“Protective Eyewear and Educational Interventions for the prevention of Ocular injuries among Stone Quarry Workers”

A dissertation submitted in partial fulfillment of the rules and regulations for M.S. Branch III (Ophthalmology) examination of The Tamil Nadu Dr. MGR Medical University, Chennai to be held in March 2008.

Declaration

I hereby declare that the investigations that form the subject matter of my thesis was carried out by me under the guidance of Dr. Renu Raju, Professor, Department of Ophthalmology, Christian Medical College, Vellore. This has not been submitted in any other university in part or in full.

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CERTIFICATE

This is to certify that this dissertation entitled

"Protective Eyewear and Educational interventions for the prevention of Ocular injuries among Stone Quarry Workers"

is the bonafide work done by

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Introduction

Vision remains a defining character of our interaction within society and loss of this sense can be devastating to the individual. Eye injuries are common and of global concern. An important world-wide public health problem is ocular trauma. In India the impact of trauma on visual acuity is particularly important because of the repercussions on the socio-economic status of the individual and the family. The personal impact of ocular injury is difficult to define, although the lifestyle of the affected individual may be permanently altered.

Ocular trauma is a result of the redistribution of kinetic energy to the various ocular structures. This is a force that can disturb any organic or inorganic substance. The extent of ocular injury depends on the nature of trauma, extent of damage to the intraocular structures, presence of intraocular foreign body, and the site of injury.

Ocular injuries can occur in various settings, including sports related activities, recreational, workplace or occupational, the home, at school and play, civil disturbances and various causative agents have been implicated which can cause injuries ranging from minor injury to serious vision threatening injury. The causative agents are classified broadly as sharps, chemicals, liquids, explosives, radiation and social activities.

Epidemiologic investigations reveal that there are individuals who have a high risk of eye injury and there are situations where eye injuries occur with far greater frequency than would be expected by chance. Since many eye injuries can be prevented by using protective eyewear, and modifying dangerous environment, individuals at high risk can be focused on for educational and other preventive measures.

Though studies on various occupational injuries have been conducted in many countries, there are very few occupational ocular injury related studies reported from India.

A particularly hazardous occupation in relation to the potential for ocular injuries is stone quarrying. Stones from quarries are required by us for various purposes like building houses, laying roads, for making household grinding stone etc. These quarries employ several hundreds of workers, both men and women who are vulnerable to ocular injuries, either while actively involved with work, or as a bystander.

The socio-economic conditions of those who are engaged in stone cutting is very poor and they are vulnerable to eye trauma by nature of their work. The quarries employing these poor people do not come under the purview of any social security legislation. Hence, they are not provided any social security measures against accidents and loss of vision in the course of their employment.

The department of ophthalmology at the Christian Medical College, Vellore had noted a number of stone quarry workers reporting with ocular injuries and a pilot study revealed that the frequency of accidents, especially, the entry of foreign body into the eyes was very high. Due to their ignorance and poor economic conditions, many quarry workers do not seek medical help unless they develop intolerable pain.

In the case of severe injury, cost of treatment at a tertiary level hospital is very high, and unaffordable by these stone cutters. In some cases of severe trauma, it is medically impossible to restore vision. This further hinders their earning capacity and affects the family as a whole in many ways.

Due to their vulnerability to ocular injury and the resultant consequences, a need was felt to formally institute a study on the prevalence and nature of injuries among the stone quarry workers and plan an intervention that would benefit quarry workers in the area. Protective eyewear seemed an obvious choice but the special difficulties caused by the nature of quarry work needed to be evaluated and the role of educational interventions to encourage regular use the protective eyewear needed to be evaluated.

This work forms part of the growing body of work in India in the area of public health ophthalmology.

Aim

The overall aims of this study were to:

1. To document the pattern of ocular injuries among quarry workers in quarries around Vellore.
2. To evaluate the efficacy of protective eyewear in reducing ocular injuries.
3. To evaluate the durability of protective eyewear
4. To enhance the acceptance of protective eyewear among quarry workers using educational interventions. For this last aim, a pragmatic cluster randomized trial was designed to compare the effectiveness of enhanced educational interventions over a simpler educational procedure. The unit of randomization were quarries and this cluster design was chosen to prevent contamination of educational interventions between quarries.

Review of Literature

Ocular trauma is an important worldwide preventable public health problem. Apart from trauma as a public health problem and the morbidity it causes, the impact of trauma on visual acuity is particularly important in India because of its effect on the socioeconomic state of the individual and family. Prevention is better than cure is an old adage which is the foundation on which the health of the community can be built. Ocular trauma has been reported to be one of the most important causes of unilateral visual loss in the developing countries[1,2].

The literature search done here looked for demographic factors, clinical profile of patients with ocular trauma, occupational ocular injuries, ocular protection with protective eyewear device, classification of occupation, methods of reporting a cluster randomized tria1.

Demographic Profile

Eye care programs may need to consider ocular trauma as a priority, because the lifetime prevalence of ocular trauma in some occupational groups is higher than that reported for glaucoma, age-related macular degeneration, or diabetic retinopathy[3,4].

Incidence of ocular trauma varies from place to place depending on the local industrial growth, mechanization of agriculture, methods of ocular protection, and the awareness of the people. The ocular surface area is only 0.27% of the body surface area and 0.1% of the frontal body silhouette, and thus, it would seem logical that the estimated ocular injury rate should be less than 1%[5], but such is not the case as per the various studies done in India and abroad. All the studies have different incidence rates and because of these epidemiological studies, we now understand that eye injuries are rarely the result of random, unrelated, and unpreventable factors (“accidents”); rather, they are usually preventable events[6].

Studies Done Outside India

Resource and Reference	Study Period	Year of Publication	Study Population	Study design	Injury Definition	Eye Injury Rate per 100,000 population
Smith AR et al.[7]	1995-2002	2006	Queensland, Australia	Hospital based	ICD- 9, ICD-10	11.8
Karaman et al[8]	1998-2002	2004	Croatia	Hospital based	ICD	23.9
Wong et al[9]	1985-1994	2000	US Army	Hospital based	ICD-9	77.1
Wong & Tielsch[10]	1991-1996	1999	Singapore	Hospital based	ICD-9	12.6
Desai et al[11]	1991	1996	Scotland	Hospital based	ICD-9	8.1
Fong LP[12]	1989-1990	1995	Victoria, Australia	Hospital based	ICD-9	15.2
Byhr E[13]	1989-1991	1994	Sweden	Hospital based	ICD-9	3.3
Klopfer et al[14]	1984-1987	1992	USA	Based on hospital discharges	ICD-9	29.1
Tielsch et al[15]	1979-1986	1989	Maryland, USA	Hospital discharges and all ages	ICD-9	13.2
Karlson and Klein[16]	1979	1986	USA	Based on emergency room and hospital records	Non standard	423

ICD-International Classification of diseases 9- Ninth Revision, 10- Tenth Revision

A study done in Australia reports an annual ocular injury rate to be 11.8 per 100,000 population and 3.7 per 100,000 population for open globe injuries with closed globe being more common than open globe injuries[7].

Karaman et al, retrospectively analyzed data on 383 patients with eye injuries (397 eyes) hospitalized at Split University Hospital, Department of Ophthalmology, Croatia between January 1998 and December 2002 and showed that the incidence of ocular injuries requiring hospitalization in Split-Dalmatian County was 23.9 per 100,000 population and the incidence of monocular blindness caused by injuries was 4.1 per 100,000 population[8].

Another study done in Pakistan to describe the pattern of ocular injuries took into account the records of 1105 patients and found that ophthalmic trauma comprised of 6.78% of hospital admissions, open globe injuries being 46.18% and closed globe injuries being 42.98% of the total number of injuries[17].

Statistics from Greece suggest that the average annual rate of hospitalized ocular injuries was 71.0 eye injuries per 1000 admissions at the Department of Ophthalmology and closed globe injuries being the most common accounting for 49.5% of the cases[18].

A population-based incidence study involving all Singapore citizens and residents with information from two government-administered databases on severe ocular trauma in Singapore, suggest the overall annual incidence rate of hospitalized ocular injury was 12.6 per 100,000, and the annual incidence rate of open globe injury was 3.7 per 100,000[10].

A prospective observational study was carried out of all patients with ocular trauma admitted to hospitals in Scotland, and all ophthalmic departments in Scotland participated and a total of 415 residents of Scotland were admitted. The 1 year cumulative incidence of ocular trauma necessitating admission to hospital was estimated

to be 8.14 per [19]100 000 population (95% CI 7.38 to 8.97). About 13.2% (n = 26/197) of patients discharged from follow up had a poor visual outcome with a visual acuity less than 6/12 in the injured eye[11].

Reports of ocular trauma were collected from 1995 through 2000 from patients presenting to the only eye care clinic in Sarlahi district, Nepal and 525 cases of incident ocular injury were reported, with a mean age of 28 years. Using census data, the incidence was 65 per 100,000 males per year, and 38 per 100,000 females per year[19].

The Beaver Dam Eye Study that took place from 1988 through 1990 (n = 4926) and the follow-up study that took place from 1993 through 1995 (n = 3684), had a standardized interview at baseline and follow-up study, reported a cumulative lifetime prevalence and 5-year incidence of self-reported history of ocular trauma to be 19.8% and 1.6% respectively[20]. Cumulative lifetime prevalence ranges from 860[21] to 14,400[22] per 100,000 population.

Studies on ocular injuries from India

Studies done in India project different incidence and prevalence rates. A total of 7771 subjects of all ages, representative of the rural population of Andhra Pradesh were done and the prevalence of history of eye injury in this rural population was found to be 7.5% in the rural population and 3.9% in the urban population[23] the rates of which are higher than the previously reported study from urban India[24].

