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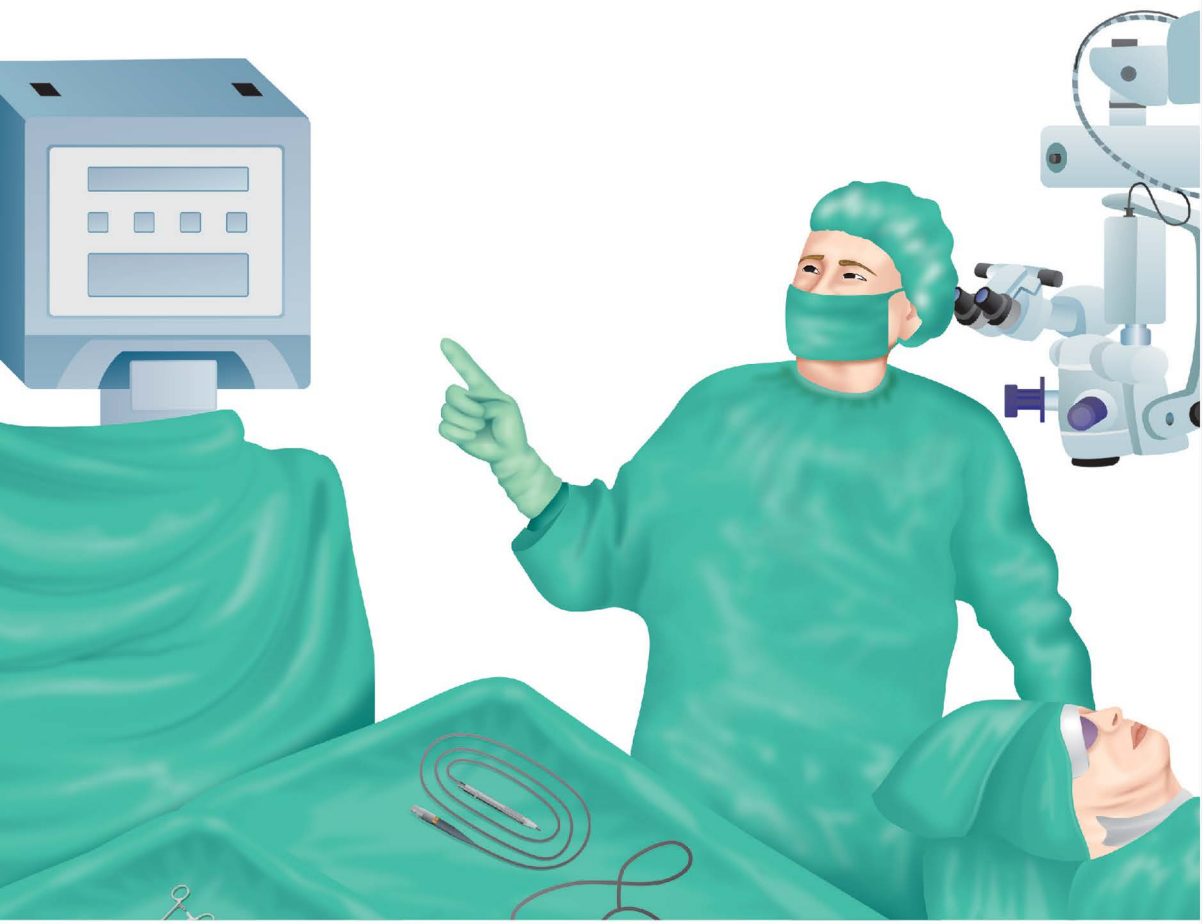
PHACO MACHINE
and its Applications



Navneet Toshniwal

Foreword
Prof Keiki R Mehta

JAYPEE

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CHAPTER

3

Energy

DEFINITION

Energy is defined as the ability to emulsify the nucleus.

PRINCIPLE

Emulsification of nucleus is in the following ways:

- *Jackhammer effect*:
  - It is the direct mechanical impact on the nucleus to emulsify it.
- *Cavitational effect*:
  - This is a highly effective source of emulsification.
  - High-frequency vibration of needle and acoustic wave form tiny air bubbles.
  - These tiny air bubbles induce localized implosion on nuclear material for better emulsification.
- *Acoustic wave of fluid*:
  - It is like wave of ocean, generated by the forward movements of the tip which can disintegrate the lens material.

