

## Original Article

# Trends in the distribution of donor corneal tissue and indications for corneal transplantation: the New Zealand National Eye Bank Study 2000–2009

William J Cunningham MBChB, Nigel H Brookes MSc, Helen C Twohill BA, S Louise Moffatt BSc, David GC Pendergrast FRANZCO, Joanna M Stewart MSc and Charles NJ McGhee PhD FRANZCO  
New Zealand National Eye Bank, and Department of Ophthalmology, New Zealand National Eye Centre, Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand

## ABSTRACT

**Background:** To investigate the indications for corneal transplantation and the distribution of donor corneal tissue in New Zealand.

**Design:** Analysis of the prospective database of the New Zealand National Eye Bank.

**Participants:** A total of 2205 corneal transplants were assessed.

**Methods:** New Zealand National Eye Bank records were analysed for the decade 2000–2009.

**Main Outcome Measures:** Variables analysed included donor corneal tissue distribution (including public and private sectors), indications for transplantation, donor corneal tissue recipient demographics (age and gender) and corneal transplantation type.

**Results:** An average of 220 corneal transplants were performed each year over the 10-year period ( $n = 2205$ ). The median recipient age was 45 years (range 3 to 102 years) and 54.0% of recipients were male. In total 71.8% of transplants were performed in the public health sector. Surgeons in the Auckland metropolitan area performed 47.2% of all corneal transplants. The most common indications for corneal transplantation were: keratoconus (41.1%), repeat transplant (17.0%), aphakic/pseudophakic

bullous keratopathy (13.9%), corneal dystrophy (10.7%), keratitis (7.9%) and trauma (3.7%). Overall, penetrating keratoplasty accounted for 90.7% of all corneal transplants, however, during the latter half of the study there was a progressive shift in transplantation type, with deep anterior lamellar keratoplasty and Descemet's stripping endothelial keratoplasty combined accounting for 32.3% of all transplants in the final year of the study period.

**Conclusions:** This New Zealand National Eye Bank study provides valuable data regarding the indications for corneal transplantation, transplant recipient demographics and changes in transplantation type in New Zealand over the past decade.

**Key words:** cornea, corneal graft, corneal transplantation, eye banking.

## INTRODUCTION

New Zealand ophthalmologists perform an average of 220 corneal transplants per year, serving a current estimated population of over 4 365 000 that is distributed widely throughout a country that is geographically a little larger than the United Kingdom. New Zealand's healthcare system is funded primarily through general taxation making most public health system treatments free, although private healthcare is also available. There are over 445

■ **Correspondence:** Professor Charles NJ McGhee, Maurice Paykel Professor of Ophthalmology, Private Bag 92019, University of Auckland, 1020 Auckland, New Zealand. Email c.mcghee@auckland.ac.nz

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hospital centres nationwide, with 21 of these providing specialist services for corneal transplantation.

Since 1991, the New Zealand National Eye Bank (NZNEB) has been the primary supplier of donated corneal tissue to ophthalmology centres throughout New Zealand, acquiring an extensive database which has been vital in the completion of previous New Zealand National Eye Bank and corneal transplantation studies.<sup>1</sup> The purpose of this study was to analyse NZNEB data for the decade 2000–2009, investigating the indications for corneal transplantation and the distribution of donor corneal tissue throughout New Zealand to identify any trends in comparison with previous NZNEB and international studies.

## METHODS

The NZNEB records were analysed for the decade 1 January 2000 to 31 December 2009 inclusive. Variables analysed included donor cornea distribution (including public and private sectors), indications for transplantation, donor cornea recipient demographics (age and gender) and corneal transplantation type. The various transplant indications were also compared with NZNEB data from the previous decade (1 January 1990 to 31 December 1999).

