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Clinical performance and *Willingness To Pay* for soft toric contact lenses in low and moderate astigmats

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A R T I C L E I N F O

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A B S T R A C T

Purpose: To determine clinical performance and the 'Willingness To Pay' for toric vs. spherical soft contact lenses in an astigmatic population.

Methods: In the clinical study, subjects with binocular low to moderate astigmatism (-0.75DC to −1.50DC) wore pairs of soft toric (Biofinity toric) and spherical (Biofinity) contact lenses in random sequence. Visual acuity (high and low contrast, monocular and binocular), subjective comfort and subjective vision were recorded. In the economics study, first subjects who had participated in the clinical study were presented with a series of randomised economic scenarios in order to determine their Willingness To Pay a premium (i.e. an increase) for toric lenses. Then, a similar set of scenarios were presented to a much larger group of online respondents and again, Willingness To Pay was established.

Results: For the four measures of visual acuity, the Biofinity toric lens out-performed the Biofinity spherical lens by 0.6 to 1.1 lines.. Subjective vision performance was statistically significantly better with the toric lens for the distance task only. Comfort scores were not significantly different. Similar findings for Willingness To Pay were established for the clinical subjects and for the online respondents. The Willingness To Pay *premium* (additional fee) for a monthly supply of toric lenses (over spherical lenses) was between £13 and £16, if a toric lens provides better vision and similar comfort, as shown in the clinical study.

Conclusion: Consumers are willing to pay a monthly premium of around 50% to benefit from the typical experience of better vision and similar comfort for toric vs. spherical lenses. The level of additional cost for toric lenses compared to their spherical equivalents is less than this in the market, so eye care professionals should consider that toric lenses are delivering a greater clinical return than anticipated by wearers for the relatively small increase in price.

1. Introduction

1.1. Market background

Soft toric contact lenses represent a mainstay of the management of refractive astigmatism in modern optometry. Previous work with a large UK cohort reported that around 45% of people require an astigmatic correction of 0.75DC or greater in one or both eyes [1] and in many markets the fitting of soft toric lens designs (when only single vision corrections are considered) approximates to this proportion [2–4]. However, this is not universal. In recent work, Morgan and Efron [3] noted a much lower fitting rate for soft toric contact lenses in Czechia, Japan, Lithuania, Russia and Taiwan compared to many other markets. The similarity of ethnicities and other demographics between Czechia, Lithuania and Russia compared with other European markets studied in the same work suggests other factors must account for this discrepancy. Similarly, ethnicity-related corneal features do not appear to account for reduced toric lens fitting in Japan and Taiwan on the basis that mean refractive and keratometric astigmatism appears to be as least as great in Japanese people [5] as in other ethnic groups [6], and the the magnitude of refractive astigmatism is similar for Chinese vs. Caucasian populations [6]. One barrier to the use of soft toric lenses could be their

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higher cost compared to soft spherical contact lenses [7], affecting practitioner prescribing and patient purchasing decisions.

1.2. Willingness to pay

One method of assessing the potential for the price of a contact lens or any other product to represent a barrier to its use is to measure the *Willingness To Pay* of a consumer for that product. From the perspective of an ECP, understanding Willingness To Pay is potentially a useful method of quantifying in monetary terms the visual improvement brought about by contact lenses or spectacles and for determining appropriate product pricing. This could include determining the Willingness To Pay for the convenience in presbyopia of a single pair of progressive spectacles compared to two single-vision (distance and near) spectacles or - as is the focus of this paper - the Willingness to Pay in astigmats for soft toric lenses compared with their spherical equivalents. For a manufacturer, this metric is also helpful for product pricing. For example, if a manufacturer perceives consumer Willingness To Pay to be lower than its 'true' level when setting its prices, it may fail to capture all the potential profit, or producer surplus, in the market. On the other hand, If the price is set too high, the resulting decrease in quantity demanded could result in the product failing to take a foothold in the market. Moreover, in markets with close substitutes such as different designs of contact lenses, understanding the values that consumers place on different attributes of these competing goods can also provide important feedback for marketing and other strategic decisions by ECPs and manufacturers [8,9].

A small number of papers have investigated the Willingness To Pay of consumers for spectacles, particularly for citizens in developing nations [10–13]. Typically, this research has explored the Willingness To Pay for spectacles to determine whether an affordable and financially sustainable spectacle supply could be established in areas where existing spectacle provision levels are inadequate. Within this research area, various Willingness To Pay elicitation mechanisms are used. For example, Laviers et al. examined the Willingness To Pay of adults in Zanzibar for spectacles to correct for presbyopia [11]. Research teams visited adults aged 40 years or over in clusters across the country to measure visual function followed by interviews with 323 participants regarding the amount that they were willing to pay for corrective spectacles using an open-ended elicitation method. Du Toit and colleagues surveyed individuals in Fiji to ascertain whether any household member currently or previously wore spectacles and to elicit Willingness To Pay from individuals with compromised near and distance vision [14]. This was achieved by using a modified five-choice payment card technique in which respondents were asked to select a single price range – from the existing lowest price for custom-made spectacles to a researcher-determined upper bound – containing the amount that they would be willing to pay for spectacles if they were required to see clearly. Burnett and co-workers conducted vision screenings for children in Cambodia to identify those with impaired vision and then explored the Willingness To Pay of parents for custom-made spectacles by employing a binary-with-follow-up method [13]. Finally, Sarker et al. conducted exit interviews with 558 patients from five selected eyecare facilities in Bangladesh to elicit Willingness To Pay for spectacles using the contingent valuation method [15]. Despite this range of Willingness To Pay reports for spectacle provision, this technique does not appear to have been previously used to explore contact lenses.