INTRODUCTION

Energy is one of the important parameters of Phaco machine.

- Energy is delivered by Phaco probe.
- It is ultrasound energy.
- Energy is used to emulsify the hard part of cataract, i.e., nucleus.
- Sometimes, energy is used to emulsify thick or sticky epinucleus.
- As energy can burn cornea or iris during Phaco, one should have an overall idea about parameters used in all steps of nucleus management.
- One should know the different modes and delivery system of energy used for Phaco.

LONGITUDINAL PHACO (TRADITIONAL PHACO)

This is the most commonly used ultrasound energy.

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Stroke Length

- It is the distance by which the Phaco tip moves to and fro.
- It can be altered by changing the Phaco power.
- More energy means more stroke length, i.e., more area of emulsification of nucleus ahead of the Phaco tip.

Frequency

- It is the number of times the Phaco tip moves.
- It is fixed for every Phaco handpiece.
- It is measured in kHz.

TYPES OF DELIVERY SYSTEM OF ENERGY

Linear

This is a gradual rise in the energy from zero to preset level in a linear way as foot pedal is pressed.

Panel

This is sudden rise in the energy from zero to preset level as soon as foot pedal is pressed.

DIFFERENT MODES OF ENERGY

- *Continuous energy*
- *Pulse*
- *Hyperpulse*
- *Short pulse*
- *Long pulse*
- *Low-power pulse*
- *High-power pulse*
- *Single burst*
- *Multiburst*
- *Continuous burst*

Continuous Energy

- It is the continuous form of energy (**Fig. 1**).
- There is no off time.

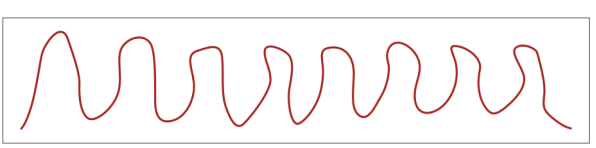

Fig. 1: Continuous energy.

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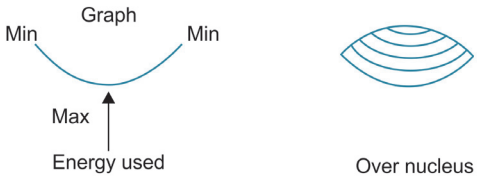

Fig. 2: Trench.

It can be linear or panel.

Linear

- Energy used is from 0 to 100.
- It is a commonly used form of energy.
- As the foot pedal is pressed, it will gradually increase.
- It is controlled energy.

Indications:
*Trench (**Fig. 2**)*:
- Continuous linear mode is the most important form of energy used for trench.
- Hardness of nucleus varies from one end to the other and anterior to posterior.
- Energy can be set according to the hardness of nucleus.
- Energy used minimum to start with, maximum in the center, and then minimum to complete the trench

Parameters:
- Generally 60–80% energy is used for trench.
- In hard cataract, it can be set to 70–80% or more.
- In soft cataract, it can be decreased 60–70% or less.

Division:
After trench, one can separate or divide the nucleus either mechanically or sometimes can hold (engage) the half mass of nucleus with Phaco tip and then divide with chopper.

Parameter:
Generally, 20–50% energy is used.

Hold and chop:
- Continuous linear mode is the most important form of energy for hold.
- In this step, not only hold but also maintaining the hold is important.
- Needs adequate energy to embed in the mass.

Parameter:
Generally, 20–50% energy is used.

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Panel

- As the foot pedal is pressed, energy reaches to the preset level suddenly.
- Energy used in panel is called "burst mode."

Indications:

- It can be used in trench, hold and chop, and direct chop step of nucleus management.
- In very hard cataract, one can set 70% energy during trench; it means tissue will emulsify with same energy from start to end point. Subsequently, 40–50% of energy can be used for hold and chop.
- For direct chop technique in hard cataract, this mode of energy is helpful.

Disadvantages:

- Turbulence in anterior chamber
- Consumption of energy is more.
- Wound burn

Pulse Energy

- Energy used in pulses (**Fig. 3**)
- This form of energy has cutting and holding ability.
- Controlled way of emulsification of nucleus
- Energy transferred in the eye is less.
- Generally, it is used in linear mode.

Indications:

- Removal of small pieces of nucleus
- This mode of energy is used sometimes in grades I and II cataract for hold and lift of nucleus before chop for which energy can be set according to the hardness of nucleus.

