Comparison of characteristics of femtosecond laser-assisted anterior capsulotomy versus manual continuous curvilinear capsulorrhexis: A meta-analysis of 5-year results

Muhammad Hassaan Ali, Samee Ullah, Usman Javaid, Mamoona Javaid, Samreen Jamal, Nadeem Hafeez Butt

Abstract

Objective: To perform a meta-analysis on the precision and safety of femtosecond laser-assisted anterior capsulotomy versus conventional manual continuous curvilinear capsulorrhexis.

Methods: This meta-analysis was conducted from February 2010 to November 2014. Literature search on PubMed, Google Scholar, ExcerptaMedica database and Cochrane Library was done to identify randomised controlled trials and case-control studies. SPSS 20 was used for data analysis.

Results: Of the 10 articles included, there were 3(30%) randomised controlled trials and 7(70%) non-randomised controlled trials. The meta-analysis was based on a total of 2,882eyes. Of them, 1,498(51.97%) underwent femtosecond laser-assisted capsulotomy and 1,384(48.02%) underwent manual continuous curvilinear capsulorrhexis. The diameter of the capsulotomy and the rates of anterior capsule tear showed no statistical difference between the femtosecond laser group and the manual capsulorrhexis group (p=0.29 and p=0.68). In terms of circularity of capsulotomy, femtosecond laser group had a more significant advantage than the manual capsulorrhexis group (p<0.001).

Conclusion: Femtosecond laser performed capsulotomy with more precision and higher reliability than the manual continuous curvilinear capsulorrhexis.

Keywords: Femtosecond laser, Cataract, Phacoemulsification, Capsulotomy, Capsulorrhexis. (JPMA 67: 1574; 2017)

Introduction

Cataract surgery is the most commonly performed ophthalmic surgery in the world.[1] One of the most crucial steps in cataract extraction is creation of a continuous round window in the lens anterior capsule named capsulorrhexis.[2] Continuous curvilinear capsulorrhexis (CCC) is considered to be the standard method of performing anterior capsulotomy. The size, shape and centration of capsulorrhexisarekey determinants of positioning intraocular lens and eventually visual outcome. Too small or too large capsulorrhexis can cause various problems, including intraocular lens (IOL) decentration, hyperopic shift, posterior capsule opacification, etc. CCC is a manual procedure and even with experienced surgeons the size, shape and centration of capsulorrhexis can be variable depending on the type and maturity of the cataract.

Femtosecond is the latest laser platform which has revolutionised cataract surgery by minimising surgeon dependent variations of capsulorrhexis. Now eye surgeons can customise the size, shape and centration of capsulorrhexis depending upon type of intraocular lens and nuclear sclerosis.

Femtosecond lasers (FSL) use as shorter pulse time as 10-15seconds, thus further decreasing the energy output for a given effect without the collateral tissue damage.[3] FSL first became available for refractive surgery in 2001. The flaps produced by FSL were more reproducible, uniform, perfectly centred, closer to the intended thickness and provided greater safety profiles as compared with manual keratomes.[4] Therefore, FSL-assisted surgery proved to be more precise and accurate in terms of producing predictable anterior capsulotomy that led to desired positioning of intra-ocular lens.[4] There were certain reports that showed higher rate of anterior capsule tear with the use of FSL as compared with conventional CCC.

The current study was conducted to critically analyse and compare various characteristics of capsulotomy using this new laser platform and see its added benefits, if any, over the conventional technique in a meta-analysis approach.

Materials and Methods

This meta-analysis was conducted between February

Department of Ophthalmology, Allama Iqbal Medical College, Jinnah Hospital, Lahore, Pakistan.

Correspondence: Muhammad Hassaan Ali. Email: mhassaanali@hotmail.com

2010 and November 2014. Literature search on Google Scholar, PubMed, Excerpta Medica database (EMBASE) and the Cochrane Library database was conducted using certain key words for the articles published during the above mentioned period. References of all the potentially relevant articles were manually searched to identify the searches not available electronically.

Randomised controlled trials (RCTs) and non-randomised controlled trials (non-RCTs) that compared FSL capsulotomy versus manual CCC morphology (diameter, circularity, complications, etc.) were included. Case reports, case series, editorials and non-systematic reviews were excluded (Table-1).

Three researchers independently conducted the literature searches keeping in view the selection criteria and filled their results in a proforma making note of first author of the study, year of publication, type of study and the number of patients in the study. Only full text articles were included in the meta-analysis.

