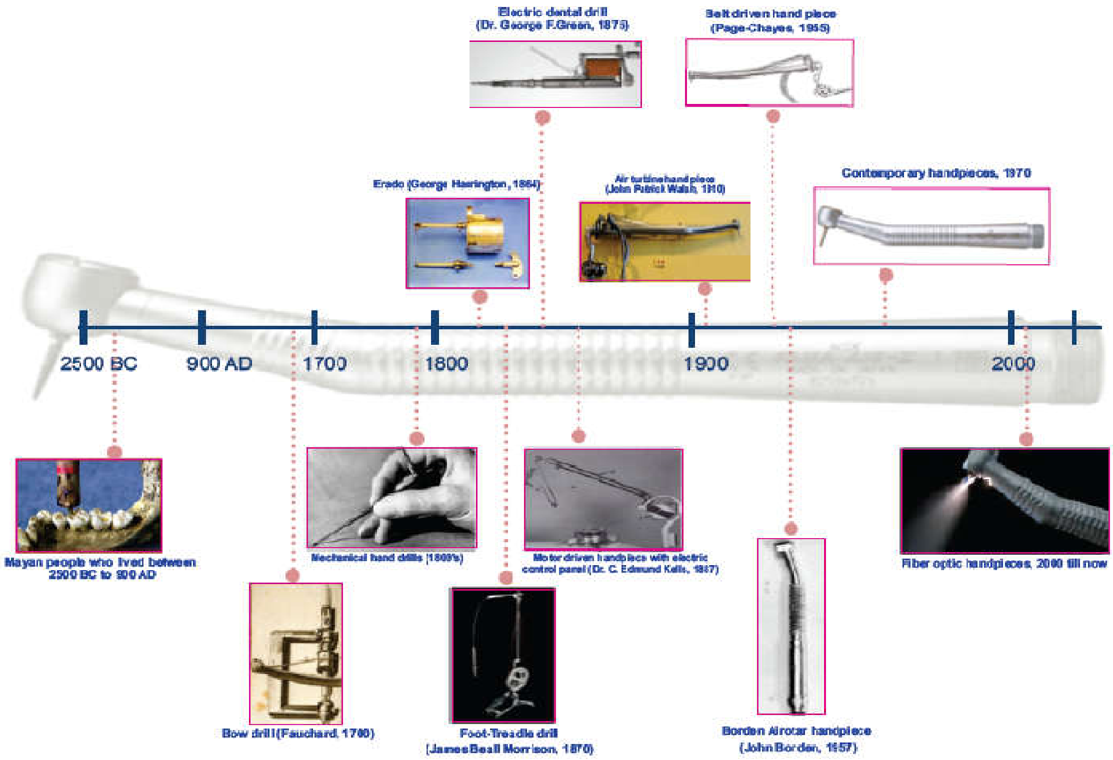

Figure 1. Evolution of Handpiece

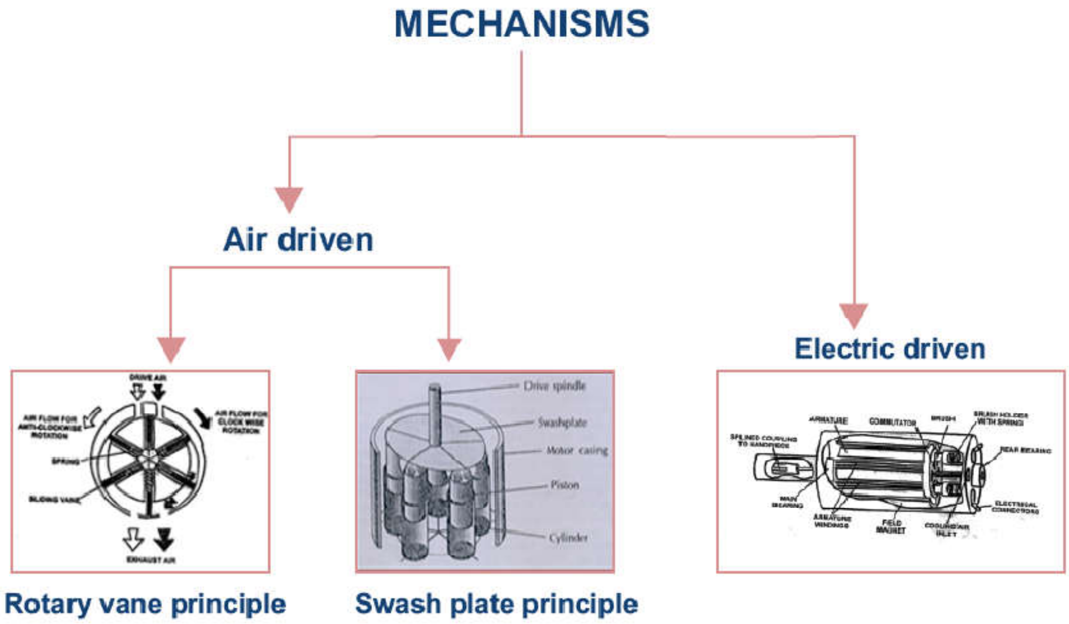

Figure 2. Mechanism of Handpiece

Since heat production will cause pulps of teeth to be permanently damaged If a temperature of 130°Fis reached, heat must be carefully controlled. This can be accomplished by using various coolants such as flowing water, a water air spray, or air.

Vibration

It is not only a major annoying factor for the patient, but it also causes fatigue for the operator, excessive wear of instruments and most importantly, a destructive reaction in the tooth and supporting tissues vibration is a product of the equipment used and the speed of rotation

The deleterious effects of vibration are

- Amplitude
- Undesirable modulating frequency

Torque

Is the ability of hand piece to withstand lateral pressure on the revolving tool without decreasing the speed or reducing its cutting efficiency.

Depends on

- Type of bearing used
- Amount of energy applied to the hand piece [6, 12, 13]

MECHANISMS

According to mechanism of working handpieces are divided into two types [14, 15, 6]

- Air driven
- Electric driven

Air driven – mechanism

The air driven mechanism works on two principles [14]

- Rotary vane principle
- Swash plate principle

- Design and power of the magnetic field