1.3. Soft torics vs. Soft spheres for refractive correction

Compared to soft spherical lenses, soft toric lenses improve visual performance in people with astigmatism, including at low and moderate levels [16–18] but appear to not be universally prescribed even when they are apparently the best option. In part this may be due to the following ECP beliefs:

- Extra 'chair time' is required for toric lens fitting and/or aftercare.
- Soft toric lenses are less comfortable than their spherical equivalents.
- Any improvement in visual performance is not merited by the increased cost of soft toric contact lenses.

The first two beliefs are not generally supported by the literature. For example, recent evidence suggests a similar chair time requirement for toric and spherical soft lenses [19]. Issues around comfort are more complex and certainly worthy of consideration given that contact lens discomfort is considered to be the primary reason for the cessation of contact lens wear [20]. There is some literature to support the notion of reduced comfort with soft toric contact lenses [21,22] and at least one report which refutes this [23], but overall, the data supporting this sentiment are not strong and may not relate to current contact lens designs.

The final belief posits that soft toric lenses are overpriced given their level of visual benefit so determining Willingness To Pay for soft toric contact lenses is of potential value to both ECPs and manufacturers. The current project sought to address this area, using a novel approach. As information regarding consumer preferences for the attributes of different contact lens types is not generally available *a priori* (as would normally be the case in Willingness To Pay experiments), a two part experiment was designed. The first part was a clinical study to carefully characterise the difference in clinical performance (measured visual acuity and subjective vision and comfort) between soft spherical and soft toric lenses in low and moderate astigmats, and then to assess the Willingness To Pay a premium for soft toric lenses. In part two, after an economic analysis was conducted on the clinical participants, findings from the clinical study were presented to a large online cohort of contact lens-wearing astigmats, with the large number of participants allowing for more sophisticated Willingness To Pay modelling and robust conclusions.

2. Methods

2.1. Clinical study

The clinical study component of this work was a randomised, participant-masked, crossover, non-dispensing study which explored visual acuity, subjective vision and subjective comfort in a group of low and moderate astigmats who wore soft spherical and toric contact lenses. A power analysis to determine the sample size required for this study using data from previous, similar work demonstrated that a power of at least 0.8 for subjective vision would be achieved with 27 completing participants, based on an standard deviation of intra-participant differences of 18 units on 100 point visual analog scale, an assumed meaningful difference of 10 units, a two-tailed paired analysis and an alpha of 0.05.

Participants were recruited by email and social media. Subjects needed to be aged 18–45 years, have refractive astigmatism in both eyes of between −0.75DC and −1.50DC with a spherical refractive correction of −0.50DS to −6.50DC and to have no noteworthy ophthalmic history (e.g. corneal distortion including keratoconus, aphakia, refractive surgery or a condition which would contraindicate contact lens wear in the opinion of the examining investigator). Subjects provided written consent for their participation and the study conformed to the tenets of the Declaration of Helsinki.

This was a single visit study. The following baseline assessments were initially conducted: participant medical history, refraction, visual acuity and slit lamp biomicroscopy. Participants meeting the inclusion and exclusion criteria were fitted with commercially-available Biofinity and Biofinity toric contact lenses (CooperVision Inc, both comfilcon A, 'the study lenses')), used in random sequence. In the event of a subject attending the first study visit with no prior contact lens experience, clariti 1 day (CooperVision Inc, somofilcon A) lenses were fitted and worn for one hour to allow for some adaptation experience prior to the study lenses being worn. Notwithstanding the fact that the two study lenses were worn in random sequence, it was considered that this adaptational step would act to minimise the response to the first study lens being influenced by a lack of prior contact lens wear.

The first lens pair of study lenses was applied and allowed to settle for 10 min. The following measures were then performed:

- Lens fit assessment.
- Lens rotation assessment (for the toric lens).
- High and low contrast distance logMAR visual acuity.

Subjects then performed a range of tasks: mobile phone use for two minutes (a near task), browsing web pages on a desktop computer for two minutes (an intermediate task) and walking around the building for five minutes whilst viewing signage including a car number plate at about 20 m (a distance task). Subjects then provided a score from 0 to 100 visual analogue scales (with written descriptors every 20 units with increasing values representing better satisfaction as previously presented [24]) for vision quality and stability for each of these three tasks, and for ocular comfort. After the computer task, participants also completed the Computer Vision Syndrome Questionnaire (CVS-Q) [25].

