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Research Article

A Comparative Interventional Study of the Changes in Astigmatism and Corneal Aberrations between 2.4mm and 3mm Opposite Clear Corneal Incisions During Phacoemulsification With IoL Surgery In Cataract Patients At SMS Hospital

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ABSTRACT

Aim: The aim of the present study was to assess and compare changes in astigmatism and corneal aberrations between 2.4mm and 3mm opposite clear corneal incisions during phacoemulsification with IOL surgery.

Methods: The present study was conducted in the Upgraded Department of Ophthalmology, S.M.S. Medical College and Hospital, Jaipur, Rajasthan from 1st November, 2022 to 31st July, 2023 after IEC approval. All patients attending OPD in SMS Medical College, Jaipur Eye department were included. A total of 80 cases were enrolled in the study.

Results: The age distribution revealed that the largest proportion of patients fell within the 61-70 years age group (43.8%), with a relatively balanced distribution between the 2.4 mm (45.0%) and 3 mm (42.5%) groups. The gender distribution was nearly equal, with 47.5% female and 52.5% male patients. Both the 2.4 mm and 3 mm groups had identical gender distributions, with 47.5% of females and 52.5% of males in each group.

Conclusion: This study demonstrated that 3.0 mm OCCIs provide better astigmatic correction and visual outcomes than 2.4 mm OCCIs, with minimal long-term impact on HOAs. The findings reinforce the role of OCCIs as a reliable and accessible technique for managing preexisting astigmatism during cataract surgery. Future research should explore the use of OCCIs in combination with other techniques to enhance outcomes in patients with higher degrees of astigmatism. The 2.4 mm group had slightly more right-eye surgeries (55.0%), while the 3 mm group had a slightly higher proportion of left-eye surgeries (52.5%), showing a well-distributed allocation across both groups.

Keywords: Astigmatism, Corneal Aberrations, Clear Corneal Incisions, Phacoemulsification with IOL Surgery.

INTRODUCTION

Cataract surgery is our most powerful refractive procedure based on spherical power that we can correct. Anything from -30D of myopia to +20D of hyperopia can be brought down to a spherical equivalent of a plano by virtue of the IOL power that we calculate and select. The main refractive problems post phacoemulsification includes the PEA (Pre-Existing Astigmatism)[1-3], limitation to just a monofocal vision and also corneal aberrations. Addressing these issues within the same surgical session can greatly enhance visual outcomes, improving prognosis and offering the potential for a spectacle-free postoperative experience.

While Corneal Aberrations is one thing which the surgery does not deal with, Presbyopic Multifocal IOLs as an alternative to monofocal IOLs have a major disadvantage of decreased contrast sensitivity and glare. For Astigmatism, available options include Toric IOLs.[4,5] Limbal Relaxing Incisions (LRIs) and Opposite Clear Corneal Incisions (OCCIs).[6] While Toric IOLs are highly effective, they are costly and may present challenges such as unpredictable refractive outcomes and sensitivity to rotational misalignment, which can significantly reduce their effectiveness.[7]

LRIs offer a more cost-effective option but are heavily dependent on the surgeon's skill and the cornea's healing response, making results variable.[8] In contrast, OCCIs offer the advantage of a simple to perform, no major additional time requiring and inexpensive procedure with requirement of the same metal keratome used for primary incision, where experience has shown that CCIs produce a stable flattening effect on the cornea over the long term.[9,10]

So for low degrees of astigmatism , the study is conducted to explore the astigmatic corrective potential of OCCIs, focusing on comparing 2.4 mm and 3 mm incision sizes to assess their impact on both astigmatism and higher-order aberrations. By refining these techniques, we can potentially enhance visual outcomes and move closer to an emmetropic, spectacle-free postoperative vision.

The aim of the present study was to assess and compare changes in astigmatism and corneal aberrations between 2.4mm and 3mm opposite clear corneal incisions during phacoemulsification with IOL surgery.

MATERIALS AND METHODS

The present study was conducted in the Upgraded Department of Ophthalmology, S.M.S. Medical College and Hospital, Jaipur, Rajasthan from 1st November, 2022 to 31st July, 2023 after IEC approval. All patients attending OPD in SMS Medical College, Jaipur Eye department were included. A total of 80 cases were enrolled in the study.