## RESULTS

### Corneal distribution

A total of 2205 corneas were transplanted during the decade, with an average of 220 corneal transplants per year (range 179–246). There were no significant trends in transplantation numbers over the 10 year period. The majority of transplants were performed

in the public sector (71.8%,  $n = 1583$ ), with the remainder performed in the private health sector (28.2%,  $n = 622$ ). During the study period there were no reported cases of postoperative infection attributable to the donor tissue. There was a steady decline in the number of ophthalmic surgeons performing corneal transplants from 32 in 2000, to 19 by the end of the decade.

There were a total of 21 public and 34 private centres that provided services for corneal transplantation over the 10-year period. Surgeons in the Auckland metropolitan area performed 47.2% of all corneal transplants ( $n = 1040$ ), followed by Wellington (14.6%,  $n = 322$ ) and Christchurch (9.9%,  $n = 219$ ). Table 1 demonstrates the larger centres (centres that performed  $\geq 60$  corneal transplants for the decade) total number of procedures (including public and private sectors) and their contribution to the total number of transplants performed nationwide (Fig. 1).

### Recipient demographics

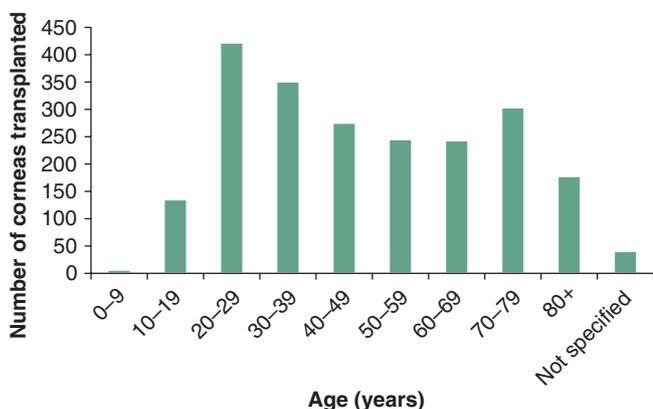
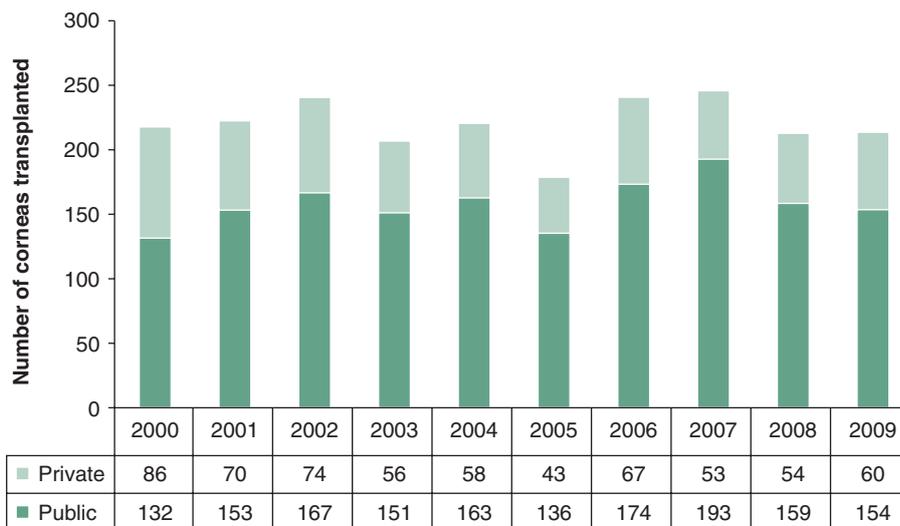
There were no significant trends in gender proportions over the decade. In total, 54.0% of corneal transplant recipients were male ( $n = 1191$ ) and 42.2% female ( $n = 929$ ). Gender was not specified in 3.8% ( $n = 85$ ) of recipients. The age of transplant recipients ranged from 3 to 102 years, with a median age of 45 years (mean = 48 years [standard deviation = 21.4]). The median age for each of the study years ranged from 41 to 50 years, with no observable trend identified. The most common recipient age group was 20–29 years (19.2%,  $n = 422$ ), followed by 30–39 years (15.9%,  $n = 351$ ) and 70–79 years (13.8%,  $n = 304$ ). Recipient age was not specified in 41 cases (1.9%). Corneal transplantation totals for the various age groups are displayed in Figure 2.