On completion of these questionnaires, the first pair of study lenses was removed, the second pair applied and the experimental process repeated.

Data were analysed using JMP 16 (SAS Institute Inc., Cary, North Carolina). High and low contrast visual acuity and subjective scores were evaluated for the two study lenses and compared using linear regression models with lens as a fixed factor and participant ID as a random factor.

2.2. *Economics study*

When designing this work, it was recognised that in general, large numbers of participants are required to participate in Willingness To Pay evaluations in order to facilitate complex modelling. A sample which is too small has the potential for a disproportionate number of individuals to be unrepresentative of the population as a whole, skewing any results. On the other hand, it is not feasible to fit hundreds of people with study contact lenses due to logistical, clinical and cost reasons. In this work, therefore, two online survey instruments were developed using Qualtrics Inc. software. The first survey – termed the 'laboratory component' – was administered immediately following the clinical study visit described in the above section. This allowed for feedback on the vision and comfort of the two lens types worn to be collected. The second survey - the 'online component' - was conducted on a much larger group of participants to whom the key data from the laboratory component were described.

2.2.1. *The laboratory component*

Having completed the clinical study, participants participated in the laboratory component of the economics work, first providing their assessment for vision and comfort for the two pairs of study lenses just worn They reported the subjective response to their experience with the toric lens on a five-point Likert scale, with possible answers ranging from 'much worse than spherical lenses' to 'much better than spherical lenses', with the option of a neutral ('about the same') midpoint.

Subjects were then asked a series of price questions around contact lens use. After technical terminology about contact lenses was carefully explained, participants were told that, while both spherical and toric lenses are available as daily disposable and reusable products, for the purposes of this survey, they should consider how much they would pay for two boxes of 30 daily disposable lenses (i.e., enough lenses for one month of full-time wear). Those not currently wearing daily disposable spherical lenses were taken sequentially through a series of price options to solicit the approximate amount they would pay for such lenses.

The next part of the laboratory component was a stated preference Discrete Choice Experiment, a commonly-deployed approach for the estimation of Willingness To Pay [26,27]. This provided a pivot design with variation in three attributes (vision, comfort, and a price premium). Under each scenario, participants were given vision and comfort ratings for toric lenses compared to spherical lenses, and asked whether they would pay a given premium (over the stated amount that they pay or would pay for spherical lenses) for two boxes of daily disposable toric lenses that correct for astigmatism. As is typical in such experiments, participants were informed that the choices they were about to make were hypothetical and they would not be asked for any money during the experiment. However, they were told to imagine a realistic real-world situation where they would, every month, either need to use their disposable income (cash they have on hand) or use a debit or credit card to pay. This strategy is a form of 'cheap talk' often used in experiments which elicit Willingness To Pay measures as a means to mitigate hypothetical bias and uncertainty in individuals' responses [28,29].

The first question in the Discrete Choice Experiment was a baseline scenario using the vision and comfort ratings *that the participant provided earlier in the survey* (see Table 4). For example, suppose that a participant stated that they currently paid £25 for two boxes of daily disposable spherical lenses and that the participant reported 'better' vision and 'about the same' comfort for their toric lens experience vs. their spherical lens experience. Such a participant would then be presented with the following 'baseline' scenario:

> "Compared to spherical lenses, you rated changes in your vision clarity and comfort level with toric lenses as follows:
> Vision: **Better**.
> Comfort: **About the same**.
> Compared to the **£25** price that you said you would pay for two boxes of 30 daily disposable spherical lenses, would you pay an additional **£x** for two boxes of **daily disposable toric lenses that correct for astigmatism**.".

The stated price premium, £x, was randomly assigned from a researcher-generated range (from £0.50 to £10). Possible responses were "yes", "no", and "I don't know".

Respondents were then provided with three additional *hypothetical* scenarios describing different results for vision and comfort, pivoting from the baseline conditions just answered. Subjects were again asked, based on these attribute levels, if they would be willing to pay a stated premium for toric lenses that correct for astigmatism, over spherical lenses. These Discrete Choice Experiment scenarios used the same five-point Likert scale for vision and comfort (ranging from much worse to much better) presented to participants earlier in the survey. Under each follow-up scenario, participants randomly received either the same or improved vision rating and the same or worse comfort rating. Under each scenario, the participant was asked whether they would be willing to pay a randomly assigned price premium.

Finally, participant sociodemographic details were solicited.

2.2.2. *The online component*

The second part of the economics work involved another online survey, also using the Qualtrics survey engine. Qualtrics Inc. offer a service where they construct bespoke research panels of respondents; in this case 413 UK contact lens wearers of whom 264 were astigmatic. Most of the group (63%) were full time contact lens wearers (defined as 5–7 times per week) with 27% wearing contact lenses 3–4 times per week, and the remainder less frequently.

