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Full Length Research Paper

New Technique for Nuclear Fragmentation in Phacoemulsification

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The hard nucleus is considered as a piece of stone, so we use high phaco energy in standard phaco to fragment it. A new technique was described in this paper for nuclear fragmentation in Phacoemulsification, which does not depend mainly on phaco energy but depends on osmotic pressure of the nucleus. The nucleus is a living tissue and has its own special anatomical and physiological rules so we tried to fragment these hard nuclei rapidly and safely without phaco energy at all. This study included 20 patients with hard cataract managed by our new technique. 15 patients with hard cataract managed by divide and conquer technique (control group). we aimed to create a groove with two edges, to inject saline 0.9% at one edge and fixate from the other. Also we aimed from this groove to compensate for relative increase in the size of the nucleus after hydration then we used two blunt choppers to divide the nucleus into four pieces. All pieces were similar to gelatinous mass with no sharp borders. We found that corneal oedema, rupture of posterior capsule and mean effective Phaco time were significantly higher in controls versus patients (P <0.019, P <0.026 and P <0.0001, respectively). While there were insignificant difference in macular edema, increase in intra-ocular pressure and visual acuity parameters between patients and controls (P <0.681, P <0.681 and P <0.944, respectively). In conclusion, the hard nucleus has high osmotic pressure if activated it can fragment itself. Fragmentation of the hard nucleus by simple method rendered it more soft, easily aspirated, with less manipulation. This new technique save energy and its related complications.

Keywords: Phacoemulsification, cataract, saline , lens nucleus

INTRODUCTION

Despite advances in phacoemulsification, (PE) technology, sight-threatening complication related to excessive or in appropriate application of PE energy still occur, this is especially true for hard nucleus, these hard or brunescent cataract necessitate large amount of ultrasonic energy to emulsify and are associated with increased risk for endothelial damage and incision burn (Jones et al., 1999). Disassembly of dense nucleus necessitates additional physical maneuvers, mechanical forces generated during sculpting, rotation and cracking may be transmitted to the capsule and Zonules resulting in capsular tears and zonular dehiscence (Sugar and Schertzer, 1999) In standard phaco the hard nucleus is considered as a piece of stone so we use high energy to fragment it ,the lens nucleus is physiologically immune against water flow from outside to inside, but we found that it is not the case in opposite direction, moreover it

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has a high concentration of insoluble protein with high osmotic pressure (vérétont and Tardieu, 1989). So if we introduce a needle inside the center of the nucleus and inject few drops of saline (0.9%) it will be attracted rapidly to outside forming a strong wave. If the nucleus is soft this will cause a bubble of air follow this wave. Then the entire nucleus becomes relatively soft and we can fragment it easily and all fragments look as gelatinous mass so that the lens fibers can be separated from each other so easily. We used this osmotic pressure in fragmentation of these hard nuclei.

METHODS

Surgical Technique

This study included 20 patients with hard cataract N3-4 managed by our new technique. 15 patients with hard cataract N3-4 managed by divide and conquer technique (control group). All cases were performed at the ophthalmic department of Assiut University Hospital, Egypt, "Between" (March 2011 to April 2012).

A standard temporal 2.8 mm clear corneal incision is made and a side port created with a 1.0 mm blade approximately 3 clock hours away. After continuous curvilinear capsulorhexis (6 mm) is made, hydrodissection and hydrodelineation are performed. Then we made a shallow groove 1 mm in depth and 2.5 mm in length. By phaco-probe with phaco-tip bevel up at the center of the nucleus using continuous mode with power at 60% and low vacuum (20 mmHg) we aimed to create a groove with two edges, to inject saline 0.9% at one edge and fixate from the other. Also we aimed from this groove to compensate for relative increase in the size of the nucleus after hydration. In addition this groove will drive the fracture line in its direction. We used 30 G needle (8 mm x 0.3 mm) for injection. The plane of injection was parallel to the iris plane. The length of the inserted needle was 2.5 mm. the amount of the injected saline was 0.05 ml per injection. The very hard nucleus may need 3 injection or more. The lapse time between each injection was 30 seconds. Then we used two blunt choppers to divide the nucleus into four pieces. All pieces were similar to gelatinous mass with no sharp borders.