**Table 1.** Centres that performed  $\geq 60$  corneal transplants in total over the 10 year period 2000–2009 shows that only four centres averaged one corneal transplant per month and only one, Auckland, averaged at least one case per week

| Centre           | Population <sup>2</sup> | Total transplants | % of transplants nationwide 2000–2009 |
|------------------|-------------------------|-------------------|---------------------------------------|
| Auckland*        | 1 303 068 <sup>a</sup>  | 1040              | 47.2                                  |
| Wellington       | 448 956 <sup>b</sup>    | 322               | 14.6                                  |
| Christchurch     | 521 832 <sup>c</sup>    | 219               | 9.9                                   |
| Hamilton         | 382 716 <sup>d</sup>    | 129               | 5.9                                   |
| Dunedin          | 193 800 <sup>e</sup>    | 93                | 4.2                                   |
| Whangarei        | 148 470 <sup>f</sup>    | 82                | 3.7                                   |
| Tauranga         | 257 379 <sup>g</sup>    | 68                | 3.1                                   |
| Hawkes Bay       | 147 783 <sup>h</sup>    | 61                | 2.8                                   |
| Palmerston North | 222 423 <sup>i</sup>    | 60                | 2.7                                   |

These numbers are highlighted in context with the local population estimates though it should be noted Auckland\* is a major tertiary centre with cases referred from throughout New Zealand. <sup>a</sup>Includes Auckland Region (Rodney, North Shore, Waitakere, Manukau, Papakura and Franklin districts). <sup>b</sup>Includes Wellington Region. <sup>c</sup>Includes Christchurch Region. <sup>d</sup>Includes Waikato Region. <sup>e</sup>Includes Otago Region. <sup>f</sup>Includes Northland Region. <sup>g</sup>Includes Bay of Plenty Region. <sup>h</sup>Includes Hawkes Bay Region. <sup>i</sup>Includes Manawatu-Wanganui Region.

**Figure 1.** Total number of corneal transplant procedures performed in New Zealand during the 10-year period 2000–2009 with the proportion of these performed in public/private sectors. There was a mean of 220.3 cases per annum (range of 179–246) and the majority of corneal transplantation procedures were performed in the public hospital sector (mean 71.8%, range 60.5%–78.4%).



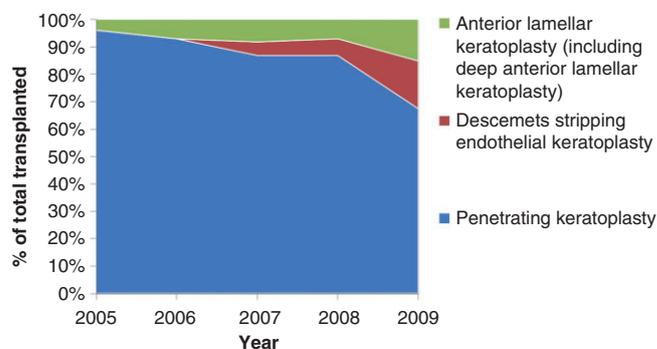
**Figure 2.** Age distribution of corneal transplant recipients for the decade 2000–2009.

### Transplantation type

Overall, from 2000 to 2009, penetrating keratoplasty accounted for 90.7% ( $n = 1998$ ) of all corneal transplants, the remainder being anterior lamellar keratoplasty 6.2% ( $n = 136$ ), Descemet’s stripping endothelial keratoplasty 2.8% ( $n = 62$ ) and tectonic ‘patch’ keratoplasty 0.3% ( $n = 9$ ), respectively. During the latter half of the decade there was a significant increase in the number of anterior lamellar, and more recently, endothelial transplants (see Fig. 3). In 2009, anterior lamellar keratoplasty and Descemet’s stripping endothelial keratoplasty combined accounted for 32.3% of all transplants ( $n = 69$ ).