Before respondents were asked any questions, important terminology used throughout the survey was carefully explained (e.g. *astigmatism*, *spherical contact lenses*, and *toric contact lenses*).

As in the laboratory component, the survey first determined the current monthly expenditure for daily disposable spherical lenses (actual or modelled) from which any premium could be determined. Respondents were then presented with the Discrete Choice Experiment component of the survey which mirrored the design used in the laboratory component with a baseline and three stated preference scenarios. The key aspect of this part of the work was that the online survey respondents were not fitted with any contact lenses, so the vision and comfort findings of the clinical study were presented to the participant group as follows:

> "To help understand better any potential differences between wearing spherical lenses and toric lenses, in the Fall of 2020 and Spring of 2021, a clinical trial was conducted at the University of Manchester's Division of Pharmacy and Optometry. In this trial, 25 individuals (subjects) were fitted with both spherical and toric lenses and then asked to rank both lens types in terms of vision clarity and comfort."

Respondents were then informed that after being fitted with both types of lenses, 25 participants in the clinical trial were asked to rank the differences they experienced with toric lenses compared to spherical lenses with respect to vision and comfort. They were shown the question and five-point Likert scale used (ranging from "much worse than spherical lenses" to "much better than spherical lenses") and presented with the average responses (see *Results* section):

> "On average, the subjects ranked **vision clarity** with toric lenses compared to spherical lenses as: **Better than spherical lenses**.
> On average, the subjects ranked **comfort** with toric lenses compared to spherical lenses as: **About the same as spherical lenses"**.

The first Discrete Choice Experiment question presented was a baseline scenario using the average vision and comfort ratings from the clinical trial and the respondent-specific stated price or willingness to pay price for spherical lenses. Respondents were asked, based on these attribute levels, if they would be willing to pay a stated premium for toric lenses that correct for astigmatism, over spherical lenses. As in the laboratory component, the stated price premium for toric lenses, **£x**,was randomly assigned from a researcher-generated range (from £0.50 to £20). The possible responses were "yes", "no", and "I don't know".

The next three Discrete Choice Experiment scenarios presented to respondents pivoted from the average baseline ratings from the laboratory component using the same five-point Likert scale for vision and comfort. Under each follow-up scenario, participants randomly received either the same or improved vision rating and either the same or worse comfort rating. Full modelling was conducted only for the sub-set of the online panel who were astigmatic.

Finally, participant sociodemographic details were once again also solicited.

2.2.3. *Data modelling*

Consumer preferences for toric and spherical lenses were modelled in a random utility framework. Random utility theory suggests that the utility consumers derive from a product is a function of the product's attributes [30]. Subject to a budget constraint, consumers choose the set of attributes that maximise their utility. Consumers are hypothesised to maximise utility by making tradeoffs between the attributes of contact lenses. Assuming a linear function, consumer utility can be expressed as

$$U_{ij} = \beta X_{ijk} + \varepsilon_{ij}$$

where U_{ij} represents the ith consumer's utility from contact lens, j, X_{ijk} represents the kth attribute for contact lens j for consumer i, β is a vector of coefficients that are homogenous across consumers, and ε_{ij} is assumed to be an *i.i.d.* type I extreme value (EV1) distributed error term. Then, a consumer's utility associated with the alternative j can be written as

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

where V_{ij} represents the utility determined by contact lens attributes and ε_{ij} is a stochastic element. The probability that the alternative j is preferred by consumer i is expressed as

$$P_{ij} = prob(V_{ij} + \varepsilon_{ij} > V_{is} + \varepsilon_{is}; j \in T_i, \forall s \neq j)$$

where $T_i = \{t_1, t_2,..t_T\}$ represents the choice occasions faced by respondent i. In this design, with consumers facing two alternatives (toric or disposable lenses), the probability of consumer i choosing alternative j can be expressed by the binary logit model

$$P_{ij} = \frac{e^{V_{ij}}}{\sum_{j=1}^{J} e^{V_{ik}}}$$

In the binary choice model, the assumption is that all consumers have the same preferences, which is likely to be violated. This assumption is relaxed under the Random Parameter Logit model. This model allows consumer preferences to be heterogeneous across respondents [31]. In the Random Parameter Logit context, the deterministic component of the utility function takes the following term

$$V'_{ij} = (\beta' + \sigma_i) X_{ijk} + \varepsilon_{ij}$$

where β' is a vector of attribute coefficients and σ_i is individual-specific deviation from the mean β'. When a Random Parameter Logit is assumed, the unconditional choice probability is the integral of the logit formula over all possible values of random parameters

$$P_{ij} = \int \frac{e^{V'_{ij}}}{\sum_{k=1}^{K} e^{V'_{ik}}} g(\theta) d\beta$$

where $g(\theta)$ denotes the joint elasticity of random parameters. Next, the probability of consumer i's choices over $T_i = \{t_1, t_2,..t_T\}$ choice occasions, $P_{i_{(t_1, t_2, \ldots, t_T)}}$, can be expressed as

$$P_{ij_{(t_1,\ t_2,\ldots,t_T)}} = \int \prod_{t=1}^{T} \left[\frac{e^{V'_{ij}}}{\sum_{k=1}^{K} e^{V'_{ik}}} \right] g(\theta) d\beta$$

In estimation, consumer preferences are analysed using both binary logit and Random Parameter Logit models.