As part of the population-based Andhra Pradesh Eye Disease Study, 2522 people of all ages from 24 clusters representative of the population of Hyderabad city in southern India, underwent a detailed interview and standardized dilated ocular evaluation and reported a cumulative prevalence (combined age sex-adjusted) rate of 3.97% and a combined age-sex-adjusted prevalence of blindness in one eye due to trauma of 0.60% (95% CI 0.23-1.04%) [24].

Data from a population-based cross-sectional study of 5150 persons 40 years or older in a randomly chosen rural population of 3 districts of southern India report ocular trauma as a priority in this population, because the lifetime prevalence of ocular trauma is higher than that reported for glaucoma, age-related macular degeneration, or diabetic retinopathy from this population and the prevalence of ocular injury in this rural population to be 4%[3] similar to the results from the Andhra Pradesh study[24].

Studies done in India

Resource and Reference	Year of Publication	Prevalence (%)	Place
Krishniah et al[23]	2006	7.5(Rural) and 3.9(Urban)	Andhra Pradesh
Nirmalan et al[3]	2004	4.0(Rural)	TamilNadu
Dandona et al[24]	2000	3.97(Rural)	Andhra Pradesh

Majority of the other studies published in India, like those abroad are retrospective, hospital based, low figured and the criteria for selection was different in different studies thus making comparison difficult. The incidence rates range from 0.082% to 2.89% as shown in the table. Studies done outside India, give varying degrees of the incidence and prevalence of ocular injuries.

Studies done in India

Resource and Reference	Year of Publication	Incidence (%)	Study Population
Malik & Gupta[25]	1968	2.7	Delhi
Shukla et al[26]	1979	2.2	Raipur
Parmar et al[27]	1985	0.082	Haryana
Jain & Soni[28]	1987	1.43	Jhansi
Shukla B[29]	2002	6.2/100,000 population/Year	Gwalior

Most of the studies have shown that the highest incidence of ocular injuries is among the young or very young groups except, few which have a bimodal peak with the highest peak in adolescents and young adults, and another peak among those 75 years or older[14], [15] or 65 years and older[10], [11]. Voon et al[30], reported the trauma cases to be more in the less than 40 age group. The highest incidence of ocular trauma as quoted by most of the studies was in the less than 30 age group[11, 18, 31, 32-35].

The percentage of those less than 30 years with ocular trauma is 60% as per the United States Eye Injury Registry (USEIR), 52% as per the Hungarian Eye Injury Registry (HEIR)[32] and between 50-58% as per other studies[18, 33].

Sex Incidence

In most of the studies the incidence is much higher in males than females probably because males are more involved in outdoor activities, majority of the workers

are males in various industries, take involved in sports, indulge more in violence, rash driving.[29] Approximately 80% of those injured are males[15, 16, 22, 30- 34].

Male: Female ratio in the studies done abroad range from 4.3:1 to 6.50:1[6, 8, 33, 36, 37] and those done in India range from 3.00:1 to 5.10:1[25, 26].

Sex Ratio in Ocular Injuries

Resource and Reference	Male: Female Ratio	Place
Karaman[8]	5.4:1	Croatia
Kuhn[6]	4.6:1(USEIR)	USA
Kuhn[6]	4.3:1(HEIR)	Hungary
May DR[33]	4.6:1	USA
Macewen[37]	6.5:1	Glasgow
Glynn[36]	5.5:1	New England
Shukla & Verma[26]	5.10:1	India
Malik[25]	3.00:1	India

The devastating impact of ocular trauma on society is increasingly recognized both in industrialized and in developing nations. Most of the studies report work related injuries to be more common than those at home or at other sites.

Open Globe Injuries

A population-based study involving all residents of Northern Sardinia, hospital records were analyzed to obtain information on open globe injury reported the over all annual incidence was 3.2 per 100,000 with a bimodal age pattern, with peaks at ages 20-24 and 50-59 years. The commonest occupation was "retired" (13.6%); 71% of injuries occurred during domestic or leisure activities[38].

A retrospective study of cases in Queensland, Australia suggests the annual rate of injury was 3.7 per 100 000 for open-globe and 11.8 per 100 000 in total[7].

In a retrospective study, of a series of open globe injuries presenting to a major centre at the Manchester Royal Eye Hospital UK, it was found that injury to the eye with a sharp object accounted for 71/107 (66%) cases and blunt mechanisms for 30/107 (28%) cases. In six (6%) cases the cause of injury was unknown. The rate of secondary enucleation in this series of 107 open globe injuries was 13/107 (12%) [39].

A prospective study of 315 patients in Lithuania with severe open-globe ocular injuries had penetrating injuries (56.83%), perforating injuries (2.54%), globe ruptures (12.38 %), and IOFB injuries (28.25%). Home (53.65%), streets and highways (19.05%) were the most common place of injury, followed by industrial premises (11.11%), agricultural activities (8.25%), recreation and sports (5.40%); 15.56% of cases were work-related. Sharp objects (43.17%) and hammering on metal (24.44%) were the two major causes of injury. Alcohol intoxication was observed in 13.65% of cases[40].

Retrospective analysis was performed of medical records of 1,026 patients with open globe injuries primarily treated at the Universities of Freiburg and Wurzburg, Germany, the risk for open globe injury was 1.7 times the average for young adults and 0.6 for seniors. In the recent years, the risk for severe eye injury has been more equally distributed and is increasing for old people[41].

In USA, Penetrating eye injuries were 3.1 penetrating eye injuries per 100,000 person-years Gun-related injuries caused 33% and motor vehicle crashes caused 21% of the worst outcomes (enucleation or NLP) [42].

A retrospective analysis of the cases with ocular injuries who attended the JIPMER Hospital, Eye Department over a 7 year period (January, 1980 to December, 1986) has been made. 1704 cases had some form or other of ocular trauma, 1439 cases had extraocular injuries, the main causes being foreign bodies in 1278 (90.2%), stick

being the most common object of insult for both penetrating and blunt injuries followed by stone for penetrating injuries[43].

Nirmalan et al, found that the major cause of trauma in a rural population of south India was blunt injuries (54.9%) [3]. Data from the United States Eye Injury Registry and the Hungarian Eye Injury Registry suggest that the most common source of eye injury is a blunt object, 31% and 45% respectively[6]. Blunt trauma (54.4%) topped the list in a Scottish population as others[11].

The nature of blunt object is different in different countries. In the United States, it is rocks, fists, baseballs, and champagne corks, bottle tops whereas in Hungary it is mainly fists, wood branches, rocks, and champagne corks, bottle tops[6, 44]. In Ethiopia the most common causes of perforating ocular injuries were wood, metal and stone objects in 67 (32.8%), 58 (28.4%) and 29 (14.2%) respectively. Most of the injuries occurred during chopping or cutting wood, hammering metals or nails and carving stone, associated with professions such as farming, garage work and carpentry in adults[45].

In Split-Dalmatian County in Croatia the most frequent objects causing mechanical injuries were tree branch or wood (15.9%) causing 26.3% of ruptures and 21.4% of contusions; pieces of metal or stone (13.9%) cause 80.8% of intraocular foreign body lacerations; and nails, wire, or scissors (8.8%) causing 26.7% of lamellar and 23.9% of penetrating lacerations[8].

At the Royal Adelaide Hospital, the predominant referral centre for serious ocular injury in South Australia, the commonest cause of injury was hammering metal followed by motor vehicle accidents. Falls in the elderly were the commonest cause of globe ruptures[46]. In Scotland tools or machinery, either at home (13.9%) or at work (10.3%), were collectively (24.2%) the most frequent cause of injury, followed by assault (21.8%) and sports-related activities (12.5%)[11].

In industrialized nations, motor vehicle crashes are an important source of ocular injuries[15, 34, 47, 48].

The significance of sports and recreational activities in industrialized nations appears to be increasing[16, 49 - 50] which is 9% as per Hungarian Eye Injury Registry and 12% as per the US Eye Injury Registry[6].

Violence is typically responsible for about 15% of the serious eye injuries[16, 31, 50, 51] and upto 43% in the urban setting[34]. In the United States Eye Injury Registry about 16% of the cases are the result of assault[6]. About 34% of those assaulted end up with no perception of light initially at presentation[52].

The United States Eye Injury Registry (USEIR) and the Hungarian Eye Injury Registry (HEIR) have been collecting data on all types of serious ocular trauma, a retrospective analysis, report home as the most frequent place of injury in both countries (USEIR: 41%, HEIR: 35%); industrial premises represented no more than 14%. Guns were responsible for 12% of cases in the USEIR (HEIR, 1%). Champagne corks were identified as a unique and relatively common source of eye injury in Hungary (1.4%, as opposed to 0.07% in the U.S.)[32].

Another prospective study done in Scotland attributes home to be the most common place of injury The home was the most common place for a serious injury to occur (30.2%), followed by the workplace (19.6%) and a sports or leisure facility (15.8%). The home was the single most frequent place of injury for the 0-15 year and 65 year and over age groups. Tools or machinery, either at home (13.9%) or at work (10.3%), were collectively (24.2%) the most frequent cause of injury, followed by assault (21.8%) and sports-related activities (12.5%)[11].

A retrospective case analysis of 899 consecutive patients with ocular injury in Greece showed that most injuries (32.8%) occurred at the workplace, most commonly during construction activities. Injuries at home approximated the work-related injuries (30.0%) [18].

According to Macewen, 69.9% of the ocular injuries occurred at work, 18.3% during leisure and domestic activities (excluding recognized sport), 2.3% during sport, and 1.9% were due to assaults; contact lens injury occurred in a further 2.3%, and the cause was unknown in 5.3%[37].