Chatter means repulsion of nucleus; it occurs if energy is used more than needed.

Hyperpulse Energy

*This is new modulation of energy to overcome all disadvantages of traditional energy (**Fig. 4**).*

- On and off time is fixed.

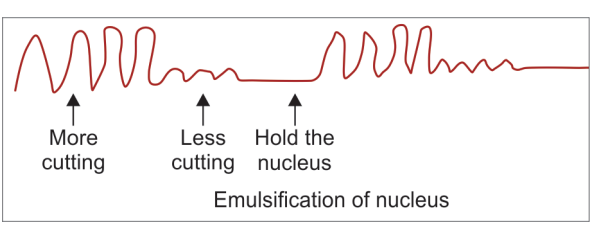

Fig. 3: Pulse energy.

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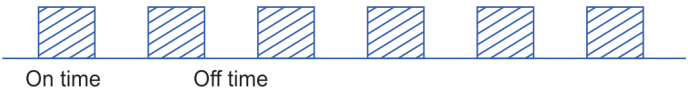

Fig. 4: Hyperpulse energy.

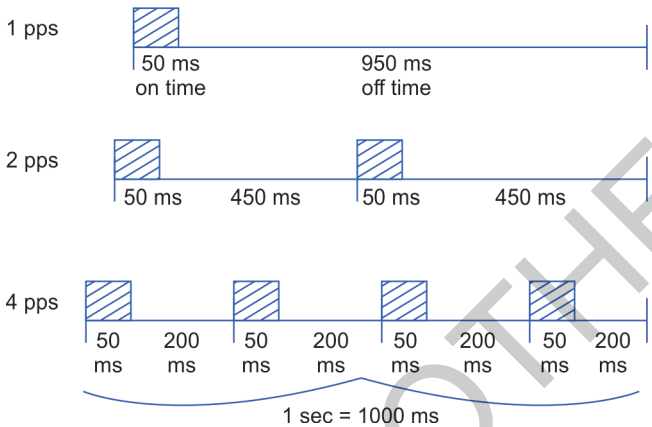

Fig. 5: Short pulse. (PPS: pulse per second)

- On time is for emulsification of nucleus.
- Off time is for hold of nucleus.
- Energy consumption is less without compromising the cutting efficiency of nucleus.

There are different types of modification in hyperpulse, where on time is fixed and off time is variable.

Short Pulse (Fig. 5; Table 1)

Introduction:

- 50 ms on time is fixed.
- Off time is variable.
- Short pulses can be set from 1 to 14 pps.

Parameters:

- Commonly used parameters are 6 pps.
- Delivery of energy is linear.

Indications:

- For removal of small pieces of nucleus
- For removal of last pieces of nucleus
- In soft cataract:
  - In stop and chop technique, after nucleus division for hold and lift of half part of nucleus

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Table 1: Chart of short pulse.

PPS (pulses per second)	*Calculation*	*On time (ms)*	*Off time (ms)*
1	1,000 ÷ 1 = 1,000	50	950
2	1,000 ÷ 2 = 500	50	450
3	1,000 ÷ 3 = 333	50	283
4	1,000 ÷ 4 = 250	50	200
5	1,000 ÷ 5 = 200	50	150
6	1,000 ÷ 6 = 166	50	116
7	1,000 ÷ 7 = 142	50	92
8	1,000 ÷ 8 = 125	50	75
9	1,000 ÷ 9 = 111	50	61
10	1,000 ÷ 10 =100	50	50
11	1,000 ÷ 11 = 90	50	40
12	1,000 ÷ 12= 83	50	33
13	1,000 ÷ 13 = 76	50	26
14	1,000 ÷ 14 = 71	50	21
1 s = 1,000 ms			

  - Hold, lift, and emulsification of complete nucleus after hydrodelineation
- For removal of epinucleus

Advantages:

- Due to more off time, pieces come toward the Phaco tip easily, i.e., better followability.
- It is safe for cornea as on time is less.
- It is a safe mode for removal of last pieces of nucleus to avoid PCR.

Long Pulse (Fig. 6; Table 2)

Introduction:

- 150 ms of on time is fixed.
- Off time is variable.
- Long pulses can be set from 1 to 6.

Parameters:

- Commonly used parameters are 4 pps.
- Delivery of energy is linear.