### Indications for corneal transplantation

The indications for corneal transplantation for the periods 1990–1999 (1625 transplants) and 2000–2009 (2205 transplants) are displayed in Table 2. The most common indication for corneal transplantation



**Figure 3.** Changes in corneal transplant type New Zealand National Eye Bank 2005–2009 ( $n = 1093$  transplants).

was keratoconus, accounting for 41.1% ( $n = 938$ ) of all transplants. Other common indications were bullous keratopathy (13.9%,  $n = 315$ ), repeat transplantation (17.0%,  $n = 391$ ), corneal dystrophy (10.7%,  $n = 243$ ), keratitis (7.9%,  $n = 180$ ) and trauma (3.7%,  $n = 85$ ), respectively. A small proportion of transplants were classified as ‘other’ (5.0%,  $n = 115$ ), with the various indications within this group displayed in Table 3. Over the 10 year period there was a decrease in the number of transplants performed for bullous keratopathy, with an increase in those for corneal dystrophy (see Fig. 4).

### DISCUSSION

The world’s first successful corneal transplant was performed in 1905 by Dr Eduard Zirm.<sup>3</sup> Since this time the art and science of corneal transplantation has grown markedly, with current worldwide estimates for corneal transplantation reaching over 100 000 per year.<sup>4</sup> Located in the far southwest Pacific, New Zealand (Aotearoa) is a relatively small nation, with a population of 4.3 million and total

**Table 2.** Indications for corneal transplantation reported to the New Zealand National Eye Bank for the decades 1990–1999 and 2000–2009.

| Indication for surgery     | 1990–1999         |            | 2000–2009         |            |
|----------------------------|-------------------|------------|-------------------|------------|
|                            | Number            | % of total | Number            | % of total |
| Keratoconus                | 745               | 42.3       | 938               | 41.1       |
| Bullous keratopathy        |                   |            |                   |            |
| Pseudophakic               | 188               | 10.7       | 241               | 10.6       |
| Aphakic                    | 116               | 6.6        | 43                | 1.9        |
| Unspecified                | 0                 | 0          | 31                | 1.4        |
| Total                      | 304               | 17.3       | 315               | 13.9       |
| Repeat keratoplasty        |                   |            |                   |            |
| Re-graft with rejection    | 68                | 3.9        | 132               | 5.7        |
| Re-graft without rejection | 64                | 3.6        | 185               | 8.1        |
| Unspecified re-graft       | 0                 | 0          | 76                | 3.3        |
| Total                      | 132               | 7.5        | 391               | 17.0       |
| Corneal dystrophy          |                   |            |                   |            |
| Fuch's dystrophy           | 70                | 4.0        | 187               | 8.2        |
| Other dystrophy            | 79                | 4.5        | 56                | 2.5        |
| Total                      | 149               | 8.5        | 243               | 10.7       |
| Keratitis                  |                   |            |                   |            |
| Viral keratitis            | 129               | 7.3        | 82                | 3.6        |
| Bacterial/fungal keratitis | 54                | 3.1        | 57                | 2.5        |
| Amoebic keratitis          | 0                 | 0          | 7                 | 0.3        |
| Non-infective keratitis    | 26                | 1.5        | 29                | 1.3        |
| Unspecified keratitis      | 0                 | 0          | 5                 | 0.2        |
| Total                      | 209               | 11.9       | 180               | 7.9        |
| Ocular trauma              |                   |            |                   |            |
| Penetrating trauma         | 83                | 4.7        | 68                | 3.0        |
| Chemical trauma            | 14                | 0.8        | 7                 | 0.3        |
| Thermal trauma             | 0                 | 0          | 1                 | 0.0        |
| Unspecified trauma         | 0                 | 0          | 9                 | 0.4        |
| Total                      | 97                | 5.5        | 85                | 3.7        |
| Other indication           | 126               | 7.2        | 115               | 5.0        |
| Not specified              | 0                 | 0          | 14                | 0.6        |
| Total indications          | 1762 <sup>†</sup> | 100        | 2283 <sup>‡</sup> | 100        |
| Total transplants          | 1625              |            | 2205              |            |