3. Results

3.1. *Clinical study*

Twenty seven participants (14 females and 13 males, with a mean ± standard deviation age of 28.7 ± 7.9 years) successfully completed the study. The spherical component of their refractive error was −3.36 ± 1.69DS. Fourteen of the participants presented with a refractive cylindrical component in their right eye of −0.75 DC, six with −1.00DC, one with −1.25DC and six participants with −1.50DC.

All final lens fits were considered acceptable in terms of centration, movement and coverage, and all end-of-visit biomicroscopy findings were within clinical normal limits. For the Biofinity toric lens, 96% of lenses settled within 10° of the ideal orientation position.

3.1.1. *Visual acuity*

Mean low and high contrast visual acuity scores are presented in Table 1. All measures were statistically significantly better with the Biofinity toric lens, with the magnitude of improvement between 0.6 and 1.1 lines.

Table 1
LogMAR visual acuity (n = 27).

	Biofinity	Biofinity toric	Statistical summary
Right high contrast	0.00 ± 0.09	−0.08 ± 0.08	F = 17.5, p = 0.0003
Right low contrast	+0.29 ± 0.11	+0.18 ± 0.12	F = 34.90, p < 0.0001
Binocular high contrast	−0.07 ± 0.06	−0.13 ± 0.06	F = 17.4, p = 0.0003
Binocular low contrast	+0.20 ± 0.08	+0.11 ± 0.08	F = 33.2, p < 0.0001

Table 2
Subjective scores (n = 27).

Task	Parameter	Biofinity	Biofinity toric	Statistical summary
Mobile phone use	Quality of vision	89.6 ± 1.5	89.8 ± 11.0	F = 0.0, p = 0.93
	Vision stability	85.3 ± 11.6	88.4 ± 10.7	F = 1.8, p = 0.20
Desktop web browsing	Quality of vision	85.2 ± 14.4	87.8 ± 15.8	F = 0.7, p = 0.39
	Vision stability	83.4 ± 15.1	87.8 ± 12.0	F = 3.6, p = 0.07
Walking	Quality of vision	78.1 ± 18.6	89.9 ± 13.5	F = 11.5, p = 0.002
	Vision stability	82.6 ± 15.2	88.2 ± 14.8	F = 4.4, p = 0.05

Table 3
Sociodemographic descriptive statistics for the laboratory component (n = 25).

Variable	Description	Mean	Min	Max
Sex	Male = 1	0.44	0.00	1.00
Age	In Years	27.72	18.00	41.00
Income	Annual Reported Subject Income (£)	18,562.50	15,000.00	90,000.00
Employment	Employed Full Time = 1	0.52	0.00	1.00
Education	No High School = 1; High School = 2; College = 3; Higher-level Degree = 4	2.88	1.00	4.00

3.1.2. Subjective scores

All subjective scores for vision (Table 2) numerically favoured the Biofinity toric lens. Differences for the distance (walking) task were statistically significant, and the difference between the lenses for vision stability for the intermediate task (desktop web browsing) approached the p = 0.05 threshold. There was no difference between the two lenses for comfort (Biofinity: 79.8 ± 19.9, Biofinity toric: 81.6 ± 16.5, F = 0.2p = 0.68) or CVS-Q score (Biofinity: 3.0 ± 2.0, Biofinity toric: 2.7 ± 2.2, F = 0.7p = 0.40).

3.2. Economics study

3.2.1. The laboratory component

Twenty five participants from the clinical study participated in the first part of the economics study (Table 3).

A clear majority (80% vs. 12%) of participants reported that vision with the toric lens was 'better' or 'much better' than the spherical lens (Table 4) (chi-square = 12.6, p = 0.0004). Comfort preferences for the two lens types were similar (48% vs. 32%) (chi-square = 0.8, p = 0.37) (Table 4). A reasonable summary of these findings – used to later present the average performance of the toric and spherical lenses as part of the online component – was that toric lenses are 'better than spherical lenses' for vision and 'about the same as spherical lenses' for comfort.

The mean response across the entire laboratory sample (n = 25) for the price of a current monthly supply of daily disposable lenses (or their Willingness To Pay for the same) was £22.92, ranging from a low of £12.50 to a high of £37 (Table 5).