Alternative technique also was used. This technique begins in a similar manner to pop-and-chop by prolapsing the nucleus out of the bag during hydrodissection (hydroflotation) (Park et al., 2013), but following this step the techniques diverge. Rather than entering the eye with the phaco hand-piece and utilizing ultrasound energy to divide the nucleus, the surgeon enters the eye with a bent 30 G needle (2.5 mm is bent from the tip) at the anterior nuclear surface in the center with support from behind by cyclodialysis spatula, then we inject 0.05 ml saline 0.9%. Then we continue the operation as usual. The nuclear fragmentation becomes easier and rapid. 5 cases were done in first group through this technique. This concept is also valid as supracapsular nuclear fragmentation.

For Scanning Electron microscope

The lens nuclei were extracted through extracapsular cataract extraction ,the nuclei were injected by saline in its centers , then we excise 1mm from each nucleus. All samples were fixed in 2.5% gluteraldhyde for 24 hours and washed by PBS for 3times. then Samples were dried to remove all volatiles from the material. Samples were first dehydrated through a six step ethanol bath (30%,50%,70%,80%,95%,100%) where all water was exchanged from the sample to the ethanol bath. The samples were then placed in the Critical point of dryness (CPD) baskets and inserted into the CPD. The CPD was used to exchange the secondary fluid (ethanol) with the transition fluid (CO2) then conformal gold coating was applied to the samples using a Desk II sputter coating machine to deposit a 100 Angstrom layer. The coating was used with an electron beam accelerating voltage of 3.00 KeV as greater voltages further exacerbated the anathematic charging problem Jeffree and Read (1991).

RESULTS

Best corrected visual acuity was 6/18 or better in all cases. Posterior chamber intraocular lenses were implanted in all cases in the bag except in 4 cases in control group (in sulcus). The type of IOL was one piece foldable acrylic lens in all cases except 4 triepece a crylic lens in control group. The central corneal thickness at one week post-operatively was 522 µ or more in all cases diagnosed as post-operative corneal edema. As regard post-operative complication such as mild corneal edema, rupture of posterior capsule and mean effective phaco-time were significantly higher in controls versus patients ($P<0.019$, $P<0.026$ and $P<0.001$, respectively). While there were insignificant difference in post-operative cystoid macular edema, post-operative intraocular pressure rise and best corrected visual acuity (BCVA) parameters between patients and controls ($P<0.681$, $P<0.681$ and $P<0.944$, respectively). (Table 1 Figure 1)
Data were expressed as mean +/- standard deviation (minimum–maximum) or number (%) as appropriate. Parametric parameters were compared using student “t” test and non parametric parameters using Chi-square test.

The corneal edema, rupture of posterior capsule and Mean effective Phaco time were significantly higher in controls versus patients ($P <0.019$, $P <0.026$ and $P <0.0001$, respectively). While there were insignificant difference in macular edema, increase in intra-ocular pressure and visual acuity parameters between patients

Table 1

Post-operative Parameters	Patients (n=20)	Control (n=15)	Significance
Corneal edema (number, %)	2 (10.00%)	7 (46.70%)	P <0.019
Rupture of posterior capsule (number, %)	0 (0.00%)	4 (26.70%)	P <0.026
Macular edema (number, %)	1 (5.00%)	1 (6.70%)	P <0.681
Increase intra-ocular pressure (number, %)	1 (5.00%)	1 (6.70%)	P <0.681
Mean effective Phaco time (seconds) (mean±SD, minimum – maximum)	15.65±12.48 (1.00-40.00)	69.07±27.28 (39.00-130.00)	P <0.0001
Visual acuity (mean±SD, minimum – maximum)	0.65±0.24 (0.33-1.00)	0.64±0.25 (0.33-1.00)	P <0.944