<sup>†</sup>For the period 1990–1999, 8.4% ( $n = 137$ ) transplants listed more than one indication. <sup>‡</sup>For the period 2000–2009, 3.5% ( $n = 78$ ) transplants listed more than one indication.

land area of 268 021 square kilometres. New Zealand's geographical location also impacts on the patient population, with over 20% reported to be of Maori or Polynesian descent.<sup>2</sup> The reported higher prevalence of keratoconus in the Maori/Polynesian population<sup>5</sup> creates a unique set of challenges with regard to the ophthalmology patient population and corneal transplantation in New Zealand.

A total of 2205 corneal transplants were reported during the study period, which is almost double the number reported from the previous decade.<sup>1</sup> It is thought this change is largely because of increased efforts from the NZNEB surrounding eye donation and storage, now meeting the high demand for corneal tissue in New Zealand. Despite the number of operating corneal surgeons declining over the decade, transplantation numbers remained relatively stable with an average of 220 corneal transplants per year. The reason for the decrease in the number of surgeons

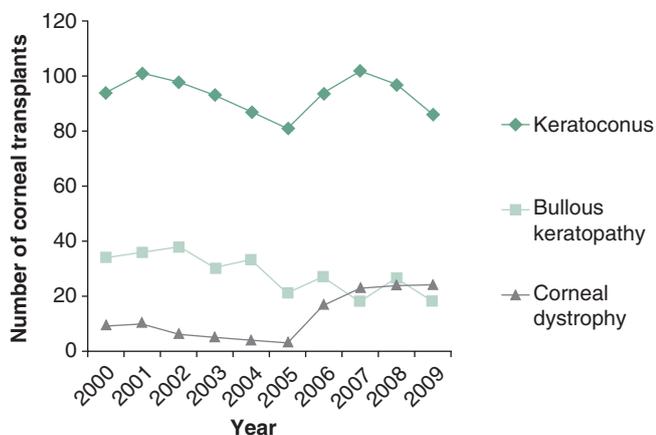
performing corneal transplants is beyond the scope of this study but is believed to include increasing sub-specialisation within the New Zealand ophthalmology workforce and increasing complexity of keratoplasty techniques in the last 10 years.

Transplant recipient demographics were very similar compared with the previous decade,<sup>1</sup> displaying a slight male preponderance at 54%. The median age was 45 years, which is younger than that reported in large international studies from the UK (54 years)<sup>6</sup> and Canada (70 years).<sup>7</sup> This may reflect the fact that almost half of the keratoplasty procedures in New Zealand are for keratoconus. However, the age distribution displayed a bimodal pattern echoing other studies,<sup>1,8,9</sup> with peaks in the 20- to 29-year and 70- to 79-year groups – the larger, younger, peak largely representing those with keratoconus and the second peak those with bullous keratopathy.

**Table 3.** Miscellaneous other indications ( $n = 115$ ) for corneal transplantation in the decade 2000–2009

| Other indication                          | 2000–2009 |
|---|-----------|
| Corneal scarring                          | 38        |
| Corneal decompensation                    | 24        |
| Perforation, cause not specified          | 5         |
| Post-radial keratotomy                    | 5         |
| Pellucid marginal degeneration            | 5         |
| Allograft for autograft donor eye         | 5         |
| ICE syndrome                              | 5         |
| Post-LASIK                                | 4         |
| Limbal dermoid                            | 5         |
| Other keratopathy                         | 3         |
| Ectasia not specified                     | 2         |
| Corneal blood staining                    | 2         |
| Mooren's ulcer                            | 1         |
| SCC excision                              | 1         |
| Melanoma                                  | 1         |
| Limbal stem cell deficiency               | 1         |
| Cicatrizing conjunctivitis                | 1         |
| Iatrogenic Descemet's detachment          | 1         |
| Ocular pemphigoid                         | 1         |
| Corneal melt post-pterygium MMC treatment | 1         |
| Ruptured descemetocoele                   | 1         |
| Total                                     | 115       |

ICE, iridocorneal endothelial syndrome; SCC, squamous cell carcinoma.