With 25 survey respondents answering four choice sets each (i.e. the baseline Discrete Choice Experiment scenario and the three follow-up scenarios), a binary logit with clustered standard errors was estimated (Table 6). The dependent variable, yes, takes on a value of 1 if the respondent is willing to pay the stated premium, and 0 otherwise. The five-level Likert scale variables for vision and comfort are converted to four dummy variables and measure perceptions about vision and comfort. With most of the participants from the clinical study rating the toric lens as 'better' or 'much better' for vision, dummy variables were created for the two levels of improved vision with the base case being the same or worse. Performance of the two lenses for comfort was similar, so dummy variables for 'worse' and 'much worse' comfort levels were created with 'better' or 'the same' comfort as the base case.

Table 4
Frequency responses for vision and comfort for toric lenses compared to spherical lenses (n = 25).

Attribute	Much worse	Worse	About the same	Better	Much better
Vision	0%	12%	8%	44%	36%
Comfort	4%	28%	20%	24%	24%

Table 5
Stated monthly price paid or Willingness to Pay for daily disposable spherical lenses in the laboratory component (n = 25).

Price	Observations	Mean	Min	Max
Monthly Price Paid	20	£24.4	£12.5	£37.0
Monthly Willingness to Pay	5	£19.0	£15.0	£30.0

The model is statistically significant ($p < 0.01$) and the McFadden's R^2 value suggests much of the variation in the dependent variable is captured by variation by the independent variables. In terms of the coefficients, the price coefficient is negative and statistically significant – so, as the price increases, participants are less willing to pay a premium for toric lenses. The other attribute coefficients are statistically different from zero except for better vision. In terms of vision ratings, participants rating toric lens vision as 'much better than spherical', were more willing to pay a premium for toric lenses, compared to those that rate them the same (or worse). The statistically insignificant result on the better vision variable indicates that those who rate toric lenses as better than spherical are not willing to pay any additional premium relative to those who rate toric lenses as the same (or worse).

The negative sign on the comfort coefficients means that, as comfort is rated 'worse' or 'much worse', participants are less willing to pay a premium for toric lenses. Further, the coefficient on 'much worse' is more negative than the coefficient on 'worse' comfort, but the difference is not statistically different from zero.

Using the coefficients from the binary logit model, mean Willingness To Pay a premium for daily disposable toric lenses was estimated under two different scenarios. Under the first scenario, if respondents rate toric lenses as providing much better vision than spherical lenses (with comfort held constant), the Willingness To Pay a monthly premium is £13.33 [£4.78, £21.89]. Further, if respondents rate toric lenses as providing much better vision but worse comfort, the willingness to pay a premium falls to £4.10 [£-0.69, £8.88]. While the 95% confidence interval includes zero, this willingness to pay estimate is statistically significant at the 90% confidence level (Table 7).

3.2.2. The online component

Socioeconomic information for the participants in the online component is shown in Table 8.

Table 6
Binary logit model for the laboratory component (n = 25).

	Coefficient	Standard Error*	t-ratio
Constant	2.155	0.812	2.65
Price	−0.301	0.115	−2.63
Vision: better	0.541	0.834	0.65
Vision: much better	1.864	0.862	2.16
Comfort: worse	−2.784	0.788	−3.53
Comfort: much worse	−3.717	0.699	−5.31
Ending LL	−42.45		
Beginning LL	−69.13		
Model $\chi 2$	53.38		
McFadden's R^2	0.39		
Sample size	25		
Choices	4		

*Clustered Standard Errors.

Table 7
Willingness to Pay estimates for the laboratory component (n = 25).

Scenario	Willingness To Pay	SE	t-ratio	95% Confidence Intervals Lower Bound	Upper Bound
Much Better Vision	13.33	4.36	3.05	4.78	21.89
Much Better Vision + Worse Comfort	4.10	2.44	1.68	−0.69	8.88

Table 8
Sociodemographic descriptive Statistics for the online component (n = 413).

Variable	Description	Mean	Min	Max
Sex	Male = 1	0.38	0.00	1.00
Age	In Years	35.40	18.00	73.00
Income	Annual Reported Subject Income (£)	37,361.48	15,000.00	90,000.00
Employment	Employed Full Time = 1	0.68	0.00	1.00
Education	No High School = 1; High School = 2; College = 3; Higher-level Degree = 4	2.08	1.00	4.00

The average price across all respondents for a monthly supply of spherical lenses was £28.37 (Table 9).

The binary logit model is shown in Table 10. In this model the constant has a different interpretation. Since only two levels of the vision attribute are presented in the choice experiment, the constant captures the 'better' vision level. Three levels of the comfort attribute are presented to respondents: same, worse and much worse. The model is statistically significant ($p < 0.01$) with a lower McFadden's R^2 relative to the laboratory data model in Table 6.

The coefficients have the expected signs and all of the coefficients are statistically different from zero except for the much better vision coefficient. This is a different result from the laboratory where the participants were willing to pay more for much better vision relative to better vision. A similar blurring of the attribute levels occurs for the comfort variable where there is very little difference in the point estimates of the worse and much worse attribute levels. This means that respondents who were told that toric lens comfort levels are reported as either worse or much worse than that achieved with spherical levels are less likely to pay a premium for toric lenses.