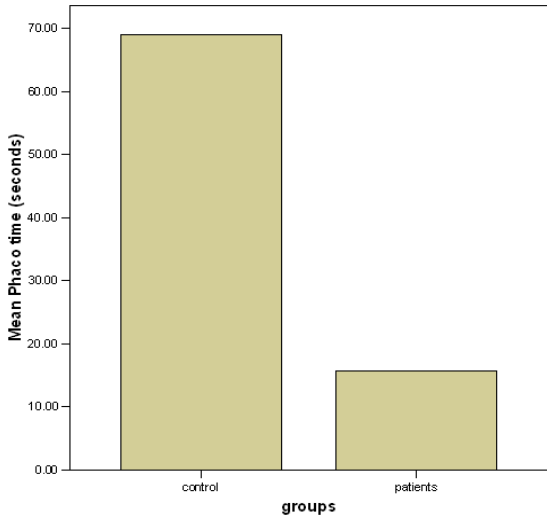

Figure 1

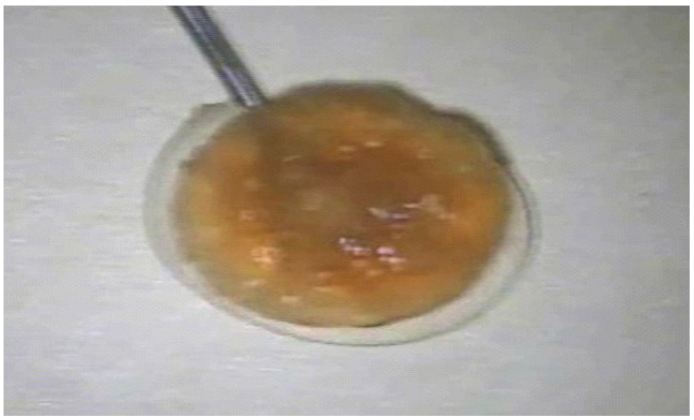

Figure 2. A hard nucleus injected from behind by bent 25 G needle

and controls (P <0.681, P <0.681 and P <0.944, respectively).

In ex vivo demonstration: the hard nucleus is injected from behind by bent needle the by saline solution 0.9%, the saline will attracted to outside by osmotic pressure of the nucleus aided from behind by injection force (Figure 2).

Then the entire nucleus becomes relatively soft and we can fragment it easily and all fragment look as gelatinous mass (Figure 3 and 4).

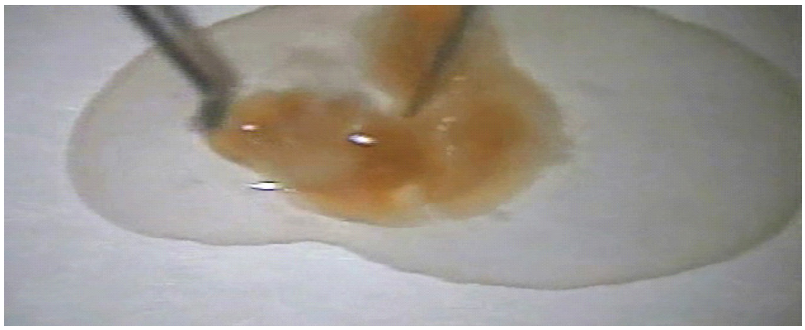

Figure 3. The hard nucleus is easily divided into four segments
In another ex vivo demonstration if we inject the hard nucleus by saline after 2 minutes we can separate the lens fiber from each other so easily