Inclusion Criteria

1. Patients who are willing to give informed consent for study.
2. No other ocular pathology
3. Against the Rule Astigmatism between 1-2D extending between 150-30 degrees meridian
4. Pupil dilation greater than 7mm

Exclusion Criteria

1. Uncooperative patients
2. Corneal ectasias
3. Corneal dystrophies
4. Corneal opacities
5. Corneal Ulcer or Abscess
6. Compromised Endothelial Cell function
7. Subluxated lens or with Zonular Dialysis
8. Intraoperative Complications during surgery
9. Previous history of trauma
10. Previous history of ocular surgery
11. History of corneal refractive surgery,
12. Pterygium surgery

Study Methodology

- This single-centre experimental type of analytical study was performed with the approval of the Institutional Ethics Committee.
- Written informed consent was obtained from all the patients after giving them a full explanation of the study.
- The study recruited patients who underwent cataract surgery using either 2.4 mm or 3mm Opposite Clear Corneal On axis Incisions in either eye.
- A brief history was taken and an ocular examination was conducted.
- Patient�much preoperative Sim K, True K, axis and power of cylinder, RMS value of central 4mm cornea, and fourth order aberration (Z4) of central cornea values were noted via Scheimpflug corneal tomography.
- All surgeries were performed by the same experienced Cataract surgeon. The pupil was dilated using Phenylephrine 5%W/V+ Tropicamide 0.8%W/V and topical anesthesia was given using Proparacaine 0.5%. A paracentesis of 1mm was made, at 12 o‛clock in right eyes and 5 o‛clock in left eyes. Next, a cohesive OVD was injected (sodium hyaluronate 1%).
- During surgery, the visual axis was marked and the steepest meridian identified. Initially, only one of the two identical CCIs was created along the steepest meridian using a keratome of width 2.2mm. A capsulorhexis of 5-5.5mm was created using forceps.
- Hydrodissection was performed. Dispersive OVD was injected. The cataractous lens was extracted with the direct chop phacoemulsification technique. Irrigation and aspiration were performed.
- Then, a single piece hydrophilic acrylic IOL was implanted in the capsular bag. The residual OVD was aspirated. At the end of surgery, with the 2.2 keratome blade the second OCCI was made.
- Intracameral moxifloxacin was injected at the end of the procedure. All incisions were sealed with corneal stromal hydration and were checked for leakage with a microsponge, hence ensuring no wound leakage. The patient was shifted out of the OT without an eye patch.
- In Group 1, 2.4 mm incisions were made with the 2.2 keratome blade, while in Group B, initially a 2.4mm incision was made to

perform the entire surgery and then at the end of the surgery the first incision was widened to a width of 3mm, along with which a fresh 3mm OCCI was also created.

- Here, one CCI was used to perform phacoemulsification and to insert an intraocular lens (IOL) in the bag; the opposite CCI was not used during the procedure. In cases of against- the-rule (ATR) astigmatism, the OCCIs were made at the 3 o'clock and 9 o'clock positions (temporal CCI was used for phacoemulsification; the nasal CCI was not used), while in cases of oblique astigmatism, the OCCIs were made on the steepest meridian.
- Follow-up visits were conducted at Day 3, Day 7, 1 Month and 3rd Month. Measurements of Sim K, True K, axis and power of cylinder, and fourth order aberration (Z4) of central cornea values were noted via Scheimpflug corneal tomography.
- Assessments included changes in Astigmatism, changes in high order aberration, and overall astigmatic refraction. • Statistical analysis was conducted using suitable tests of significance.
- This single-centre comparative type of interventional study was performed with the approval of the Institutional Ethics Committee.

Study Tool

1. Scheimpflug Corneal Tomograph
2. Accomodative Refeacto/Keratometer(ARK)

Statistical Analysis

- Collected data (Pre and Post-operative) entered in Microsoft Excel Worksheet.
- Continuous data summarized in the form of mean and standard deviation. Difference in mean of the two groups was analyzed using Student_t' test.
- Discrete data expressed in form of proportions and difference in proportions was analyzed using chi-square test.
- The level of significance kept at 95% for all statistical analysis and a p value of 0.05% considered statistically significant.