**Figure 4.** Trends in specific indications for corneal transplantation, New Zealand National Eye Bank 2000–2009, for: keratoconus, aphakic/pseudophakic bullous keratopathy and corneal dystrophy.

The majority of corneal transplants were performed in the Auckland metropolitan region, followed by Wellington and Christchurch. This activity reflects the distribution of the population in New Zealand, with the Auckland region home to approximately one-third of the nation's population, followed by the second and third largest cities of Christchurch and Wellington.<sup>2</sup> In addition, these centres are generally regarded as tertiary referral

centres, thus increasing their capacity for undertaking more complex corneal transplantation surgery.

When the various indications for corneal transplantation are compared internationally (Table 4), New Zealand appears to have the highest reported proportion of transplantation surgery for keratoconus worldwide. Keratoconus was responsible for 41.1% of transplantations, and has long been the leading indication for penetrating keratoplasty in New Zealand.<sup>1</sup> There are little published data on the exact prevalence of keratoconus in New Zealand, however, one study reported a rate of 1 in 2000 in the Hawkes Bay region.<sup>16</sup>

The aetiology of keratoconus appears to be multifactorial and has yet to be fully elucidated,<sup>17</sup> but in this context there may be several possible explanations for such a high proportion of corneal transplantation surgery for keratoconus in New Zealand. First, Maori and Pasifika comprise over 20% of the population, and although exact figures remain unknown, reports suggest a higher incidence of keratoconus in both the Maori and Pacific populations.<sup>5</sup> Second, it has been suggested that New Zealand has a particularly progressive form of keratoconus different to that seen elsewhere,<sup>1</sup> with a more rapid progression of the disease to a stage that requires transplantation. Third, New Zealand has one of the highest reported rates of atopic disease in the world,<sup>18</sup> with previous studies suggesting possible relationships between atopy and keratoconus.<sup>19</sup> Finally, New Zealand's geographic location in the southern hemisphere with less ultraviolet (UV) protective ozone, results in UV radiation levels that are amongst the highest in the world<sup>20</sup> and studies have previously highlighted that UV light may induce keratocyte apoptosis,<sup>21</sup> a process that has been implicated in the development of keratoconus.<sup>22</sup>

Although the proportion of corneal transplants performed for bullous keratopathy is reported to be increasing in other international centres,<sup>6,7</sup> a trend also recorded in New Zealand during the previous decade of study,<sup>1</sup> the current study highlights the proportion of transplants for bullous keratopathy to be declining – from 17.3% in the period 1990–1999, to 13.9% in the period 2000–2009. This encouraging trend perhaps reflects advances in surgical technique and IOL technology, suggesting that modern cataract surgical techniques are positively impacting on what was once a major cause of corneal decompensation and subsequent need for corneal transplantation.

During the latter half of the study we witnessed a dramatic shift in transplantation techniques, with increased utilisation of anterior lamellar transplantation, particularly deep anterior lamellar keratoplasty (DALK) and Descemet's stripping endothelial keratoplasty (DSEK). Interestingly, DALK and DSEK