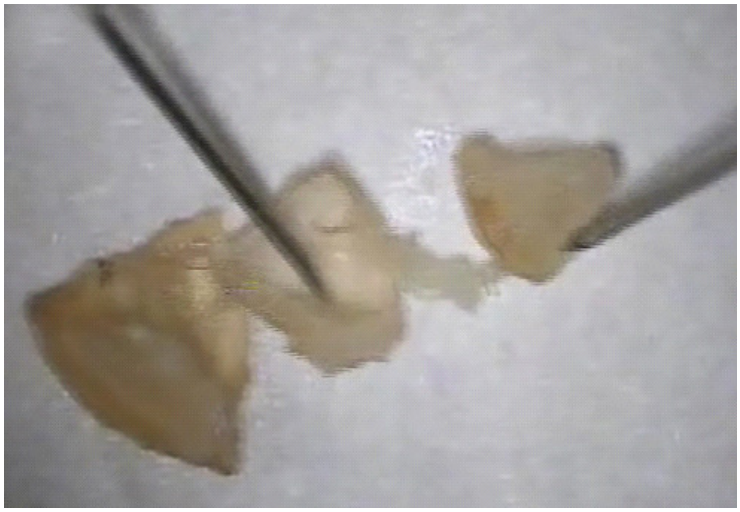

Figure 4. Lamellar separation of the injected nucleus

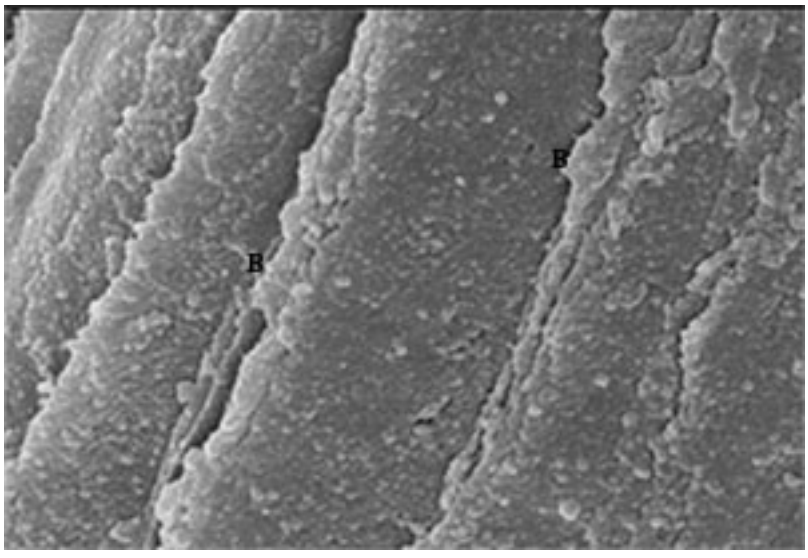

Figure 5. Scanning micrograph of control hard nucleus of male patient 64 years at the external surface of specimen marked ball and socket junctions (B). X5,000

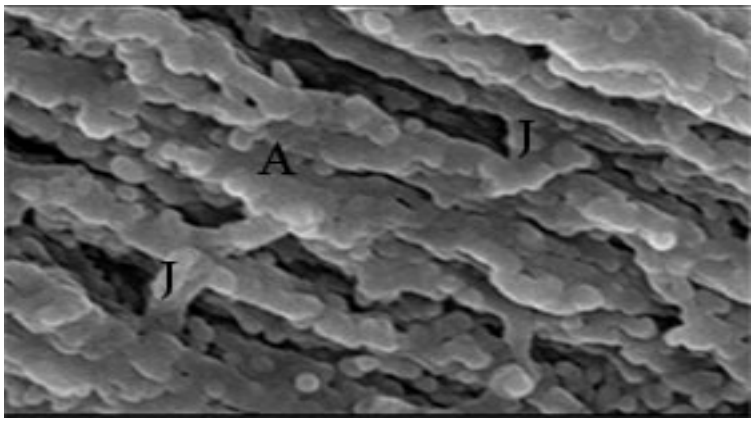

Figure 6. Hard nucleus of female patient aged 69 years (Non-injected) as control showing : Most of fibers exhibited low-amplitude accordion-like compaction folds(A) along their length, however, regions of junctions(J) at membranes were also present (X7,500).