RESULT

Table 1: Baseline Characteristics

Age Group	2.4 mm (%)	3 mm (%)	Total (%)
<50	6 (15.0%)	0 (0.0%)	6 (7.5%)
50-60	10 (25.0%)	13 (32.5%)	23 (28.7%)
61-70	18 (45.0%)	17 (42.5%)	35 (43.8%)
>70	6 (15.0%)	10 (25.0%)	16 (20.0%)
Total	40 (100.0%)	40 (100.0%)	80 (100.0%)
Gender			
Female	19 (47.5%)	19 (47.5%)	38 (47.5%)
Male	21 (52.5%)	21 (52.5%)	42 (52.5%)
Eye			
Left	18 (45.0%)	21 (52.5%)	39 (48.8%)
Right	22 (55.0%)	19 (47.5%)	41 (51.2%)

The age distribution revealed that the largest proportion of patients fell within the 61-70 years age group (43.8%), with a relatively balanced distribution between the 2.4 mm (45.0%) and 3 mm (42.5%) groups. The 50-60 years group comprised 28.7% of patients, with a slightly higher representation in the 3 mm group. The <50 years group was the smallest, with only 7.5% of total patients, none of whom were in the 3 mm group. The >70 years group accounted for 20% of patients, with a higher percentage in the 3 mm group (25.0%) compared to the 2.4 mm group (15.0%). The gender distribution was nearly equal, with 47.5% female and 52.5% male patients. Both the 2.4 mm and 3 mm groups had identical gender distributions, with 47.5% of females and 52.5% of males in each group, indicating no gender-based bias in the distribution of patients between the two groups. The distribution between the left and right eyes was almost balanced, with 48.8% of surgeries performed on the left eye and 51.2% on the right eye. The 2.4 mm group had slightly more right-eye surgeries (55.0%), while the 3 mm group had a slightly higher proportion of left-eye surgeries (52.5%), showing a well-distributed allocation across both groups.

Table 2: Comparison of Flat Axis Measurements [Degree] and Steep Axis Measurements [Degree] Between Groups

Flat Axis Measurements Time Point	2.4 mm (Mean ± SD)	3 mm (Mean ± SD)	P value
Preop Flat Axis	90.13 ± 14.52	93.60 ± 14.57	0.289
Day 3 Flat axis	79.38 ± 14.82	80.25 ± 14.86	0.0474
Day 7 Flat axis	78.89 ± 13.54	78.03 ± 14.06	0.0327
1 Month Flat axis	76.54 ± 14.01	76.35 ± 15.03	0.0350
3 Months Flat axis	75.31 ± 12.88	75.70 ± 13.06	0.0215
Steep Axis Measurements Time Points			
Preop Steep Axis	180.13 ± 14.52	183.60 ± 14.57	0.289
Day 3 Steep axis	169.38 ± 14.82	170.25 ± 14.75	0.0474
Day 7 Steep axis	167.38 ± 14.61	168.03 ± 15.06	0.0327
1Month Steep axis	166.25 ± 14.44	167.35 ± 13.03	0.0150
3 Months Steep axis	165.40 ± 14.16	165.40 ± 14.06	0.0221

Notably, the 3 mm group demonstrates a slightly greater shift of flat axis values at all postoperative time points, with significant differences observed from Day 3 onward ($p < 0.05$). This suggests enhanced correction of astigmatism with the larger incision size over time. The steep axis also shows a vertical meridian shift postoperatively for both the 2.4 mm and 3 mm groups. The 3 mm incision group presents with slightly higher shift of steep axis values compared to the 2.4 mm group, with significant differences becoming more evident by Day 3 and remaining consistent up to 3 months ($p < 0.05$).

This result reflects the superior capability of the 3 mm incision in flattening the steep axis, leading to better astigmatic control.