Quality assessment of the retrieved articles was done by means of Downs and Black checklist which was considered to be valid and reliable for critically evaluating the RCTs and non-RCTs5.

The data of both FSL-assisted anterior capsulotomy and the manual CCC on diameter, circularity and the rate of anterior capsule tear were aggregated by the means and standard deviation. After combining the data, mean difference (MD) between groups, odds ratio (OR) and 95% confidence interval (CI) were calculated between the two groups. Chi-square and I2tests were used to assess the heterogeneity of the studies.[6] The studies in our meta-analysis differed in the design and FSL platform which was the potential source of the heterogeneity between the studies.[7] All of the analyses were performed using SPSS 20. P<0.05 was considered statistically significant.

Results

Of the 423 articles found, 348(82.3%) remained after removing duplicate studies. Out of them, only 29(8.3%) full text articles were available, and of them only 10(34.5%) met the inclusion criteria. Of the 2(20%) studies on same patients, 1(50%) was included. Moreover, there were 3(30%) RCTs and 7(70%) non-RCTs. Our meta-analysis was based on a total of 2,882 eyes, of which 1,498(51.97%) underwent FSL capsulotomy and 1,384(48.02%) underwent manual CCC. Also, 5(50%) studies reported diameter, 5(50%) reported circularity of the capsulotomy, 6(60%) reported the rate of the anterior capsule tear (complication) whereas 4(40%) did not mention any of

Table-1: Inclusion and Exclusion Criteria for selection of studies for this meta-analysis.

Inclusion Criteria	Exclusion Criteria
◆ Randomised and Non-Randomised Controlled trials (RCTs and Non-RCTs) that compared FSL capsulotomy versus manual CCC morphology (diameter, circularity, complications etc.)	◆ Case reports ◆ Case series ◆ Editorials ◆ Non-systematic reviews

FSL: Femtosecond lasers
CCC: Continuous curvilinear capsulorrhexis.

Table-2: Characteristics of Studies Included in This Meta-Analysis.

Study (author, year)	Country	Design	No. of Cases (n)		Diameter		Circularity		Tears	
			FSL	CCC	FSL	CCC	FSL	CCC	FSL	CCC
Schultz T, 2014[16]	Germany	Case control	50	50	0.99±0.03	0.98±0.34	0.95±0.02	0.81±0.07	-	-
Abell RG, 2014[8]	Australia	Case control	804	822	-	-	-	-	15	1
Abell RG, 2013[18]	Australia	Case control	151	50	-	-	-	-	0	0
Reddy KP, 2013[23]	Germany	RCT	56	63	1.02 ± 0.05	0.93 ± 0.09	0.97 ± 0.02	0.92 ± 0.05	1	1
Conrad-Hengerer I, 2013[20]	Germany	RCT	75	75	-	-	-	-	0	1
Abell R, 2012[18]	Australia	Case control	200	200	-	-	-	-	1	1
Nagy ZZ, 2011[10]	Hungary	RCT	54	57	-	-	0.86±0.04	0.85±0.03	-	-
Kranitz K, 2011[22]	Hungary	Case control	20	20	1.01±0.15	1.04±0.42	0.86±0.01	0.83±0.02	-	-
Friedman NJ, 2011[15]	US	Case control	39	23	0.99±0.03	0.93±0.26	0.94±0.04	0.80±0.15	0	0
Tackman RN, 2011[14]	Mexico	Case control	49	24	0.97±0.18	0.92±0.53	-	-	-	-

FSL: Femtosecond laser capsulotomy
CCC: (Manual) continuous curvilinear capsulotomy
RCT: Randomised controlled trial.
US: United States

Table-3: Comparison of Diameter of Capsulotomy Between Femtosecond Capsulotomy and Manual CCC Groups.

Study	Femtosecond Assisted Capsulotomy Group			Manual CCC Group			Mean Deviation
	Total	Mean	SD	Total	Mean	SD	
Tackman RN 2011[14]	49	0.97	0.18	24	0.92	0.53	0.05
Kranitz K 2011[22]	20	1.01	0.15	20	1.04	0.42	-0.03
Friedman NJ 2011[15]	39	0.99	0.03	23	0.93	0.26	0.06
Reddy KP 2013[23]	56	1.02	0.05	63	0.93	0.90	0.09
Schultz T 2014[16]	50	0.99	0.03	50	0.98	0.34	0.01
Total	214			180			0.03

Heterogeneity: I2=0, tau2 = 0, p =0.8976
CCC: (Manual) continuous curvilinear capsulotomy
SD: Standard deviation.