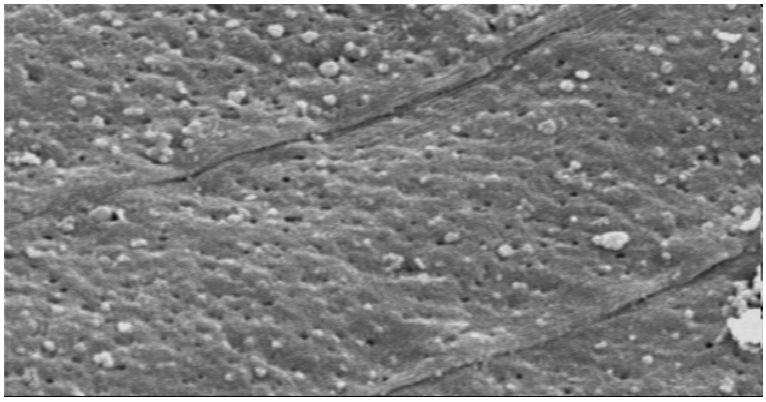

Figure 7. Another hard nucleus (male patient 65 years) was injected at the center of the nucleus by 1 m saline showing : relative increase in the size of the injected lens fiber with loss of ball and socket junction Also there are multiple openings at the external surface of the lens fiber (may be reopened Jap junction). (X5,000)

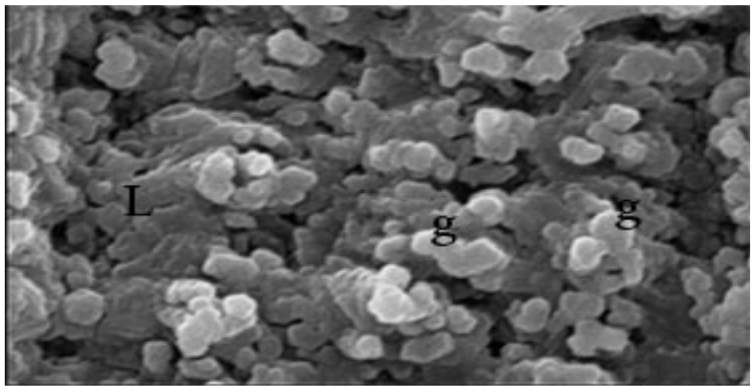

Figure 8. Scanning micrograph of hard nucleus of female patients 68 years old after injection of saline 0.9% (1 m of saline through the center of the nucleus) Showing : increase in size of the lens fiber with loss of ball and socket junction (L). The ends within the plaque are dilated/globular (g) with loss of end to end interaction. Some PSC plaques maintained the end to end interaction, but were severely dilated and had completely lost their filopodia. This micrograph is away from the center of the specimen by 500 µ and 1500 µ from the site of injection. X7,500

DISCUSSION

The most obvious structural change in catarctous lens is the formation of accordion-like folds, which account for much of the compaction along the A±P axis. Structural changes are reflected from the underlying modifications in the cytoskeleton (Garland et al., 1996) proteins age-related changes, and /or water loss (Bours, Fodisch and Hockwin, 1987), modifications to membrane lipids (Borchman and Yappert, 1998) all these changes might be implicated in the observed increase in the compaction folds. These changes are consistent with the extensive protein modifications (Andley, Liang and Lou, 2000), and lipid peroxidation (Babizhayev and Costa, 1994). The loss of cytoplasmic water results in the reduction of cell volume without decrease in cell surface area. The tendency of the crystallins to self-associate into larger aggregates and the resulting reduced osmolarity of nuclear cytoplasm might be driving force for the loss of water in the lens nucleus (Kenworthy et al., 1994). These changes will bring high concentrations of proteins in nuclear cytoplasm to exist adjacent to cortical fiber cells with relatively high water content. Furthermore extensive condensation of cytoplasmic proteins during cataract formation might be resulting from oxidative damage in lens membrane proteins and lipids, (Truscott, 2000). Albuminoid aggregates with molecular weight of about 5 x 10 gmarl could explain lens turbidity. Clark et al., 1980 and Benedek 1971). Progressive losses in soluble α-crystallin with age might be implicated in the protein aggregation within the cell and resulting in lens stiffness. (McFall-Ngai et al., 1985; Roy et al., 1976). Similar observations were reported in microradiographic study of nuclear cataract whereas aggregation of protein molecules into dense clusters of -50--100 nm diameter is evident without enlargement of intercellular spaces, or breakdown of cell membranes. (Philipson1973).