- Design and number of armature coils
- By varying the distance from the magnets to the rotating armature, the speed of the motor can be altered. More the armature coils, the smoother and less jerky the operation of the motors.[14, 18, 19]

The biggest difference in comparing an electric handpiece to an air driven is its constant speed and less noise. However the major disadvantages of an electrical handpieces (a) it consists of several complex parts like gears and bearings. This intricate array of gears and bearings makes repair more costly than for air driven.(b) Unlike an air driven handpiece, which loses torque as the turbine components wear, the electric motor is so powerful that it will continue to drive the attachment even if the internal parts fail and this friction leads to heat that can burn the tissue.

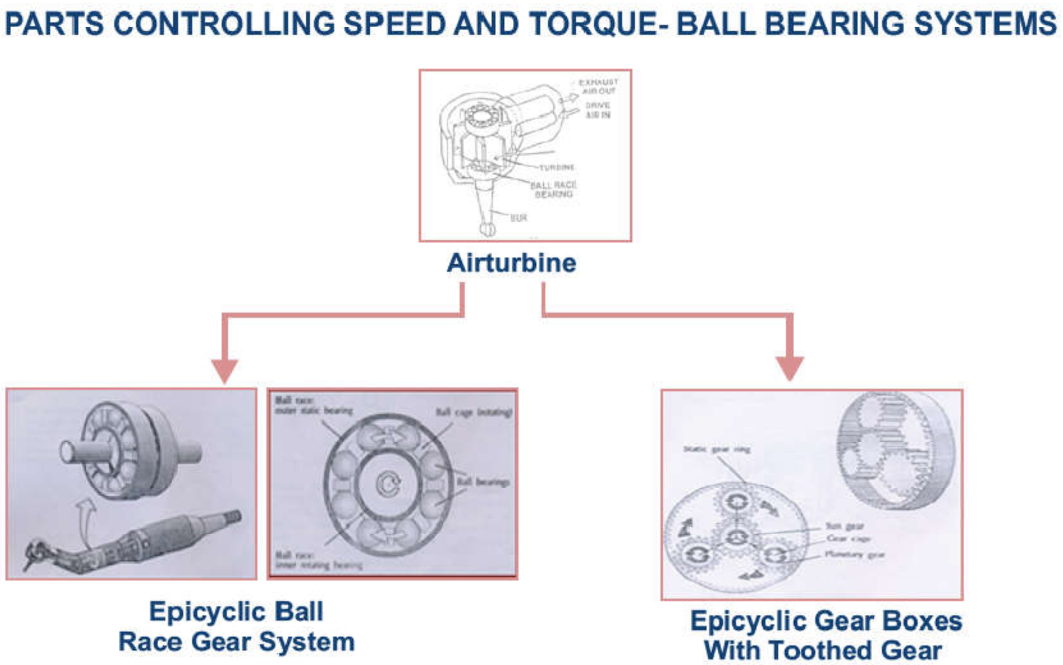

Figure 3. Electric driven Handpiece

Rotary vane principle

- Central core is an off set with a cylinder which is divided into chambers by means of sliding vanes and seals from the core to the cylinder wall.
- If compressed air is forced into one of the chambers at high pressure side, expansion of air within the chamber will drive it towards the low pressure side, where the air is exhausted from the system. Such motors run smoothly and can develop considerable torque.[14, 16]