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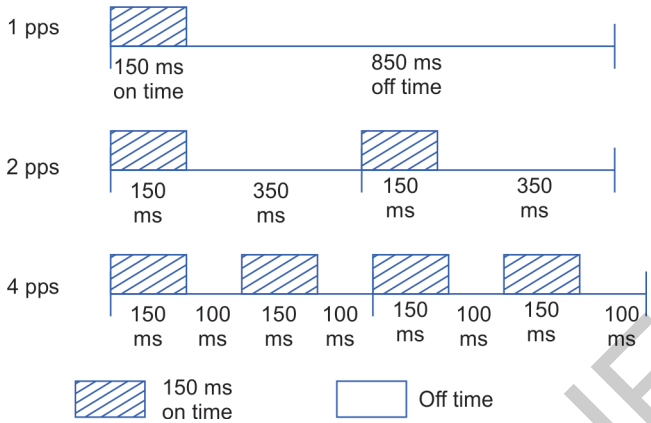

Fig. 6: Long pulse. (pps: pulse per second)

Table 2: Chart of long pulse.

PPS (pulses per second)	*Calculation*	*On time (ms)*	*Off time (ms)*
1	1,000 ÷ 1 = 1,000	150	850
2	1,000 ÷ 2 = 500	150	350
3	1,000 ÷ 3 = 333	150	183
4	1,000 ÷ 4 = 250	150	100
5	1,000 ÷ 5 = 200	150	50
6	1,000 ÷ 6 = 166	150	16
1 s = 1,000 ms			

Indications:

For removal of small pieces of nucleus:

- In hard cataract, for removal of small pieces of nucleus, one can use the parameters from 2 to 4 pps.
- In soft cataract, for removal of small pieces of nucleus, one can use the parameters from 1 to 2 pps.

For hold and lift of nucleus:

- In grades III and IV cataract, parameters used are 4–6 pps.
- In soft cataract, parameters used are 2–4 pps.

For epinucleus:

In thick epinucleus or in sticky epinucleus cataract, one can use this mode with 1 pps or 2 pps.

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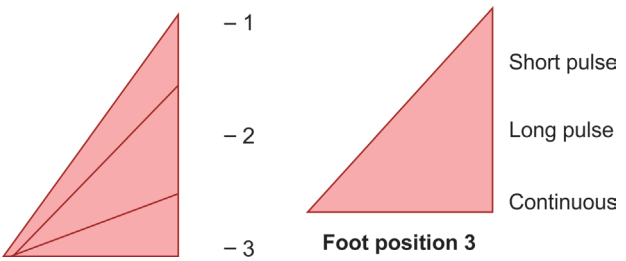

Fig. 7: Low-power pulse.

Advantages:

- Due to on and off time, followability of the nuclear pieces is better.
- Chances of corneal burn and PCR are less.

Low-power Pulse

Introduction:

- This energy mode is working in foot pedal position 3.
- Foot pedal position 3 is divided into three compartments from top to bottom. As you press the foot pedal, it will start working as short pulse, then in mid-phase as long pulse and when you press completely, it works as a continuous mode of energy **(Fig. 7)**.
- It means that the duration of energy is gradually increasing from a small duration of 50 ms, then 150 ms, and then works as a continuous mode.

Indications:

Low-power pulse works in the following ways:

- In removal of small pieces of nucleus:
  - Short pulses for soft part of nucleus
  - Long pulses for relatively hard part of nucleus
  - Continuous mode of energy used to hold and chop the big pieces during removal of small pieces
- In hold and chop of nucleus

This mode of energy is used for grades II to IV cataract.

Advantages:

Surgeon can hold, chop, and remove the small pieces simultaneously with this single mode of energy. So, there is no need to change the parameters in between the steps.

- Adequate energy for adequate purpose
- This mode can be used for normal cataract, soft cataract, and hard cataract too.

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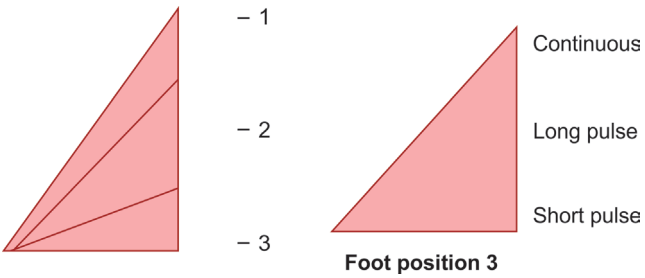

Fig. 8: High-power pulse.