Table 3: Visual Acuity (UCVA) [LogMAR] Outcomes in 2.4 mm vs 3 mm Groups and Best Corrected Visual Acuity (BCVA) [LogMAR] in 2.4 mm and 3 mm Groups

Visual Acuity (UCVA) Time Point	2.4 mm (Mean ± SD)	3 mm (Mean ± SD)	P value
Preop UCVA	0.57 ± 0.10	0.61 ± 0.12	0.116
Day 3 UCVA	0.25 ± 0.07	0.21 ± 0.09	0.031
Day 7 UCVA	0.24 ± 0.06	0.21 ± 0.09	0.072
1 Month UCVA	0.21 ± 0.10	0.16 ± 0.13	0.03
3 Months UCVA	0.21 ± 0.10	0.15 ± 0.12	0.016
Best Corrected Visual Acuity Time Point			
Preop BCVA	0.38 ± 0.11	0.39 ± 0.14	0.623
Day 3 BCVA	0.13 ± 0.10	0.11 ± 0.10	0.123
Day 7 BCVA	0.05 ± 0.08	0.04 ± 0.07	0.483
1 Month BCVA	0.04 ± 0.08	0.03 ± 0.03	0.078
3 Months BCVA	0.04 ± 0.07	0.03 ± 0.04	0.235

Preoperative visual acuity (UCVA) was similar between the two groups ($p = 0.116$). However, the 3 mm group showed significantly better visual acuity postoperatively, with significant improvements observed on Day 3 ($p = 0.031$) and at the 1 Month and 3 Months follow-ups ($p = 0.03$ and $p = 0.016$, respectively). The 3 mm group's superior visual outcomes suggest it may be a more effective intervention for improving uncorrected visual acuity. Best-corrected visual acuity (BCVA) did not differ significantly between the 2.4 mm and 3 mm groups at any time point, including preoperatively and at the follow-ups on Day 3, Day 7, 1 Month, and 3 Months (all p-values above 0.1). This indicates that both groups achieved comparable outcomes in BCVA, suggesting similar effectiveness in visual correction post visual aid.

Table 4: Corneal Curvature (Flat K) [Dioptres] Comparisons and Corneal Curvature (Steep K) [Dioptres] between Groups

Corneal Curvature (Flat K) Time Point	**2.4 mm (Mean ± SD)**	**3 mm (Mean ± SD)**	P value
Preop Flat K	43.52 ± 1.40	43.31 ± 1.68	0.56
Day 3 Flat K	43.60 ± 1.41	43.43 ± 1.68	0.0264
Day 7 Flat K	43.65 ± 1.41	43.49 ± 1.67	0.0134
1 Month Flat K	43.69 ± 1.42	43.49 ± 1.71	0.0257
3 Months Flat K	43.69 ± 1.42	43.49 ± 1.71	0.042
Corneal Curvature (Steep K) Time Point			
Preop Steep K	44.91 ± 1.40	44.81 ± 1.58	0.78
Day 3 Steep K	44.64 ± 1.42	44.47 ± 1.64	0.0262
Day 7 Steep K	44.61 ± 1.41	44.39 ± 1.67	0.0347
1Month Steep K	44.60 ± 1.43	44.34 ± 1.71	0.0339
3 Months Steep K	44.60 ± 1.43	44.34 ± 1.71	0.0312

Both groups show an upward trend in flat K values over time, indicating corneal stabilization post-surgery. The 3 mm group exhibits a slightly higher increase in Flat K across all postoperative periods, with statistically significant differences emerging by Day 3 ($p < 0.05$). This implies that the larger incision size induces a more prominent change in corneal curvature, contributing to improved refractive outcomes. Steep K values decrease progressively from preoperative levels in both groups, with the 3 mm group showing a more pronounced reduction. Significant differences between the two groups are observed from Day 3 through to 3 months ($p < 0.05$), indicating better control of corneal steepness with the 3 mm incision.

Table 5: Simulated Keratometry (Sim K) [Dioptres] and Mean Reduction [Dioptres] Over Time in 2.4 mm and 3 mm Groups

Simulated Keratometry (Sim K) Time Point	**2.4 mm (Mean ± SD)**	**3 mm (Mean ± SD)**	P value
Preop Sim K	44.21 ± 1.39	44.06 ± 1.63	0.66
Day 3 Sim K	44.12 ± 1.41	43.95 ± 1.65	0.63
Day 7 Sim K	44.15 ± 1.40	43.94 ± 1.67	0.55
1 Month Sim K	44.17 ± 1.42	43.91 ± 1.71	0.47
3 Months Sim K	44.17 ± 1.42	43.92 ± 1.71	0.47
Mean Reduction [Dioptres] Time Point			
Day 3 Mean Reduction	0.35 ± 0.14	0.46 ± 0.24	0.01
Day 7 Mean Reduction	0.40 ± 0.16	0.60 ± 0.22	0.00
1 Month Mean Reduction	0.44 ± 0.16	0.65 ± 0.21	0.01
3 Months Mean Reduction	0.44 ± 0.16	0.65 ± 0.21	0.01