**Table 4.** Recent studies comparing indications for corneal transplantation (%)

| Authors and country reported                           | Year      | Keratoconus | Pseudophakic/aphakic bullous keratopathy | Re-graft | Viral keratitis | Trauma | Fuchs endothelial dystrophy |
|--|-----------|-------------|--|----------|-----------------|--------|-----------------------------|
| Current study<br>New Zealand                           | 2000–2009 | 41.1        | 13.9                                     | 17.0     | 3.6             | 3.7    | 8.2                         |
| Edwards <i>et al.</i> <sup>1</sup><br>New Zealand      | 1991–1999 | 45.6        | 17.9                                     | 8.7      | 7.3             | 5.5    | 4.4                         |
| Al-Towerki <i>et al.</i> <sup>10</sup><br>Saudi Arabia | 1998–2002 | 40.2        | 13.5                                     | 11.3     | –               | –      | 7.9                         |
| Yahalom <i>et al.</i> <sup>11</sup><br>Israel          | 1991–2000 | 38.6        | 11.8                                     | 17.0     | 4.5             | 3.4    | 1.9                         |
| Williams <i>et al.</i> <sup>12</sup><br>Australia      | 2007–2008 | 32.0        | 26.0                                     | 19.0     | 4.0             | 1.7    | 6.1                         |
| Randleman <i>et al.</i> <sup>13</sup><br>USA           | 1997–2001 | 20.3        | 21.5                                     | 29.1     | –               | –      | 3.8                         |
| Al-Yousuf <i>et al.</i> <sup>6</sup><br>UK             | 1990–1999 | 15.0        | 11.8                                     | 40.9     | 5.9             | 1.3    | 9.3                         |
| Dorrepal <i>et al.</i> <sup>7</sup><br>Canada          | 1996–2004 | 12.0        | 26.3                                     | 26.9     | 5.3             | 3.1    | 12.0                        |
| Kang <i>et al.</i> <sup>14</sup><br>USA                | 2000–2001 | 11.8        | 16.7                                     | 27.0     | –               | –      | 23.0                        |
| Tabin <i>et al.</i> <sup>15</sup><br>Nepal             | 1994–1999 | 4.3         | 8.1                                      | 13.3     | –               | 34.1   | 0.3                         |

combined accounted for one-third of all transplants in the final year of the study period. This shift toward lamellar keratoplasty techniques has also been reported in other major international studies from the UK,<sup>9</sup> China<sup>23</sup> and the USA.<sup>24</sup>

With advances in surgical instrumentation and techniques, DALK is now becoming the transplant procedure of choice for anterior corneal diseases (including keratoconus) in New Zealand. Fuelling the shift toward DALK are reported advantages over traditional penetrating keratoplasty including: preservation of host endothelium (eliminating the potential for endothelial rejection), reduced operative risk from an essentially closed globe procedure, possible improvements in postoperative astigmatism and potentially faster visual recovery.<sup>25,26</sup> Unfortunately, as many subjects present to corneal services in New Zealand with extremely advanced disease including extensive hydrops, DALK is not always a feasible option and therefore penetrating keratoplasty still has a major role.

Similarly, Descemet's Stripping Endothelial Keratoplasty (DSEK) potentially offers many advantages over traditional penetrating keratoplasty such as: much more rapid visual recovery, improved refractive outcomes, reduced risk of intraoperative haemorrhage and fewer postoperative ocular surface problems.<sup>25</sup> These advantages make DSEK an attractive surgical option to both patient and ophthalmologist in the treatment of endothelial disorders such as Fuchs endothelial corneal dystrophy and bullous keratopathy. Notably, the data presented suggests that New Zealand ophthalmologists appear to be

slower to adopt this technique than international colleagues although NZNEB data from 2010 (unpublished) suggests that approximately 25% of cases listed for corneal transplantation surgery undergo DSEK. However, given the high proportion of transplants for keratoconus (41.1%) in New Zealand, the modest prevalence of Fuchs endothelial dystrophy (8.2%), and the relatively low proportion of cases with bullous keratopathy (13.9%), New Zealand ophthalmologists may never perform the high proportion of DSEK procedures reported in other international centres.

The NZNEB supplies corneal tissue for transplantation throughout New Zealand. The NZNEB database has proven invaluable in the completion of this and prior studies, revealing trends with respect to the various indications for keratoplasty and the evolution of preferred transplantation techniques over the last 20 years. This study of the period 2000–2009 reinforces data from previous NZNEB studies in terms of the similarity of recipient demographics, with relatively minor changes in indications, significant trends towards lamellar surgical approaches and specifically reconfirms that New Zealand has the highest internationally reported proportion of corneal transplantation for keratoconus; a disease currently under intensive investigation in several studies in New Zealand.

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