A population-based study examined the incidence of eye injuries among New England adults reported that fifty-nine percent of eye injuries occurred at work[36] and in another study done at Singapore work-related eye injuries accounted for 71.4% of the cases[30].

Prospective survey of all eye injuries treated at the Royal Victorian Eye and Ear Hospital, Australia reported that the workplace accounted for 44% of all injuries and 19% of severe trauma, including ruptured globes and internal bleeding. Sports injuries accounted for 5% of all injuries, but 19% of severe injuries. The incidence estimate for penetrating eye injuries was 3.6[53].

Studies from India, report that majority of the injuries were occupational than at home [3, 23, 28, 54]. Most ocular injuries in population-based surveys occurred at the workplace, suggesting the need to explore workplace strategies to minimize ocular trauma as a priority[23].

Most of the objects of the world which appear trivial and finite with a superficial acquaintance merge into extreme complexity and ramifications when studied in greater depths and details and ocular trauma is no exception to this. The wide range of ocular injuries, the diverse manifestations and complications, problems of investigations and evaluation, dexterity in management and above all their far reaching implications are simply bewildering to an average ophthalmologist[29].

Work-related ocular injuries though are common but have received little attention compared with other occupational injuries and it contributes to a substantial amount of lost productivity[52]. In the literature about 23 English language reports were

identified that focused entirely on work-related eye injuries or included a substantial proportion of such injuries within the report and the proportion of eye injuries that were work-related ranged from 8%-70%, construction, manufacturing and agriculture were among the most common occupations of the injured workers[52]. Hammering either on metal or with a chisel was the most frequently reported activity at the time of injury and others were handling wire, welding, grinding, drilling, and working with unspecified tools and machinery. The common agents of injury were metal foreign bodies (including wire and nails), wood foreign bodies, and chemicals[52].

The proportion of ocular trauma occurring at work varies between studies, with figures ranging for as low as 13% [55] of all ocular trauma cases at an urban trauma centre at Los Angeles, to as high as 70% reported in the UK[37].

Work-related eye injuries among individuals 15 years of age and older treated in hospital emergency departments (EDs) in the United States Foreign-bodies in the eye and chemical burns were among the most common types of work-related eye injuries[56].

Prevention of occupational ocular injuries

Even though many forms and settings of ocular trauma are preventable, ocular trauma will continue to represent a significant problem in the foreseeable future. Prevention can be effective in the workplace, sports field, and at home with the physicians and individuals being aware that safety glasses can effectively limit ocular injuries and ophthalmologists can and should play a key role in the education of patients[57].

Study from Singapore quotes 20% of patients with work related eye injuries used eye protective devices[30]. The low prevalence of eye protective device use has been a consistent finding in almost every ocular trauma survey in different settings and in different settings[12, 37, 50, 52, 53, 58] and in different industries[59-62].

The term protective eyewear usually refers to the impact-attenuating properties, of frame and lens. A device is defined as protective eyewear if it provides impact attenuation when intense(mass or speed) is placed on the device[63].

The numbers of industrial eye injuries that occur because proper industrial eye protection is not worn suggest the need to provide employees with industrial eyewear that has a pleasing cosmetic appearance and that fits comfortably.

Protective devices should be efficient (offering adequate front and side protection) and convenient (no interference with the peripheral visual field and no fogging-up during use)[64].

A projectile posing a hazard to the eye can be of almost any size or shape, and it can travel at either high or low velocity. Common projectiles in an industrial setting might include pieces of a screwdriver blade, drill bit, grinding wheel, metal debris, rock, and steel rod. They can cause injuries ranging from corneal or conjunctival foreign bodies, to penetration of the eye, to blunt trauma. Some projectiles (especially metals) can be toxic to the eye. There are many ways in which the eyes can be protected from projectiles, but the first line of defense is almost always industrial safety glasses the "**U.S. Occupational Safety and Health Administration (OSHA)**" requires side shields on the frames whenever there is potential for injury from flying objects, but they are not mandatory in all situations and need not be permanently attached. In practice, hazard assessments show that side shields are required in many situations[65].

A new standard, the "**American National Standards Institute ANSI Z87.1- 2003**", was passed recently, which describes requirements for two types of lenses: high impact and basic impact. To be rated as safety glasses, both frame and lenses must adhere to particular ANSI standards. The frames are sturdier than "dress frames," and the lenses must be able to pass a "drop ball" test. Just as the name implies, the test involves

dropping a hard one inch steel onto the lens from the height of 50 inches which generates

0.9J[63]. If the lens cracks or shatters, it fails the test, possibly because it's too thin or the material is defective. Any eye care practitioner who sells safety glasses should be familiar with these standards.

Polycarbonate is the material of choice because of its superior impact resistance, but there may be situations where its use is not indicated. For example, in cold weather a carpenter may have problems with sawdust sticking to polycarbonate lenses because of static electricity. Glass lenses may also be preferable to polycarbonate when scratching of the surface is likely to occur. At one time, workers who wanted photochromic lenses were restricted to glass or CR-39 plastic. The polycarbonate photochromic lenses are now available and are the preferred photochromic lenses for industrial eye protection[65].

The American National Standards Institute (ANSI) is a nongovernmental body, (OSHA), a governmental regulatory agency, requires that all industrial eye and face protectors meet the requirements of the ANSI Z87.1-1989 standard. OSHA may also specify additional requirements, such as the requirement for side shields when there is a potential for injury from flying objects.

Eye protection should be considered in all whose occupation involves some degree of possible injury from the hazards of mechanical injury as in all children, sports persons, car drivers, industrial workers. In general, majority of the spectacle/goggles wearers are not aware of the highly brittle glass lenses in front of their eyes which upon impact would shatter into innumerable sharp splinters. Any accident which causes an impact to the lenses may lead to an eye injury which may be superficial or as serious as the loss of an eye.

Every individual should be aware that toughened safety lenses do exist to protect their eyes from the impact caused by the accident. But toughened lens is not unbreakable and should not be described as such. When a break does occur the glass

crumbles into pieces which maybe rolled between finger and thumb without injuring. There are two types of toughening process-thermal and chemical

Thermally toughened lenses are produced by sudden cooling of both surfaces of the lenses heated to about 650 degree Celsius by blowing forced air from the jets. The process produces a layer of compressed glass on the outer surfaces of the lens whereas glass in the centre develops a tensile thereby giving to the glass the required strength. The ophthalmic lenses having an edge or centre thickness on the order of 2.5 - 3 mm or greater are usually toughened by this process.

The alternate process of chemical toughening offers a higher degree of quality to the lenses as they are heated to only 470 degree celsius which is lower than the strain point of the glass. The process consists of immersing the lenses in a tank of molten salts of potassium to produce chemical equilibrium between the sodium ions in the glass and potassium ions in the molten bath. The ion exchange process displaces smaller sodium ions at the glass surface by larger potassium ions thereby creating high surface compression in the lenses. The process has the advantage of toughening much thinner lenses compared to thermally toughened process .Toughened glass lenses are prone to breakage when subjected to an edge blow. Therefore, it is normally recommended that toughened lenses should preferably be mounted in a plastic frame rather then metal ones for extra safety, since a plastic mount would tend to absorb rather than transmit edge shocks[66].

Toughened glasses find their utility in the making of bullet proof glasses and thus act as a good impact resistant material for use in the protective eyewear.

Modern bullet-proof glass is made of layers of toughened glass and polycarbonate laminates alternately arranged and bonded together.

The overall composition of bullet-proof glass therefore is not very important but the details of the composite are. There is no specific recipe or formula and

there are many different kinds of bullet-proof glass. But all of them are, basically, multi-layered glass-plastic-glass composites.

Glass differs from crystalline materials in internal atomic arrangement. It is irregular in glass as against crystals where the atoms are arranged with perfect regularity.

This regularity leads to the definite possibility of spatial repetition of atoms over very long distances inside the material. In glass, this long-range order does not exist, but there is a kind of order known as the short-range order.

Often this short-range order is the cause of locked-in stresses inside the material in random locations and in random directions.

Therefore when an external stress is applied, the net effective stress is the total of the internal and the external stresses. The net effective stress becomes less than the applied stress, rendering the glass tougher than most of the crystalline materials.

And glass can be made extra tough by specialized heat treatments. Such treated glasses are termed as toughened glass.

Bullet-proof glass is made by binding alternate layers of such toughened glass and polycarbonate laminates. If the force exerted on the front layer of the glass by an object like a fast moving bullet, carrying a large amount of momentum and energy, exceeds the breaking strength, a crack develops in the glass layer.

But immediately, the energy deposited by the impact gets distributed in many directions because the initial crack multiplies into many cracks in different directions.

Importantly, the polycarbonate layer below further absorbs the impact force, distributes it laterally and renders the crack impervious to the next layer of glass. Thus, the bullet loses its energy and momentum, it stops.

The force of the bullet from outside is spread out by the tough plastic layer and the bullet is stopped even if the front glass layer shatters. A bullet fired from in side, however, can puncture the polymer layer easily before breaking the glass locally, only slowing down the bullet slightly[67].

Higher quality, more expensive Plano eyewear may be more cost efficient in the long run because workers are more likely to wear a protector that has been individually adjusted for maximum comfort. Moreover, when workers experience "ownership of the spectacles, they may be less likely to regard them as disposable (which can lead to high replacement costs).

Standards for industrial eyewear differ considerably from those for everyday, non-industrial (dress) prescription eyewear. Some of the most important differences include the impact resistance requirements and, for the industrial standard, specific requirements for the design and strength of the frame.