Simulated keratometry (Sim K) results were comparable between the two groups, with no significant differences observed at any time point, including preoperative and at the follow-ups on Day 3, Day 7, 1 Month, and 3 Months (all p-values above 0.4). This suggests that both the 2.4 mm and 3 mm groups experienced similar corneal refractive outcomes. The 3 mm group demonstrated a significantly greater reduction in refractive error compared to the 2.4 mm group at all postoperative time points (Day 3, Day 7, 1 Month, and 3 Months), with p-values ranging from 0.00 to 0.01. This indicates that the 3 mm intervention was more effective in reducing PEA [Pre-Existing Astigmatism] over time, suggesting better overall refractive correction.

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Table 6: Astigmatism (AST) [Dioptres] Changes and Higher-Order Aberrations (HOA) [μm] Across 2.4 mm and 3 mm Groups

Astigmatism (AST) [Dioptres] Time Point	**2.4 mm (Mean ± SD)**	**3 mm (Mean ± SD)**	P value
Preop AST	1.39 ± 0.29	1.50 ± 0.28	0.09
Day 3 AST	1.04 ± 0.27	1.00 ± 0.27	0.94
Day 7 AST	0.99 ± 0.24	0.90 ± 0.23	0.10
1 Month AST	0.95 ± 0.21	0.85 ± 0.22	0.03
3 Months AST	0.95 ± 0.21	0.85 ± 0.22	0.03
Higher-Order Aberrations (HOA) Time Point			
Pre op HOA	0.06 ± 0.01	0.07 ± 0.02	0.78
Day 3 HOA	0.13 ± 0.01	0.20 ± 0.01	0.00
Day 7 HOA	0.09 ± 0.01	0.15 ± 0.01	0.00
1 Month HOA	0.08 ± 0.01	0.11 ± 0.01	0.00
3 Months HOA	0.07 ± 0.02	0.08 ± 0.02	0.12

Astigmatism was reduced more significantly in the 3 mm group, particularly at the 1 Month and 3 Months follow-ups, where p-values were 0.03. While no significant difference was observed preoperatively (p = 0.09) or on Day 3 (p = 0.94), the consistent reduction in astigmatism in the 3 mm group postoperatively suggests a more favorable outcome in this group. The 3 mm group exhibited significantly higher higher-order aberrations (HOA) shortly after surgery, particularly on Day 3, Day 7, and at 1 Month (p = 0.00). However, this difference was not significant by the 3 Months follow-up (p = 0.12), indicating that while the 3 mm group experienced a transient increase in HOAs, these aberrations diminished over time, stabilizing by the end of the study period.

DISCUSSION

Cataract surgery has evolved significantly, with modern approaches utilizing small incisions and foldable intraocular lenses (IOLs) to achieve postoperative emmetropia 4. The goal is to restore clear vision while minimizing spectacle dependence, which makes astigmatism correction a critical aspect of the surgical outcome. Several methods, including limbal relaxing incisions (LRI), toric IOL implantation[4,5] and arcuate keratotomies[6], have been explored to manage preexisting astigmatism. However, opposite clear corneal incisions (OCCI)[9,10] offer a promising alternative due to their simplicity and effectiveness.

Opposite Clear Corneal Incisions (OCCIs) induce targeted corneal flattening via the creation of an incision opposite the main port. An incision, when made on the cornea, creates a localized flattening effect as the corneal tissue attempts to heal and stabilize, achieving a greater degree of flattening when the incision is placed along the steepest meridian of astigmatism, thereby reducing the overall corneal curvature in that axis. OCCIs with its dual-incision configuration symmetrically distributes corneal tension, leading to a more precise and stable flattening effect across the steep axis (Hoffman et al[11], 2003, Nichamin et al[3], 2006).