High-power Pulse

Introduction:

- This energy mode is working in foot pedal position 3.
- Foot pedal position 3 is divided into three compartments from top to bottom. As you press the foot pedal, it will start working as a continuous mode of energy, then in mid-phase long pulse and when you press completely, it works as a short pulse (**Fig. 8**).

Indications:

This unique power modulation works in the following way:

- *In hold and chop of nucleus*:
  - Continuous energy is to bury the Phaco tip in mass.
  - Long pulse will be helpful to maintain the hold before chop.
- *In removal of small pieces of nucleus*:
  - Long pulse and short pulse are important applications for removal of small pieces.
- *Direct chop technique*:
  - It can be used in this technique in a unique way.

In such type of modulation, energy can be used in burst mode.

Advantages:

- Energy used in panel is called a burst mode.
- It is safe for the last pieces of nucleus removal.
- Hold, chop, and removal of small pieces of nucleus can occur with this one mode, so there is no need to change the parameters in between steps.

Single Burst (Fig. 9)

- Energy used in panel is called a burst mode.
- Single burst means 110 ms is on time and 890 ms is off time.
- If energy is kept at 40%, then it means that 40% energy will work for 110 ms in one cycle.

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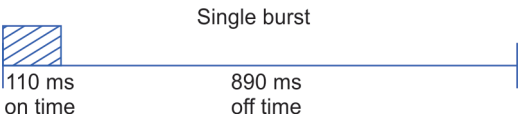

Fig. 9: Single burst.

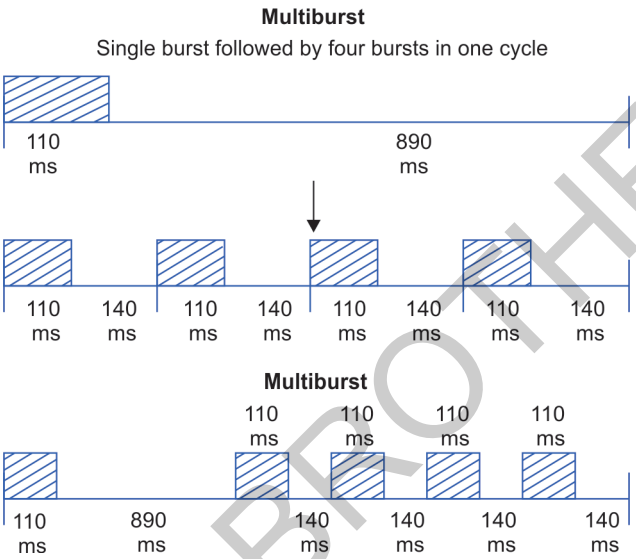

Fig. 10: Multiburst.

Indications:

- For removal of pieces of nucleus in hard cataract
- Sometimes, it is helpful for hold and chop in hard cataract

Multiburst (Fig. 10)

- One single burst gradually increases to four bursts per second as foot pedal is pressed.
- It means that single burst followed by four bursts in one cycle.
- Single burst means 110 ms on time and 890 ms off time.
- Four bursts in one cycle mean on time is 110 ms and off time is 140 ms.

Indications

This mode of energy is helpful for hard cataract.

- *In stop and chop technique*:
  - For hold and chop
  - For removal of pieces
- *In direct chop technique*

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Continuous Burst

As you press the foot pedal, it starts working as single burst; in mid-phase, it works as multiburst and it works as a continuous burst of energy.

Indications

This mode of energy is generally used in hard or very hard cataract.

- *Stop and chop technique*:
  Trench:
  - First few strokes are continuous burst and last few strokes can be used in linear mode.

  Hold and chop and removal of small pieces of nucleus:
  - Continuous mode can be used for hold and chop and single and multiple bursts can be used in removal of small pieces.
- *Direct chop technique*

This mode of energy can be used for hard cataract.

MODIFIED MODES OF ENERGY

- Whitestar
- Variable Whitestar

Whitestar

- It is combination of on time and off time which is variable.
- It can be customized for optimum use of continuous form of energy.
- Functioning of Whitestar is based on duty cycle.

*Duty Cycle (**Table 3**)*

- 1,000 ms of continuous power
- Micropulse division
- On time and off time can be customized.
- On and off time varies from 2 to 32 ms.
- Ratio of Phaco on time to total (or cycle) time is expressed as percentage.