Gunshot has recently been cited as resulting in the highest rate of blindness and the lowest rate of visual recovery. Many of these cases are hunting accidents in which safety glasses could have prevented or lessened ocular damage.

A study was done to evaluate the effectiveness of various types of safety glasses; a Remington automatic shotgun was fired at mannequin heads fitted with one of four types of safety lenses. At 30 yards, polycarbonate and heat-treated lenses provided the best protection, whereas chemically treated and CR39 lenses provided significantly less protection[64].

An adjustable strap wraps around the head to help keep the eyewear from falling off during activity. The lenses are coated with an anti-scratch out layer plus they are made from an impact resistant polycarbonate for tougher durability

Although many forms and settings of ocular trauma are preventable, ocular trauma will continue to represent a significant problem in the foreseeable future. Prevention can be effective on the sports field, in the workplace, and in the home setting.

The patients and the physicians need to be aware that safety glasses can effectively limit ocular injuries in a variety of settings. Education and common sense are two additional factors that can effectively reduce the number of ocular injuries and ophthalmologists can and should play a key role in the education of patients

Stone quarries and ocular injuries

Stone quarry workers are a group of people who are especially exposed to ocular trauma by the nature of their work and the lack of organized health care facilities at their places of work.

According to the Directorate General of Employment and Training National Classification of Occupation, India 2007, **stone** quarry workers come under Division 7, Group 71, Family 712, and subclass 71210 and 71220

Crafts and related trade workers come under Division 7 of the above classification.

"71210 Quarryman, Stone; Miner Stone: extracts various kinds of stone from quarries or open pits; removes loose soil and mud from surface and sides of blasted deposits using shovel; removes slabs of stones from earth with crowbar, wedge or pick and breaks them into convenient size using sledge hammer; dresses rough surface of stone and granite blocks by chipping and cuts them as instructed to require shape and

size; may drill shot holes in quarry face for blasting. They may sort out ore and mineral according to quality.

71220 Quarryman, other: extracts china clay, lime stone, fire clay and other non metal deposits from quarry by cutting breaking etc. using pick axe, crow bar,

spade and other tools; digs soil to reach deposits; drills specified shot holes of required depth in rock faces for blasting by SHOT FIRER; extracts lime stone, china clay, fire clay and other deposits from blasted quarry faces using shovel pick axe, crowbar etc; breaks large pieces in to convenient size with hammer and gets them removed or specified place; may charge and ignite explosive. They may specialize in extracting china clay using pick axe, shove land spade; may carry basket filled with china clay to specified place; may de-water quarry with pump or bucket, remove mud and perform alike duties if required[68].**"**

Minerals constitute the backbone of a Nation's economy and contribute directly and indirectly to its prosperity. The stones of India have ever since ages inspired the world for their beauty and elegance and have been used extensively in one of the best masterpieces that human kind has ever built. We are the largest producer of stones in the world and third largest exporter of stones in the world.

Stone quarries in Tamil Nadu

Mineral Wealth has a significant contribution in development of the nation as well as the State. The State of Tamil Nadu is the southern province of the Indian Peninsula. The rich and varied mineral resources of the State have contributed handsomely towards the development and industrialization of the State. It is one of the leading States in the reserves of the following minerals: Lignite, Garnet, Magnesite, Quartz, Feldspar, Clay, Limestone, Bauxite, Graphite and Granite. Tamil Nadu is endowed with vast resources of Granite of different colours and shades. The total reserves of granite are about 710 million cubic metres.

Granites are used in building facading, flooring, decorative & ornamental uses and in monuments. Kunnam Black of Tindivanam, Paradiso of Dharmapuri, Jubrana of Pudukkottai, Kashmir White of Madurai are popular varieties in the international market.

Black Granite occurs in the districts of Kancheepuram, Vellore, Villupuram, Dharmapuri, Salem and Erode. Other coloured Granites occur in Dharmapuri, Pudukkottai, Madurai, Salem and Namakkal districts [69].

Number of the Mining Quarrying Units in the District (Vellore)

Year: 2005-2006

Sl No	Name of the Taluk	No of Mining quarrying

Year: 2005-2006

Name of the District	Name of the Minerals	Quantity (Tonnes)	Value (Rs. in '000')
(1)	(2)	(3)	(4)
	VERMICULITE	MT 1375.000	94000
Vellore	BLACK GRANITE	CBM 6147.696	17916000
	COLOUR GRANITE	CBM 859.538	1287625
	BRICK EARTH	CBM 25226.620	93800
	STONE(BLUE METAL)	CBM 191293.850	17445035
	EARTH	CBM 142643.320	3571328

Source: Assistant Director of Mines & Minerals, Collectrate, Vellore-9.

Production and Value of Major Minerals

The above tables depict the resources of Vellore district including the production and the revenue earned from the different types of minerals.

Eye care programs targeting high-risk ocular trauma groups may need to consider ocular trauma as a priority in eye health awareness strategies to reduce blindness due to trauma.

Quarries in India employ several hundreds of workers, both men and women who are vulnerable to ocular injuries either while actively involved with work or as a bystander. Compared with construction workers, workers employed in mining and

quarrying are at significantly elevated risk (Odds Ratio = 2.7) of multiple non-fatal injuries[70].

Special issues in providing protective eyewear in quarry workers

The quarry owners do not, as a rule provide health care benefits nor protective apparel or eyewear. Financial reasons preclude the routine use of protective eyewear as an individually initiated activity among quarry workers and the design of such protective eyewear would need to allow for flying stone chips creating the need for scratchproof glasses and also needs to allow for fogging of lenses due to sweat and other occupational problems inherent in the nature of work in quarries.

A large proportion of subjects with visual impairment even in urban populations in India did not seek treatment even after noticing decrease in vision[24]. Hence protective eyewear and education for quarry workers would need to be proactive and provided in their place of work.

Reports on ocular injuries to stone quarry workers are scant. In one report from Lebanon on rock drillers who use pneumatic drills, sub-epithelial corneal opacities were found in 12/19 drillers (63%) and none of 20 controls; pigmented trabecular meshwork was noted in 13 drillers (68%) and 1 control (5%); low-tension glaucoma was diagnosed in 1 driller (5%); vitreous liquefaction was present in 17 of 17 drillers (100%) examined by a retina specialist and 9 of 20 controls (45%)[71].

We did not find any reports on ocular injures among quarry workers in India. We also did not find reports on the use, efficacy and acceptance of protective eyewear in preventing ocular injuries to quarry workers. Our pilot study has shown that usage of protective eyewear is effective in reducing ocular injuries but regular usage and acceptance needs to improve.

Stone Injuries

A total of 319 cases of ocular injuries were examined in a period of 3 years by Jain and Soni out of these only 108 cases needed hospitalization in the ALB Medical College, Jhansi, India, most of the patients involved were industrial workers (which in this area is mostly due to abundance of stone crushers) (178 cases 55.8%) followed by farmers (66, 20.8%).

The stone quarry workers form a large part of the unorganized sector workers in the state, second only to the agricultural workers.

Simple measures such as education regarding the use of protective eyewear could possibly significantly decrease this preventable cause of visual disability[72]. Eye health promotion strategies are warranted to raise awareness about the causes and prevention of corneal blindness[72].

Ophthalmology has a vital role of play in the emerging new branches of medicine like industrial/occupational medicine. The three components of an eye care system in an industry are vision screening, determining the vision requirements and eye hazards and advising on appropriate protective and corrective eyewear[73].

Methodology

Phase I: Pilot Study

A pilot study was done July – October 2005 at the quarries at Bagayam. This was done to determine the type of ocular injuries sustained by the stone quarry workers and to assess the acceptance of protective eyewear.

A cohort of 218 quarry workers aged between 18-65yrs of age and not already using spectacles for refractive errors and presbyopia were included in the study.

Health Education was given to the workers about the different kinds and modes of ocular injuries that they are prone to get and the importance of wearing protective eyewear. This was in the form of didactic talk and posters. A proforma consisting of demographics of the workers and injuries in the past three months were noted. An ocular examination with the help of a torch and a hand held slit lamp was done for all the workers followed by the distribution of protective eyewear. Follow-up consisted of a questionnaire regarding the use of protective eyewear and the problems with its usage. At the end of three months and within a week every member of our cohort was followed up and objectively assessed regarding the usage of protective eyewear. Acceptance of eyewear was assessed by a health worker and our team during surprise checks into the quarries. As the objective was to measure the acceptance of the eyewear, we didn't include a refraction and vision assessment as part of our protocol.

Our first objective was to get a historical incidence of ocular injuries; we found that 15.1% of the workers reported a history of some ocular trauma at work that caused enough discomfort to seek treatment in the previous three months. Though 2/3rd of the workers were males and though the number of males injured were more than females, this difference was not statistically significant ($p = 0.75$). The right eye was more likely to

be injured, probably because the majority of the workers were right handed,. We analyzed the effect of duration of years of work and eye-injury between those who had <5 years of experience with those more than 5 years. We found that a greater amount of experience of work doesn't confer immunity from injury to any worker (p= 0.93). The mean duration of work in years of those injured and those not injured was also not statistically significant (p = 0.82).

At the end of three months we followed up each worker of the cohort and found that 86.2% (188/218) of the workers used the protective eyewear provided. Reasons for discontinuation stated were: Staining of the eyewear with sweat; Scratches on the lenses rendering vision difficult; Feeling of heaviness; Unable to see objects clearly. The incidence of new injuries over this time period was 6%

This pilot study demonstrated that ocular injuries are common in quarry workers but majority are not vision threatening injuries. Protective eyewear does reduce the incidence of eye injuries, and quarry workers were interested in protecting their eyes with protective eyewear. However, we also found that the protective eyewear provided was prone to scratches leading to discontinuation of their use. Further efforts would need scratch resistant eyewear and education on use to improve adherence and acceptability. The protective eyewear that we used for the pilot study scratched easily within 10days to 2 weeks which led to discontinuation in the usage of the protective eyewear.