Swash plate principle: Operated by a series of pistons pressing sequentially against a disc, as the piston raises it presses against the plate and causes it to rotate.As the piston reaches the end of its travel the next piston in the series takes over and continues turning the disc.The rotation of the disc operates a rotary wave which feeds air to the pistons sequentially.[14, 17]

Electric Driven: Most are direct current motors and are designed with an armature sitting within a permanent magnet assembly (figure 3) the performance depends upon

(c) it is more heavier than air driven handpieces.[20,21] The latest evolutions of using ceramic bearings inair driven handpieces made clinicians work easier and more comfortable with air driven than the electric driven handpieces.[22,23]

Air turbine

A hand piece turbine is made up of two miniature bearings, a spindle/chuck assembly, two rings and an impeller. The spindle is the centre rotating part that is usually press fitted into the impeller, which supplies the rotary motion. Inside the spindle are miniature wedge lock mechanisms that are designed to tightly grip a dental bur.The complete turbine assembly is located in the hand piece head.[24, 25]

Parts Controlling Speed and Torque

Speed and torque are controlled by incorporation of A. Gear system and B. Ball bearings [18]

A. Gear System

Epicyclic Ball Race Gear System: This gear system is located in the shank of the hand piece. It consists of an outer ring and an inner ring. Between those 2 rings ball bearings and ball cage are present. If the outer ring is held stationary whilst the inner ring is turned it will be observed that the cage separating the balls turns at a much reduced speed.

Epicyclic Gear Boxes With Toothed Gear: It consists of small gear wheels present inside a static gear ring. The small gear wheels are, sun gear present in the centre and planetary gear present around it. Reduction hand pieces reduce the speed of the drive while increasing the torque. They are needed to rotate large diameter instruments such as bristle brushes and rubber cups in prophylaxis heads.[14, 16]

Ball Bearings

Essentially, there are two types of ball bearings used in dental handpieces. The first type is that which is composed of ceramic and includes steel rings. The second type is steel and includes steel rings. Metal ball bearings were commonly used in the handpiece to transfer the rotating force to the bur. A number of problems arise when turbines are operating at speeds in excess of 2,50,000 rpm. Firstly the wear on the support bearings is very great indeed. Research has established that the ceramic-based ball is up to 60% lighter than the steel-based ball often used in dental instruments. Not only does the lighter weight make it easier to hold and maneuver the dental handpiece, but, it generates significantly less centrifugal force when it is in full operation at high speeds. This in turn, minimizes the overall wear on the outer ring. The overall surface wear is actually reduced because of the lighter composition of the ceramic ball bearing. Due to the hard outer core of the ceramic ball bearings, it is not as likely that contaminants or debris will result in bearing failure.[18, 21, 22]
The other main benefits is that the dental instrument that contains these types of ball bearings run much cooler therefore, extending the overall life of the bearing. The lubricant that is placed on the ceramic ball bearings has a longer service life than the lubricant that is placed on the steel ball bearings.The temperatures during the operation of dental handpieces that have ceramic ball bearings are much cooler than those that have steel ball bearings.The noise level of dental handpieces that contain a ceramic ball bearing is much less than those that contains a steel bearing.[26, 27]

Conclusion

No instrument in the dental history has attracted dentistry and dentist over the past century than dental handpiece. So wide spread was the fears of the dental drill that it used to be common for many patients to opt for swift extraction rather than the prolonged filling of the carious tooth. Fear of the drill has progressively disappeared in recent decades, thelatest breakthrough is the Speed-Sensing Intelligence, it actually monitors the bur speed several hundred times per second. A sensor in the coupler detects the frequency of vibrations from the rotating bur. When the bur encounters a higher load that would normally decrease speed, a signal from a small chip in the control source increases air pressure to maintain speed, virtually eliminating stalling to provide a smooth, consistent cutting speed regardless of load. This design provides exceptionally fast removal of tooth structure, amalgam, porcelain, and metal. Because the system adjusts speed when the bur is not under load, wear on bearings is minimized, which means fewer turbine, thanks to the continuous development and improvement in the design and construction of handpieces.[28] Much can be done to prolonghandpiece life by understanding the importance of variables that can be controlled within the practice and by understanding and adhering to some basic handpiece maintenance, which will be discussed in the next review.

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