A gradient of increasing protein concentration is found from the more superficial fiber cells to deeper fiber cells in the lens. However, this protein gradient is not associated with a reciprocal gradient in the osmotic activity of water because water does not have a tendency to pass to interior of the cells of lens nucleus (Fagerholm et al., 1981). But we observed that the nuclear cataract is not immune against flow of water in opposite direction so if we inject few drops of saline 0.9% into the center of the nucleus it will be attracted rapidly to outside by the effect of high osmotic pressure of the insoluble protein of the nucleus.

vérétont and Tardieu 1989 proved that colloidal osmotic pressure of the cortical and nuclear extract of calf cataract is 10 and 7 m osmoles respectively, and the osmotic pressure of the injected saline 0.9% (0.05 ml) is equal to 0.0154 ml osmol. So the difference cause strong wave, the velocity of this wave depends on the degree of the nuclear hardness. In soft nucleus this strong wave was followed by a small bubble of air and multiple rebound waves.

Denaturation of Proteins by ions might help in increase its solubilization (Chevallet et al. 1998). Thus salt solutions (Na Cl) in this study reduce sample complexity, and render it relatively soft easily fragment. The injected saline cause sudden hydration of the lens fibers with increase in size of these fibers relative to each other and this cause loss of the junction between them. Hydration of the lens fiber occurs through this biochemical reaction.

The water molecules will attach to the peptide bond and to the hydrophilic residue of unfolded nuclear protein .The hydrophobic residue is unstable in this aqueous environment so it associates together forming a random gelatinous structure with water molecule inside it, So the whole nucleus becomes relatively soft and we can fragment it easily Rodwell et al., 2003.

The incidence of posterior capsular rupture in our group was zero compared to 4 cases in control group. In our technique we did not use energy at all during fragmentation with no excessive manipulation, the fragments have smooth gelatinous edge with no sharp edge. We divide the nucleus manually by two blunt chopper start centrally and end at the center of the anterior chamber and all instruments ware seen at all times. So our result as regard liability to Posterior capsule rupture is much better.

The mean effective phaco time in our group is better than in control group. The injected hard nucleus becomes relatively soft and easily fragmented and does not need much energy to fragment or aspirate. So the mean effective phaco-time is much better .But in some cases we need relatively high phaco energy, this is not fault in concept but the fault in the technique as we cannot inject saline deep as the center of the nucleus as we inject in plane parallel to the iris. So the hydration will occur only as the anterior plane of the nucleus and still the deep plane need more energy to fragment, in 5 cases where we inject saline as the center of the nucleus (Supra-capsular fragmentation) the mean effective phaco-time ranged from 1-4 seconds only.

CONCLUSION

This new technique save energy and its related complications Also it fragments the hard nucleus by simple method, it makes the lens nucleus more soft, easily aspirated, with less manipulation. The hard nucleus has high osmotic pressure if activated it can fragment itself.

What this paper Adds

In our technique we did not forget that the nucleus is a living tissue and has its own special anatomical and physiological rules. We tried to get great benefit from this information to fragment these hard nuclei rapidly and safely without phaco energy at all using the high osmotic pressure of the nucleus.

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