Phase II: Intervention:

A Pragmatic Cluster Randomized Trial to Evaluate the efficacy of Impact resistant Scratch-proof protective eyewear and different levels of educational interventions in preventing ocular injuries in stone quarry workers.

We planned a Cluster randomized trial taking into account all the workers in the quarry to be a cluster to avoid the threat of contamination of the intervention between the enhanced and the standard groups if randomization was done by individuals. In such a situation randomization by group is the only feasible method of conducting the trial.

The present study assesses the efficacy and acceptability of newer impact resistant scratch proof protective eyewear and *two strategies* of education, one more intensive than the other.

Methods:

Six quarries in and around Vellore were included in the study after formal informed consent from the stone quarry owners and the quarry workers individually after explaining to them regarding the purpose of the study. The study design and this method of obtaining informed consent were approved by the research committee of the Christian Medical College, Vellore. This study was performed from September 2006 through March 2007.Three quarries were randomly allocated into the Standard educational intervention group and three quarries into the Enhanced educational interventional group. Randomization and allocation of the quarries were done by the co-investigator not involved in delivery of the intervention. The outcome assessors were blind to the allocation to Standard or Enhanced interventions.

Inclusion criteria

- Each quarry should have at least 30 workers
- Workers must be aged 18 to 60 years

Exclusion criteria

- Workers already using spectacles either for any refractive error or presbyopia,
- Workers who regularly work in a particular quarry but were unable to come for the first two visits of intervention.
- Workers those who have joined the quarry after the study has started.

A total of ten stone quarries were assessed for eligibility of which as per requirements only six quarries were included in for the study and the other four were excluded from the study as they did not meet the inclusion criteria.

The six quarries were allocated into the enhanced and the standard groups. The quarries were visited by a team consisting of an ophthalmologist and health educators and the workers in all the six quarries were explained regarding the purpose of the study and educated on the different kinds and modes of ocular injuries that they are prone to get, the complications with the injury, and the importance of wearing protective eyewear. The initial health education was common for the Standard and the Enhanced groups which consist of didactic talks, posters showing various minor and major ocular injuries and their consequences and instructions regarding the care, handling and usage of the protective eyewear that was given to the workers.

A proforma consisting of the demographics of the worker, regarding any past injuries and injuries specifically in the past three months which caused enough discomfort to the individual to seek treatment, the details of the injuries, the nature of work, nature of injury, ocular findings, were filled up.

At Baseline, vision was checked unaided and with a pinhole with a Snellen 'E' chart in the quarries with the available conditions to get a rough estimate of the visual status of the individuals. We categorized them into six grades as per the World Health

Organization, 1992 system (International Statistical Classification of Diseases and related health problems, Tenth revision). Refraction was not included as part of the protocol.

Ocular examination with the help of a torch and a portable hand held slit lamp was done on all the quarry workers to look for evidence of any old and fresh injuries, foreign bodies in the conjunctiva and on the cornea. The injuries were charted and the charts were locked away and not referred to till the end of the trial.

Scratch proof impact resistant toughened protective eyewear with side shields were given to all the workers included in the study to be worn without fail while working in the quarry. Those workers who did not fulfill the criteria were excluded from the study but every worker in the quarry was provided with the protective eyewear.

The Standard group had the initial education given and the protective eyewear to start with, following which they were followed up twice in the first month, once in the second and third month and at the end of six months.

The Enhanced group got the standard initial education and the protective eyewear but was followed up every week in the first month, twice in the second and third month, once a month in the fourth, fifth and sixth month.

There were

- Group education and motivation of the workers to wear the protective eyewear provided.
- Individual discussions were held with those not using the protective eyewear, and to find out the reasons for not using the protective eyewear and to encourage them to use the eyewear.
- Group discussions and suggestions within the groups regarding the eyewear, and any problems with the eyewear.

- To motivate the workers within the cluster to support each other in wearing the protective eyewear, entertainment programme in the form of folk songs and pre recorded short plays stressing on the ocular injures and the need to wear the protective eyewear were conducted for the enhanced group.

To assess the compliance of the quarry workers to the eyewear one worker in each quarry was asked to observe the workers who were regular defaulters and to report it to the study group during subsequent visits. Acceptance was also assessed by our team during our surprise visits to the quarries.

Protective eyewear was replaced at any point in both the Standard and the Enhanced groups, as few of them were kept with the supervisor of the quarry and the old replaced eyewear assessed. The supervisor was in constant touch with the study group regarding the workers and any injury to them while working, and regarding the need for more eyewear.

The follow up for both the groups was done by an ophthalmologist who was not involved in delivering the intervention, containing the same questionnaire regarding the use of the protective eyewear, problems with the use of eyewear, injuries following the use of eyewear, assessment of the protective eyewear after using it for at least a month, at 3 months, and at 6 months

A slit lamp examination was done at 3 months and at 6 months to assess injuries and all injuries charted. These charts were compared to baseline charts.

The primary outcomes were acceptance and regular usage of protective eye wear and fresh injuries to the eyes after the start of the interventions. These outcomes were compared within the sample and also compared between groups.

Statistical Methods

Sample Size

We calculated sample size with a method that takes into account the intracluster correlation coefficient, size of the cluster, the expected effect, and the power of the study. Our pilot study had an intracluster coefficient of 0.04, a minimum of 30 workers in each quarry (cluster). With these parameters we anticipated a power of 85% to detect a difference of 15% in acceptance rates between the Standard and the Enhanced groups with alpha error of 5%, a total of 182 workers in 6 quarries. Additionally if we were to assume a baseline injury rate of 15% and a reduction in injuries to 6% for the standard intervention and 0% for the enhanced intervention, we would need 180 workers.

Descriptive statistics were obtained for all study variables. Continuous variables were summarized using mean and standard deviation; categorical variables were described using percentage and frequency. The intra-cluster correlation coefficient was calculated for the present study and found to be negative (ICC=-0.02) and negligible (). Hence standard methods of analysis were performed. Chi-square test was done to associate categorical variables with injury rate. P-value of 0.05 was considered statistically significant. Results were presented with 95% confidence interval. All the analysis was done in SPSS 13.0.

RESULTS

Six stone quarries were included in the study and each quarry was considered to be a cluster of which three were in the enhanced group and other three were in standard group. The number of workers of each cluster is shown in **Table 1**.

Table 1

Group	Cluster Number	Number of Workers
Standard	1	34
	2	33
	3	34
Enhanced	4	35
	5	35
	6	33
Total		**204**

Figure 1: Flow of Workers through Trial

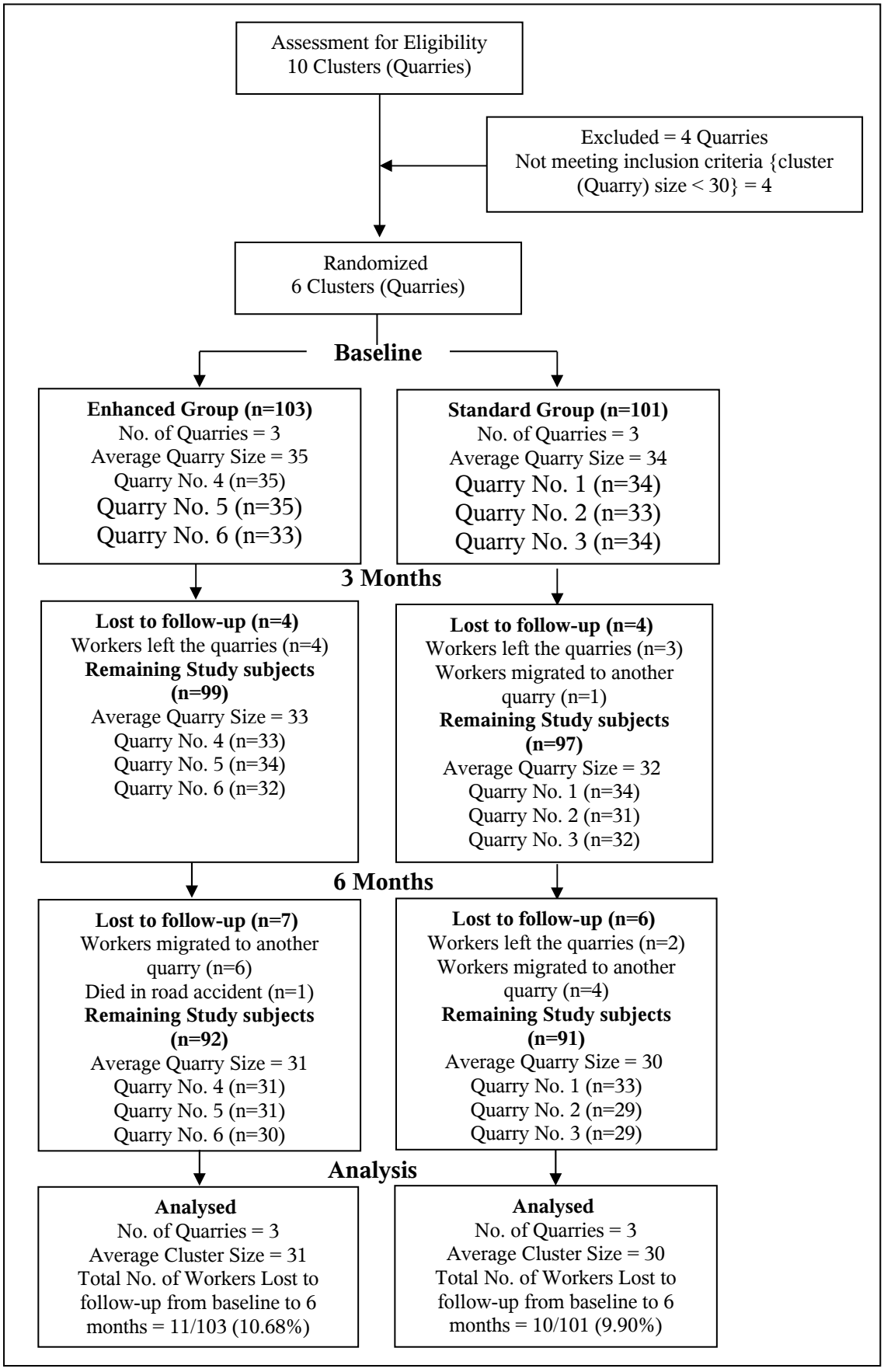


Figure 1 shows the flow of workers in quarries from the beginning (baseline) of the study, at three months and at six months. Overall 204 workers in the six quarries took part in the study which was divided into the enhanced and the standard group comprising of 103 and 101 workers respectively. Overall 92 workers out of 103 in the enhanced group and 91 out of the 101 workers in the standard group completed the study.