Table-4: Comparison of Circularity Between Femtosecond Capsulotomy and Manual CCC Groups.

Study	Femtosecond Assisted Capsulotomy			Manual CCC			Mean Deviation
	Total	Mean	SD	Total	Mean	SD	
Case Control Studies							
Friedman NJ 2011[15]	39	0.94	0.04	23	0.80	0.15	0.14
Kranitz K 2011[22]	20	0.86	0.01	20	0.83	0.02	0.03
Schultz T 2014[16]	50	0.95	0.02	50	0.81	0.07	0.14
Subtotal	109			93			0.10
Heterogeneity: $I^2 = 97.8\%$, $tau^2 = 0.0054$, $p < 0.0001$							
Randomised Controlled Trials							
Nagy ZZ 2011[10]	54	0.88	0.04	57	0.85	0.03	0.03
Reddy KP 2013[23]	56	0.97	0.02	50	0.81	0.07	0.14
Subtotal	110			107			0.08
Heterogeneity: $I^2 = 91.4\%$, $tau^2 = 0.0012$, $p < 0.0001$							
Total	219			200			0.09
Heterogeneity: $I^2 = 95.4\%$, $tau^2 = 0.00189$, $p < 0.0001$							

CCC: (Manual) continuous curvilinear capsulotomy
SD: Standard deviation.

Table-5: Comparison of anterior capsule tears Between Femtosecond Capsulotomy and Manual CCC Groups.

Study	Femtosecond Assisted Capsulotomy		Manual CCC		Odds Ratio
	Tears	Total Cases	Tears	Total Cases	
Case Control Studies					
Friedman NJ 2011[15]	0	39	0	23	0.59
Abell R 2013[18]	1	200	1	200	1.00
Abell RG 2013[18]	0	151	0	50	0.33
Abell RG 2014[8]	15	804	1	822	15.61
Sub-total	16	1194	2	1095	1.84
Heterogeneity: $I^2 = 56.1\%$, $tau^2 = 2.994$, $p = 0.0773$					
Randomised Controlled Trials					
Reddy KP 2013[23]	1	56	1	63	1.13
Conrad-Hengerer I 2013[20]	0	75	1	75	0.33
Sub-total	1	131	2	138	0.66
Heterogeneity: $I^2 = 0\%$, $tau^2 = 0$, $p = 0.5504$					
Total	17	1325	4	1233	1.40
Heterogeneity: $I^2 = 42.2\%$, $tau^2 = 1.667$, $p = 0.1236$					

CCC: (Manual) continuous curvilinear capsulotomy.

the complications (Table-2).

Statistically, there was no difference between FSL and CCC groups as far as diameter of the capsulotomy was concerned (MD=0.03; 95% CI = -0.02 to 0.08, p=0.29). There was low heterogeneity in studies for this parameter (I2=0, tau2 = 0, p =0.8976) (Table-3).

Furthermore, 5(50%) studies provided data for comparison of circularity of capsulotomy. There was statistically significant difference in the circularity of capsulotomy between the two groups (MD= 0.09; 95% CI= 0.04 to 0.11, p<0.001). There was high heterogeneity in studies for this parameter (I2 =95.4%, tau2 = 0.00189, p<0.0001). No statistically significant difference (p=0.61) was observed between RCTs and case-control studies despite high heterogeneity (I2 = 91.4% and 97.8%) (Table-4).

The rate of anterior capsule tears was reported in 6(60%) studies. Tears of anterior capsule were observed in 17(1.3%) out of 1,325 eyes in the femtosecond group and in 4(0.32%) out of 1,233 eyes in the conventional group. However, no statistically significant difference was observed between FSL and the manual group (OR=1.40; 95% CI = 0.26 to 6.82, p=0.68). Moderate heterogeneity was identified in the analysis (I2 =42.2%, tau2 =1.667, p = 0.1236). The case-control studies showed moderate heterogeneity than lower heterogeneity of RCTs (I2= 56.1% versus 0%) (Table-5).

Discussion

Femtosecond laser is able to create precise, customisable incision in the ocular tissue without causing any collateral damage.[8,9] The results of the FSL application in the cataract surgery are promising for more than 4 years.[10] Recently, one study found higher rate of anterior capsule tear in FSL capsulotomy.[6] Therefore, we performed this meta-analysis to compare the various characteristics of femtosecond laser assisted capsulotomy with the conventional manual CCC. We compared diameter, circularity and rate of anterior capsule tears with these techniques.