How to calculate duty cycle:
It can be calculated alphabetically:

- C means → 3 × 2 = 6
- B means → 2 × 2 = 4
- D means → 4 × 2 = 8
- F means → 6 × 2 = 12
- N means → 14 × 2 = 28
- L means → 12 × 2 = 24
- I means → 9 × 2 = 18

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Example:

	On time	Off time
DB →	8	4
$\frac{8}{8+4}$ →	8/12 = 67% on time	

	On time	Off time
BD →	4	8
$\frac{4}{4+8}$ →	4/12 = 33% on time	

Table 3: Duty cycle chart.

	On time	*Off time*	*Calculation: On time ÷ (On time + Off time)*	*On time*
CN	6	28	6 ÷ (6 + 28) = 6 ÷ 34	18%
CL	6	24	6 ÷ (6 + 24) = 6 ÷30	20%
BL	4	24	4 ÷ (4 + 24) = 4 ÷ 28	14%
DI	8	18	8 ÷ (8 + 18) = 8 ÷ 26	31%
CI	6	18	6 ÷ (6 + 18) = 6 ÷ 24	25%
CF	6	12	6 ÷ (6 + 12) = 6 ÷ 18	33%
CD	6	8	6 ÷ (6 + 8) = 6 ÷ 14	43%
BD	4	8	4 ÷ (4 + 8) = 4 ÷ 12	33%
DB	8	4	8 ÷ (8 + 4) = 8 ÷ 12	67%
CB	6	4	6 ÷ (6 + 4) = 6 ÷ 10	60%

Indications:

This mode of energy can be used for all steps of nucleus management.

- This different form of energy is used for trench when you will increase on time at the highest, i.e., 30-2.
- Due to variation in on time, it can be used for hold and chop step for all grades of cataract.
- Due to variation in off time, followability is better during removal of small pieces.

This module is having more advantage for hold and chop and removal of small pieces; it is especially safe for last pieces also.

Advantages:

- All the advantages of this mode are purely based on customization of on and off time.
  - Customization of on time is for emulsification of nucleus.
  - Customization of off time is for hold of nucleus.
- In this mode of energy, although cutting efficiency is better but chances of corneal burn are less.

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PHACO MACHINE
and its Applications

This book will give information about important aspects of Phaco machine:

- Definitions of all parameters of Phaco machine
- Principle of every parameters
- Actual usage of this parameters in surgical practice of Phaco machine
- Information related to parts of Phaco machine
- Troubleshooting in Phaco machine
- Phaco parameters is used in different condition of cataract such as hard cataract, soft cataract, shallow anterior chamber, small pupil, etc.
- Graphics related to principle of working
- Parameters in the form of chart has been illustrated in a simple way.

Navneet Toshniwal MBBS MS (Ophthalmology) is the Director at Navneet Hospital, Solapur, Maharashtra, India. He did his MBBS and MS from Dr VM Government Medical College, Solapur, Maharashtra and completed general ophthalmology fellowship at Sankara Nethralaya, Chennai, Tamil Nadu, India. In 1994, he joined his father, Late Dr Sham Toshniwal, who has started practice in ophthalmology since 1969 at Navneet Hospital. He started practice of phacoemulsification surgery since 1997. He attended and presented many papers, instruction courses and videos on phacoemulsification and keratoplasty procedures at regional, state, national and international conferences.

In 2002, he started a Phaco Training Program at Navneet Hospital. Many ophthalmologist not only from India but also from different parts of the world attended this program. He is conducting instruction courses on "Basic of Phaco" and "Advanced Phaco" for doctors and paramedical people. He received the prestigious gold medal from the Indian Intraocular Implant and Refractive Society in 2009 for his teaching program. He is the first Indian Surgeon who has done live Phaco Surgery in Jordan (Ibn Al Nafees Hospital at Irbid and King Hussein Military Hospital, Amman, Hashemite Kingdom of Jordan).

He invented five instruments such as Toshniwal Prechopper, Toshniwal Chopper, Toshniwal Micro Capsulorhexis Forcep, Micro Scissor, Microforcep. He has written three books: (1) Simplified Phacoemulsification, (2) Text and Atlas—Slit Lamp Biomicroscopy for Assessment in Cataract Surgery, and (3) Do's & Don'ts in Phaco Surgery—Text and Atlas. His first book, Simplified Phacoemulsification Translated in Greek language. Other books, Do's & Don'ts in Phaco Surgery—Text and Atlas translated in French language published by Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India.

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