The number of drop outs in the Enhanced group in the six months period was 11/103 and that in the Standard group was 10/101. None of the clusters (quarries) dropped out.

Table 2 shows the comparison of demographic profile, socio-economic status and work characteristics between the enhanced and the standard group at baseline.

Table 2: Baseline Characteristics of the Study Subjects

Characteristics	Enhanced (n=103)	Standard (n=101)	p Value
Age	38.7(10.4)	39.3(10.6)	0.67
Sex(%female)	24(23.3%)	22(21.8%)	0.867
Literates	49(47.6%)	44(43.6%)	0.577
Income less than 1000	26(25.2%)	16(15.8%)	0.10
Work years	14.4(9.3)	14.5(9.1)	0.91
Cutting small stones	19(18.4%)	19(18.8%)	0.947

There was no significant difference in the age and sex distribution and educational status between the two groups. Literacy rates were similar between the two groups with more than half the workers being illiterate in both the groups.

25.2% of the workers in the enhanced group had income less than Rs.1000 per month and 15.8% of the workers in the standard group had the similar outcome.

The work experience between the workers in both the groups was not significantly different and the average being just under 15 years.

81.6% of the workers in the enhanced group and 81.2% in the standard group were engaged in cutting large stones. Most of the workers work for 6 days a week (76.7% in the enhanced group and 68.3% in the standard group).

Eye Injuries Before and After Intervention

The incidence of any eye injury in the past was high in both the groups. More patients in the standard group had a past history of eye injury. We mainly chose to compare the ocular injury rate in the past three months before intervention and that following intervention to avoid recall bias.

The incidence of ocular injury in the past three months before intervention was around 18% in either group.

In the first three months following intervention, the injury rate had dropped to 3.0% in enhanced group and 5.2% in the standard group. From 4^{th} to 6^{th} month, the injury rate was 4.3% and 6.6% respectively in the enhanced and standard group.

Overall injury rates at the end of intervention were less in the enhanced group compared to the standard group although the difference was not statistically significant.

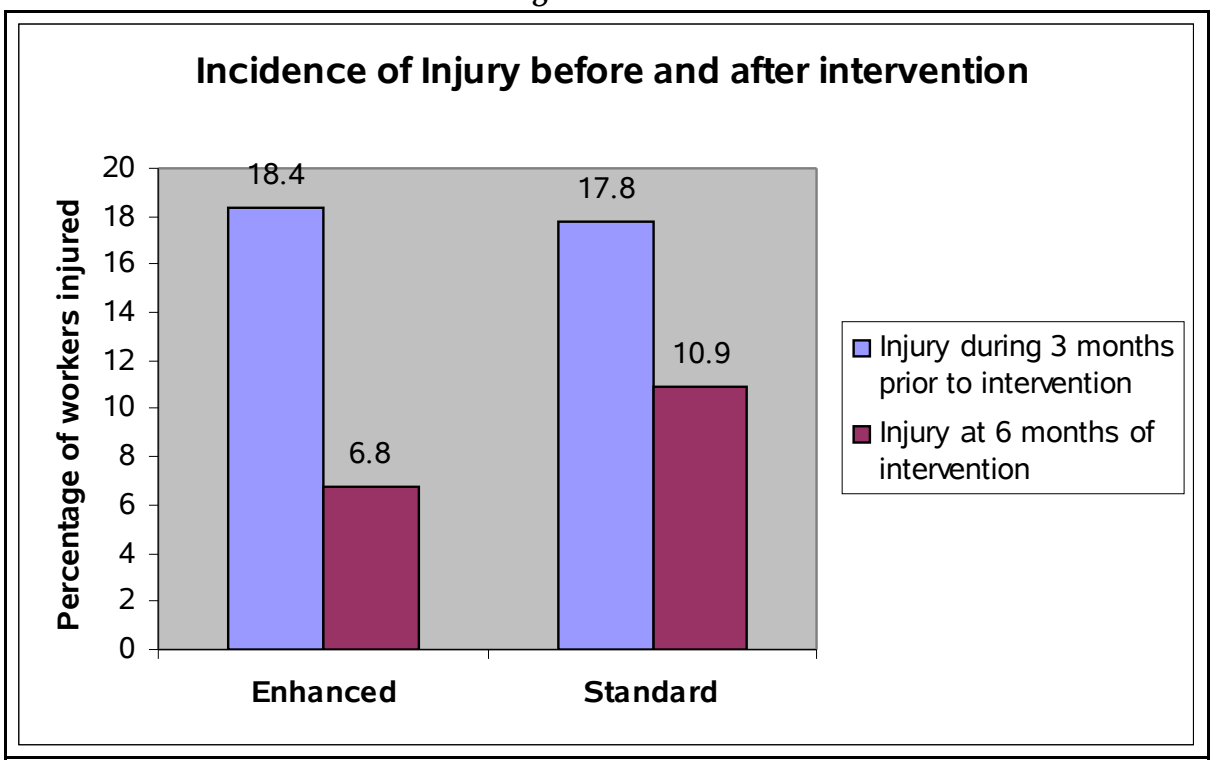
In 57.3% of the workers in the enhanced group another family member was also engaged in stone cutting as compared to 47.5% in the standard group.

Table 3: Temporal profile of eye injuries prior to and after intervention

Time points	Group	Injury	Injury Rate	95 % CI	p
Any injury in the past before intervention	Enhanced (n=103)	80	0.777	0.68-0.85	**0.08**
	Standard (n=101)	88	0.871	0.79-0.93	
Injury in the past 3 months before intervention	Enhanced (n=103)	19	0.184	0.11-0.26	**0.91**
	Standard (n=101)	18	0.178	0.1-0.25	
Injury in the first 3 months after intervention	Enhanced (n=99)	3	0.03	0.003-0.06	**0.50**
	Standard (n=97)	5	0.052	0.007-0.09	
Injury from 4th to 6th month after intervention	Enhanced (n=92)	4	0.043	0.002-0.08	**0.54**
	Standard (n=91)	6	0.066	0.02-0.12	
Cumulative injury 6 months after intervention	Enhanced (n=103)	7	0.068	0.02-0.11	**0.30**
	Standard (n=101)	11	0.109	0.05-0.17	

The overall incidence of ocular injuries in the three month prior to intervention and at the end of intervention (6 months) is shown in **figure 2**.

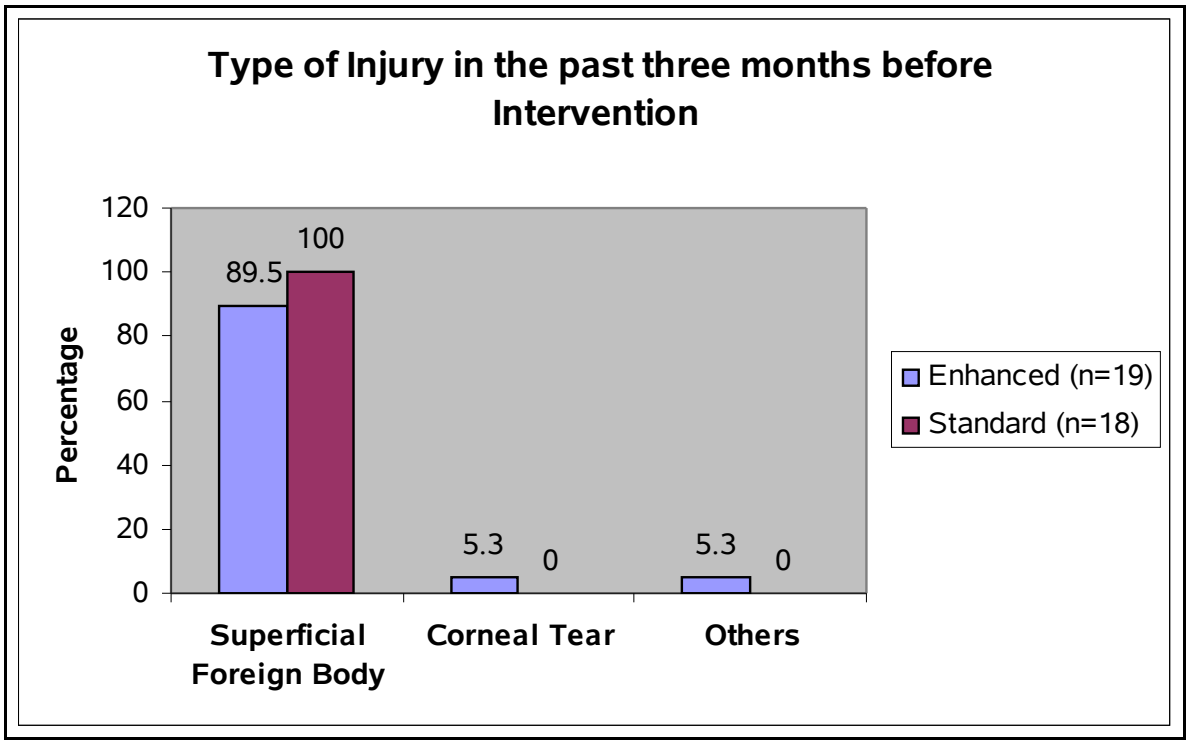
Figure 2



Type of Injuries in the Past and Post Intervention Period

Of the 204 quarry workers who were included for the study, 7 (3.4%) workers (3 in the enhanced group and 4 in the standard group) gave history of serious injury to one eye while cutting stones. Of the seven, 5 have vision less than 1/60 to perception of light and 2 have vision ranging from less than 6/60 to 3/60. One worker had corneal tear, traumatic cataract, intraocular foreign body and retinal detachment for which surgery was done else where. Another worker also had a past history of corneal tear suturing and intraocular foreign body removal. Two had traumatic cataract, and 3 had past history of corneal tear suturing and found to have corneal scar causing decreased vision.