Using results from the online survey data model, Willingness To Pay estimates under different comfort and vision rating scenarios from the are presented in Table 11. Overall, if respondents perceive toric lenses as providing improved vision (better or much better) and with comfort held constant, the Willingness To Pay a premium for toric lenses is £16.47 [£14.20, £18.74]. With better vision and worse comfort the Willingness To Pay falls to £11.51 [£8.64, £14.38].

Table 9
Monthly price paid or Willingness to Pay for daily disposable spherical lenses (online component) (n = 413).

Price	Observations	Mean	Min	Max
Monthly Price Paid	343	£29.7	£10.0	£50.0
Monthly Willingness to Pay	70	£21.9	£10.0	£40.0

Table 10
Binary logit model for the online component (n = 413).

	Coefficient	Standard Error*	t-ratio
Constant	2.222	0.156	14.23
Price	−0.135	0.012	−11.33
Vision: better	NA		
Vision: much better	0.065	0.167	0.39
Comfort: worse	−0.669	0.200	−3.35
Comfort: much worse	−0.634	0.206	−3.08
Ending LL	−531.93		
Beginning LL	−636.55		
Model χ^2	209.24		
McFadden's R^2	0.16		
Sample size	264		
Choices	4		

*Clustered Standard Errors.

Table 11
Willingness to Pay estimates for the online component using a binary logit model (n = 413).

Scenario	Willingness To Pay	SE	t-ratio	95% Confidence Intervals Lower Bound	Upper Bound
Better & Much Better Vision	16.47	1.16	14.21	14.20	18.74
Better Vision + Worse Comfort	11.51	1.46	7.86	8.64	14.38

Table 12
Random parameters logit model for the online component (n = 413).

	Coefficient	Standard Error*	t-ratio
Constant	2.336	0.162	14.40
Price	−0.151	0.011	−13.78
Vision: better	NA		
Vision: much better	0.053	0.145	0.37
Comfort: worse	−0.389	0.176	−2.21
Comfort: much worse	−0.421	0.169	−2.50
Ending LL	−499.38		
Beginning LL	−531.93		
Model χ^2	65.10		
McFadden's R^2	0.61		
Sample size	264		
Choices	4		

*Clustered standard errors.

With the much larger sample size from the online component, the survey data will support more complex econometric models that allow for preference heterogeneity. A random parameters logit model was estimated (i.e. simulated with 500 Halton draws) and the output shown in Table 12. The model outperforms the binary logit model with a lower AIC statistic (1014 in the random parameters logit vs 1079 in the fixed coefficient logit). All of the coefficients are estimated with a normal distribution except for price, which did not converge with a normal distribution (including a lack of preference heterogeneity over price). The model is similar to the online survey data binary logit model except that the comfort coefficients are about 50% lower. This indicates that accounting for preference heterogeneity, the point estimate of comfort is not as important to survey data consumers. The preference heterogeneity is considerable with standard deviations greater than the mean coefficients for each of the attributes.

The mean willingness to pay estimates appear in Table 13. The willingness to pay with better and much better vision is £15.42 [£13.86, £16.99]. With better vision but worse comfort the willingness to pay falls to £12.65 [£10.60, £14.69]. In contrast to the simpler statistical models, comfort has little effect on the willingness to pay a premium.

Table 13
Willingness to Pay estimates for the online component using a random parameters logit model (n = 413).

Scenario	Willingness To Pay	SE	t-ratio	95% Confidence Intervals Lower Bound	Upper Bound
Better & Much Better Vision	15.42	0.797	19.34	13.86	16.99
Better Vision + Worse Comfort	12.65	1.04	12.12	10.60	14.69

Specifically, willingness to pay a premium for toric lenses decreases by approximately £3 with toric lenses rated as having worse comfort levels. The decrease was approximately £9 and £5, respectively, in the binary logit models for laboratory and online survey data.

In summary, over three models, it was found that Willingness To Pay was of the same magnitude under two scenarios. When toric lenses provide better vision with similar comfort, the willingness to pay is between £13 and £16. If the toric lenses offer better vision but are less comfortable, willingness to pay decreases.

4. Discussion

4.1. Clinical study

The clinical part of this work was conducted successfully with no adverse events or discontinuations in the project. The recruited participant group was broadly representative of the contact lens wearing population as a whole although the proportion of females (52%) somewhat less than might have been expected (around 64% of UK contact lens wearers[2]). This was not considered to influence the findings given the randomised, crossover study design.

All measures of distance visual acuity (monocular and binocular, high and low contrast) favoured the Biofinity toric lens with the measured difference between the two lenses (between 0.6 and 1.1 lines) at a level which is considered clinically significant in that the differences are similar to or greater than the test–retest variability for letter-by-letter visual acuity measurement reported to be 0.7 lines [32], 0.9 lines [33] and 1.0 lines [34] by previous researchers.