A precise and well-performed capsulorrhexis can improve the steps of the cataract extraction and can reduce the complications.[11] Variation in the size of the capsulorrhexis can result in aberrant IOL positions.[12] The size and the shape of the capsulorrhexis are the key determinants in both the position and performance of the IOL. A 360-degree overlapping edge is thought to be an important factor for the standardising refractive results by keeping the IOL in desired centred position. As a result of this overlapping edge of capsulorrhexis, not only the horizontal/vertical but also antero/posterior positions of the IOL are set.[12] As data came from (dmajor/horizontal+ dminor/vertical)/2, there was a little to perform for seasoned surgeons with capsulorrhexis in order to attain the size and shape as desired. The contour of the capsulorrhexis was ellipsoid and asymmetric in manual CCC.[13] Thus, the mean deviation was 0.18±0.17 mm and less in buttons created with FSL, compared with the mean deviation of 0.53±0.54 mm among buttons constructed using manual CCC in Tackman's study.[14]

In another study by Friedman, it was shown that the mean deviation from the intended diameter of capsule button was 29±26µm using FSL and 337±258µm using manual CCC.[15] So it was concluded that the overlap of the capsule on the IOL was better in FSL group than in the manual CCC group. The difference was statistically significant (standardised mean difference (SMD) = -1.29, p<0.0001).

Circularity is the parameter used to determine the regularity and roundness of the shape of the capsulotomy. In a study by Schultz et al.,[16] the capsule disc samples of the FSL group were closer to an ideal roundness of 1.0, resembling a perfectly round circle. In this study, very little variation was observed in the circularity in the FSL group. Almost similar results were reported by a study conducted by Palanker.[17] A vital aspect of the FSL platform is the integrated optical coherence tomography (OCT) that performs three-dimensional (3-D) mapping of the cornea and lens. This system automatically aligns all the patterns of incision in 3-D to follow the contour of ocular structures, thus minimising the degree of required cutting overlaps and therefore optimises the safety zone distances. This vital feature assures safe, precise, and reproducible placement of the cutting patterns within the target tissue. Thus, FSL may provide a more circular, stronger, precisely planned and executed capsulorrhexis which could offer more control over capsulotomy and results in more accurate refractive outcome than the manual CCC.

Anterior tear of the capsule is a significant complication in the cataract surgery. Radial tear may in turn lead to a series of complications such as the zonular rupture, posterior capsule tear, and vitreous presentation, insufficient capsular support for the IOL implantation or even nucleus drop during phacoemulsification. Fifteen cases of anterior capsule tear were reported by Abell,[18] seven anterior capsule tears extended to the posterior capsule and required sulcus IOL implantation. Out of these, there were five

patients who had no vitreous, whereas the remaining two patients underwent anterior and posterior vitrectomy. Early experiences by Roberts et al.[19] demonstrated that the anterior capsule tear rate was 4%, and with experience, it decreased to 0.31% which showed that there was a clear learning curve associated with the use of FSL cataract surgery. Studies showed that with FSL little manual manipulation was required in almost 96% cases while removing the capsule, showing that a free-floating capsule was generated by FSL.[20] This meta-analysis showed that there was no statistically significant difference between the tears from FSL and manual CCC groups. With the use of scanning electron microscope, compared with the smooth edge of the manual CCC capsule disk, the FSL capsule disk edge has a wave-like structure or postage-stamp perforations which may lead to an increased rate of anterior capsule tears.[21] However, this has yet to be proved statistically.

According to our results, FSL-assisted capsulotomy showed better results statistically as compared with manual CCC in terms of circularity of capsulotomy.[22] However, as far as the diameter of capsulotomy and rate of anterior capsule tears are concerned, the difference in FSL-assisted reproducible capsulotomy with FSL gives modern cataract surgeons more confidence, especially while implanting high-end intraocular lenses.[23-26]

The current study had some limitations as well. All the studies in this meta-analysis excluded patients with ocular diseases and other systemic morbidities and only included the patients with good post-operative visual outcome. So, the results of this meta-analysis are only applicable for the patients having good prognostic factor for the visual outcome. Besides, we evaluated the studies that used various laser platforms. Further studies should be done by limiting the laser platforms to avoid bias due to different measurement techniques.

Conclusion

FSL performed capsulotomy with more precision and higher reliability than the manual CCC, but advantages of perfectly circular capsulotomy achieved through FSL should always be weighed against high cost of the procedure as well as a learning curve at least in the early period of learning this new surgical technique.

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Conflict of Interest: None.

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