Figure 3



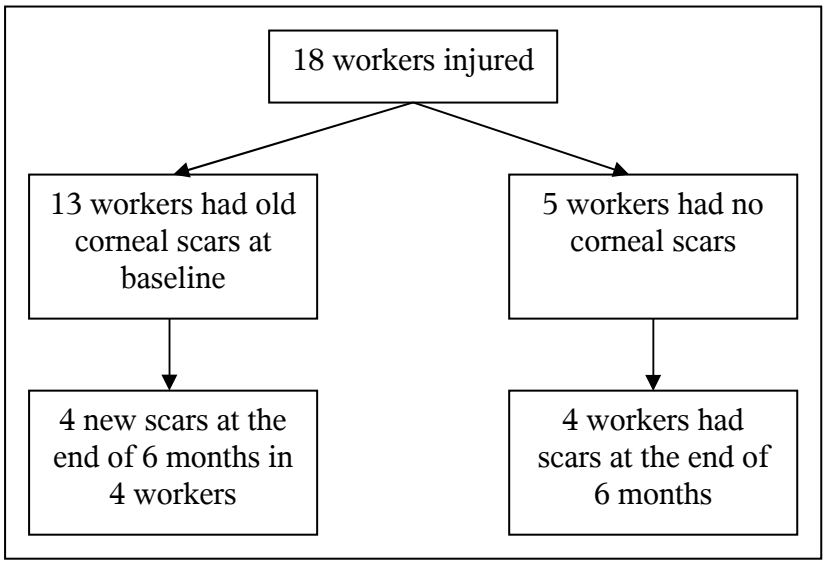
Since we aimed to compare the injury in the past three months to that after six months of intervention we specifically enquired about injury in the past three months. Most of the injuries in the past three months before the intervention in the enhanced group were from superficial foreign body except 1 corneal tear and a traumatic cataract as shown in figure 2. All injuries in the standard group were superficial.

In the 6 months follow-up period after intervention, all the injuries were superficial injuries and none were vision threatening.

Eye Findings

Of the 18 patients in both the Enhanced and Standard groups who had new ocular injury over a period of 6 months (baseline to 6 months), 13 patients had corneal scar both non-linear and linear scar at baseline and at the end of 6 months intervention, 8 new scars were found. Out of the 8 new corneal scars, 5 were non-linear scars and 3 were linear scars and none were vision threatening.

Figure 4



Hence 44% (8/18) of the workers developed new corneal scar following injury while cutting stone.

Source of primary treatment post injury

Figure 5

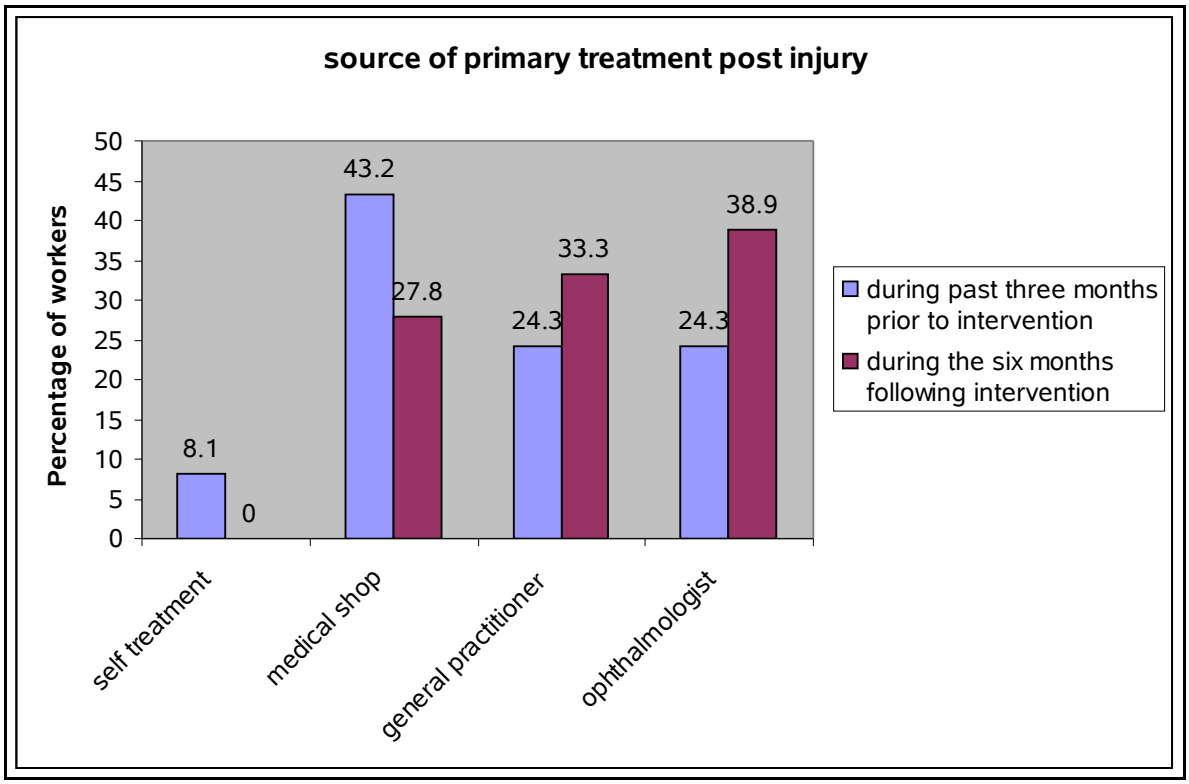


Figure 5 shows the health seeking behavior of the quarry workers following ocular injury 3 months prior to intervention and 6 months post intervention. 3 months before intervention, majority (43.2%) of the workers got treated with drugs from the medical shop and 8.1% (3/37) had self treatment. Following intervention and at the end of 6 months, the trend seems to be on the rise from medical shop to general practitioner to the ophthalmologist.

Acceptance Rate

Over the 6 months period the acceptance rate of protective eye wear remained around 90%.This was gauged taking into account whether the worker used the protective eyewear for work on a daily basis. This information was achieved by our observation during surprise checks in the quarries and information from one of the workers who without telling the other co-workers in the quarry would let us know regarding the defaulters and from the workers themselves. In the standard group, the acceptance which was 82.5% at 3 months dropped to 75.8% at 6 months as shown in **Table 4**.

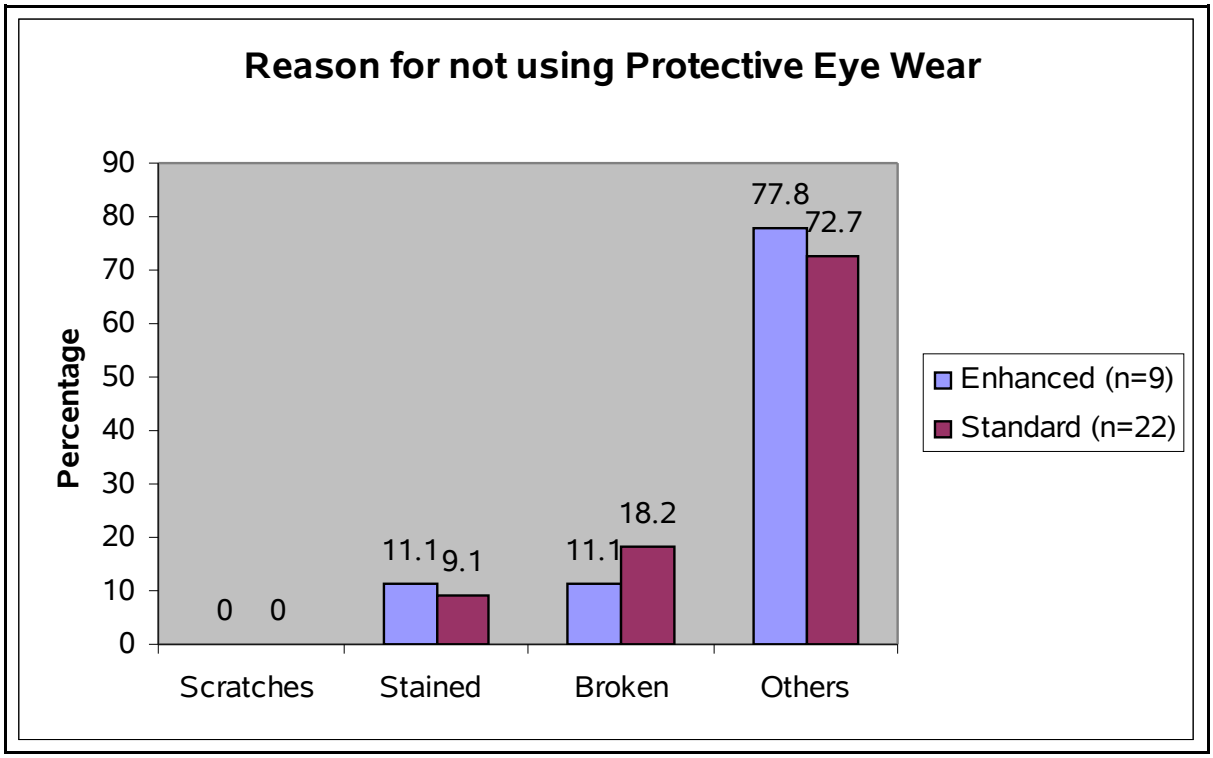
Table 4: Acceptance of protective eyewear during study period