The study included 80 participants divided equally between the two groups (2.4 mm and 3.0 mm incisions). To minimise bias, the participants were age and sex-matched. The majority of patients (43.8%) belonged to the 61–70 age groups, and gender distribution was identical across both groups, with 47.5% females and 52.5% males. Surgical distribution between the left and right eyes was nearly balanced, indicating a well-structured allocation. Astigmatism correction plays a pivotal role in achieving postoperative emmetropia, especially in patients with preexisting astigmatism. Research has highlighted that the extent of astigmatic correction can vary based on the size and location of the surgical incision.[9] Our study showed that both 2.4 mm and 3.0 mm OCCIs provided stable outcomes, with the 3.0 mm group demonstrating superior astigmatism reduction of 0.65 ±0.21 Dioptre compared to 0.44 ± 0.16 Dioptre in 2.4 mm group at a p-value of 0.01. This aligns with findings from Ren Y et al[12], where 3.0 mm OCCIs were more effective than smaller incisions, particularly in correcting low-to-moderate astigmatism. The corneal flattening effect observed during follow-up remained consistent, ensuring long-term stability, as corroborated by previous studies.

The analysis across all graphs suggests that both 2.4 mm and 3 mm opposite clear corneal incisions (OCCIs) follow a similar trend in modifying the flat and steep axes, as well as corneal curvature. However, the degree of change is more pronounced in the 3 mm incision group. The larger incision size provides superior astigmatic correction, with greater flattening effects on the steep axis, and a consistent trend in the follow up, highlighting long-term stability. These findings align with those of Hoffman et al. (2003)[11], reporting a stable and greater flattening in the larger corneal incisions groups, especially along the steep meridian. The uncorrected visual acuity (UCVA) showed a significant improvement in the 3.0 mm OCCI group across all follow-up intervals, with p-values of 0.03 or lower. Notably, approximately 87.5% of patients in the 3.0 mm group achieved a UCVA of 6/9 or better, compared to about 82% patients in the 2.4 mm OCCI group. This enhanced visual outcome in the 3.0 mm group suggests that a larger incision not only corrects pre-existing astigmatism more effectively but also contributes to better visual rehabilitation. The improvement in UCVA was sustained up to the 3-month follow-up, highlighting the stability of the correction. Our findings also align with previous studies by Kawana et al[13] and Garg S et al[14] which reported superior visual outcomes and astigmatism correction with larger or paired OCCIs. These comparative findings further substantiate the benefits of using a 3.0 mm OCCI for enhanced visual outcomes in cases of pre-existing astigmatism.

However, higher-order aberrations (HOAs) were initially higher in the 3.0 mm group, particularly in the initial first month period. The mean HOA values for the 3.0 mm group were 0.20 ± 0.01 μ compared to 0.13 ± 0.01 μ, with a statistically significant difference ($p = 0.00$). Studies have documented that larger or paired incisions may temporarily increase HOAs, especially trefoil and spherical aberrations.[15-17] In addition to OCCIs, other surgical methods like astigmatic keratotomy (AK) and limbal relaxing incisions (LRI) are employed to manage astigmatism. AK requires greater surgical dexterity and specialized equipment, such as diamond knives, and may lead to fluctuating refractive outcomes over time. LRIs, while simpler and more cost-effective, have less predictable outcomes due to their reliance on surgical skill.[8] Toric IOLs considered as gold standard for astigmatism correction, as they often achieve high accuracy in uncorrected visual acuity (UCVA) and reduction of higher-order aberrations (HOAs). Studies like Koch et al[18] and Mendicute et al[19] demonstrated in patient groups with 1 to 3.75 Dioptre Astigmatism that Toric IOLs significantly improve UCVA, with a large proportion of patients achieving 6/9 or better.

CONCLUSION

This study demonstrated that 3.0 mm OCCIs provide better astigmatic correction and visual outcomes than 2.4 mm OCCIs, with minimal long-term impact on HOAs. The findings reinforce the role of OCCIs as a reliable and accessible technique for managing preexisting astigmatism during cataract surgery. Future research should explore the use of OCCIs in combination with other techniques to enhance outcomes in patients with higher degrees of astigmatism. The 2.4 mm group had slightly more right-eye surgeries (55.0%), while the 3 mm group had a slightly higher proportion of left-eye surgeries (52.5%), showing a well-distributed allocation across both groups.

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