Visual acuity measures for distance were reflected in the subjective scores for the walking task, with quality of vision scored around 12 units higher for the toric lens. This difference is likely to be clinically significant. Interestingly, although the difference of around four units for vision stability for the intermediate task approached statistical significance, it was apparent that the improvement in vision found with the toric lens diminished as the task distance changed from distance to intermediate to near. This seems likely to be due to the reduced need for optimum visual acuity with nearer tasks. For example, a limb on a 12-point letter on a computer screen at 50 cm subtends about six minutes of arc; this is six times larger than a limb of a letter on the 0.0 (Snellen 20/20 or 6/6) line on a logMAR scale. Even a six-point letter is still three times easier to resolve. It seems, therefore, that the benefits of improved visual acuity of around a line with a toric lens are more apparent to wearers conducting distance tasks and observations rather than intermediate and near tasks.

There was no evidence of reduced 'stability' of vision with the toric lens. Indeed, this parameter was considered to be better with Biofinity toric for distance measures and the greater scores for this lens at intermediate approached statistical significance. As such, it can be concluded that this lens design provides stability of vision similar to its spherical equivalent.

Comfort was similar for the two lenses. In some situations, the interpretation of subjective comfort can be complicated due to the association between comfort and vision in soft toric contact lens wearers [35]. This is unlikely to be a factor in the current work due to the similarity in vision scores. Previous work has reported reduced comfort with soft toric lenses [21,22], but one more recent report suggests otherwise [23] and the current study certainly fails to support this notion for the toric design evaluated here. Performance on the CVS-Q was similar for the two lenses; with the other results presented here, this finding is expected as most of the questions in the questionnaire related to ocular comfort. It is also possible that the limited computer time experienced by the subject during this work might have limited the ability of the CVS-Q to differentiate between the two lens types.

4.2. Economics study

The stated preference discrete choice experiments reported here, coupled with binary and random parameters logit models demonstrated that (a) as vision improves, individuals are more likely to pay a premium for toric lenses over spherical lenses and (b) as comfort decreases, individuals are less likely to pay this premium.

Willingness to pay measures varied under different scenarios. Where toric lenses provided better vision than spherical lenses – a situation confirmed as accurate by the clinical study – the willingness to pay a monthly premium for toric lenses was between £13 and £16. Based on respondents' stated price for a monthly supply of daily disposable spherical lenses, this represents a premium of between 54 and 58 percent over spherical lenses.

However, if toric lenses are rated as providing improved vision but with decreased comfort levels, the willingness to pay premium decreased to between £4 and £13 – a premium of between 18 percent and 46 percent over spherical lenses. Overall, the analysis provides the first empirical investigation into contact lens-wearing individuals' willingness to pay a premium for toric lens. The statistical models exhibited internal validity with hypothetical purchase decisions varying in the expected directions with price, vision improvement and comfort.

A survey of online contact lens web sites determined that a typical premium for toric lenses vs their spherical equivalents is 28–33%, rather less than consumers are willing to pay. This indicates that the clinical benefits offered to a typical astigmatic contact lens wearer are greater with toric lenses than that which would be expected by a consumer paying this increase in cost.

The findings presented here are important because the potential success of a product and its profitability in the marketplace requires an understanding of how much consumers are willing to pay for the final good. Moreover, in markets with close substitutes (such as spherical and toric soft contact lenses), understanding the values that consumers place on different attributes of these competing goods can also provide important feedback for decision makers such as manufacturers and eye care professionals. As such, whether consumers are willing to pay more or less for a good based on perceived differences in specific attributes of a product (relative to a substitute good) can aid in marketing efforts and consulting room communication, and on to increased patient satisfaction and increased sales.

It should also be noted that the focus of this study was to examine individuals' preferences for toric lenses over spherical lenses based on vision, comfort, and price premium attributes. This study does not take into account the potential influence of other product-related attributes on consumer preferences – such as product design, packaging, or branding. For example, research has indicated that product branding can influence consumers' preferences for a higher-priced option, suggesting that a product brand can influence consumers' willingness to pay [36]. Future work could examine the role of other product attributes, such as packaging and branding – in a discrete choice experiment framework – on individual preferences for contact lenses and consumers' willingness to pay.

5. Conclusion

This work demonstrated that better visual acuity was achieved with the Biofinity toric lens compared with the Biofinity spherical lens to an extent which was clinically meaningful. Subjectively, a difference was reported at distance but not for intermediate and near vision whereas comfort was similar for the two lens types. Consumers are willing to pay a monthly premium of around 50% to benefit from the typical experience of better vision and similar comfort for toric vs. spherical lenses. As typical toric market premiums are lower than this value, eye care professionals should consider that toric lenses are delivering a greater clinical return than anticipated by wearers for the relatively small increase in price.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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