Time points	Group	Acceptance	Acceptance Rate	95 % CI	p
Acceptance in the first 3 months after intervention	Enhanced (n=99)	90	0.909	0.83-0.95	0.08
	Standard (n=97)	80	0.825	0.73-0.89	
Acceptance at 6 months after intervention	Enhanced (n=92)	83	0.902	0.82-0.95	0.009*
	Standard (n=91)	69	0.758	0.65-0.84	

Reasons for not using Protective Eyewear

The reasons for not using the protective eyewear were not because of scratches or staining but for various other reasons like:

Figure 5



- Size of the protective eye wear either small or big.
- Side shields with projection pressing on the orbital rim causing discomfort.
- Not fashionable.
- Interfering with vision.
- Have not any injuries in the past therefore does not want to wear.

Table 5: Comparison of baseline characteristics with acceptance of protective eyewear (At 6 months)

	Accepted(n=152)	**Not Accepted(n=31)**	**p**
Literacy	74(48.7%)	11(35.5%)	0.18
Income >Rs.1000	31 (20.4%)	7 (22.6%)	0.79
Work Experience (median , interquartile range)	14 (12)	15(10.5)	0.79
Type of Work (Cutting large stones)	127(83.6%)	21(67.7%)	0.04*
Any eye injury in the past	128(84.2%)	26(83.9%)	0.96
Family history of eye Injury	91(77.8%)	13(61.9%)	0.12
More than 1 family member working in the quarry	36(23.7%)	5(16.1%)	0.36

*** Statistically Significant**

Table 5 shows that there is no statistical difference in the baseline characteristics between those who continued to wear the protective eyewear and those who didn't, except that the majority of the workers who wore the protective eyewear were those who were cutting large stones.

Table 6: Comparison of baseline characteristics with Injury (6 months)

	Injury	No Injury	p
Literacy	11(61.1%)	82(44.1%)	0.16
Income >Rs.1000	12(66.7%)	150(80.6%)	0.22
Work Experience (Median, Interquartile range)	19(14.5)	14 (12)	0.39
Type of Work(Cutting large stones)	15(83.3%)	151(81.2%)	0.83
Any eye injury in the past	14(77.8%)	154(82.8%)	0.59
Family history of eye Injury	11(73.3%)	102(73.9%)	0.96
More than 1 family member working in the quarry	5(27.8%)	40(21.5%)	0.54

Table 6 shows that there is no statistically significant difference in the baseline characteristics between those injured and those who were not injured.

Durability of the Protective eyewear

In the course of this trial, we tried to assess the durability of the protective eyewear. Since we found that in the pilot study, the protective eyewear that was provided lasted only for about 10 days to 2 weeks. From baseline to 6 months, most of the damage that was done to the protective eyewear was due to the splinters and fragments of stone.

About 17% (35/204) of the protective eyewear had to be replaced at the end of 3 months and overall and at the end of 6 months 39% (80/204)

Discussion

Indian data on prevalence of ocular injuries among quarry workers is scarce and there is no published study on the result of any preventive intervention. In this regards we didn't have any comparison to make with our study.

Most of the workers were males as compared to females which is tune with the local culture where women mainly take care of household work and men go out for earning. More than half the workers were illiterates and one possible explanation for this may be the fact that the children take up the quarry work quite early to add to the family income rather than go to school. The work experience of the workers averaged around 15 years and most of them were engaged in cutting large stones.

A high proportion of workers (approximately 80%) already had ocular injury at some point in the past but continued to work. Thus, an intervention to reduce ocular injury appeared to be much more practical than advice on change of work. 3.4% of these injuries were serious which is much less than 63.9 % (partial or total blindness) than that reported by Jain et al from Rajasthan[28]. The explanation for this lies in the fact that theirs was a hospital based study where usually workers who are significantly injured seek medical attention (selection bias). Among our workers only 30% of them consulted an ophthalmologist for the injuries suffered prior to intervention.

The injury rate in the three months prior to intervention which was 18.4% and 17.8% in the enhanced and standard group respectively dropped to 6.8% and 10.9% in the respective group. Overall 1% of the workers had a sight threatening injury in three months prior to intervention as compared to none after intervention. Therefore provision of protective eyewear had a significant impact in reducing the injury rate and preventing serious injuries. The standard and enhanced groups did not differ significantly in the

injury rate at the end of intervention. A positive interpretation of this observation may be that provision of protective eyewear alone has a significant impact in injury reduction without having to resort to utilizing added man power for continual worker motivation and education.

The standard group had higher injury rate (although not significant statistically) and significantly lower rate of acceptance of eyewear at the end of intervention. This lower rate of acceptance may explain the higher rate of injury and probably a longer follow up study might be able to bring out the injury rate difference in a significant manner. Hence continued motivation and education of workers about importance of using protective eyewear may be beneficial in the long run. We were able to achieve a significantly higher acceptance rate in enhanced group as planned in the study by periodic visits and patient education and motivation.

Only **15%** of workers required a change in the eyewear due to scratches, staining or breakage and hence these were quite durable. The commonest reason for dropping out was migration to other quarries and this again reiterates the point that the workers seldom change the nature of their work although they may change their location.

Limitations of the study

The main limitation of the study was the short duration of follow up. Since the average work years was fifteen years a larger follow up study is needed to assess the long term impact of using protective eyewear.

Strengths of the study

This is the first study from India to focus on the prevalence of ocular injury in this vulnerable population of stone quarry workers and to design an intervention to prevent this. The pilot study provided useful information on which to design better protective eye-wear and the pragmatic nature of the intervention permits generalization and replicability to other quarries in India. The cluster randomized trial was designed according to

CONSORT guidelines for cluster randomized trials[74] and the validity of the trial was ensured by adequate concealment of allocation to the intervention arms and the blinding of outcome assessors. This study shows that over the short term, protective eyewear is acceptable to quarry workers and effective in preventing serious ocular injuries.

Conclusions

Mandatory provision of protective eyewear by the employers to the quarry workers and ensuring their continual usage may go a long way in reducing ocular injuries. Longer periods of follow up would determine the long term acceptability of protective eyewear, the frequency with which they need to be replaced and the continued effectiveness of this strategy in prevention of ocular injuries in stone quarry workers.

Bibliography

Appendix I

Proforma

Vision	1. Right	2. Left
Unaided		
Pinhole		

Serial Number:

Cluster Number:

1. Name:
2. Age:
3. Sex: 1. Male 2. Female
4. SES: 1.Family income / month
5. Education: 1. Illiterate 2.Class studied:
6. Number of Years of Work in the quarry:
7. Number of days of work/week:
8. Type of work: (Breaking) 1.Large stones 2.Small stones
   3.Loading
7. How many family members work in the Quarry:
8. Anyone else in the family with history of eye injury:
9. Any Eye injuries in the past:
   a. 1. Yes 2. No
   b. Number of Eye Injuries
   c. Eye involved: 1. Right Eye 2. Left Eye 3. Both Eyes
   d. Outcome: 1. Asymptomatic 2. Impaired Vision 3. Lost Vision
10. Any Eye injury during the past 3 months:
    1. Yes 2. No
    a. Number of Injuries:
    b. Eye involved: 1. Right Eye 2. Left Eye 3.Both Eyes
    c. Injury as: 1.Direct 2.Bystander

d. Type: 1. Foreign Body (Superficial) 2. Corneal Tear
3. IOFB 4. Others

e. Time of injury: 1. Morning 2. Afternoon 3. Evening

f. Outcome: 1. Asymptomatic 2. Impaired Vision
3.Lost Vision

11. Primary Treatment: 1.Self Treatment 2.Traditional Practitioner
3. Medical Shop 4. General Practitioner
5. Ophthalmologist

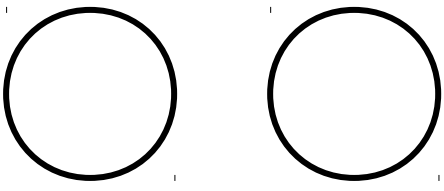
12. Was Ophthalmologist consulted if not consulted primarily: 1.Yes 2.No

13. Interval between time of injury & intervention:
    a. Injury 1
    b. Injury 2
    c. Injury 3

14. Expense for treatment:

15. Nature of Injury:
    1.Not vision threatening:
    2.Vision threatening

16. Eye findings: 1.Scar 2. Linear Scar 3.Others



Follow Up

1. Using Protective Eyewear:

   1.Yes

1	2	3	4	5	6	7	8	9	10	11

2.No

2. Number of days of Protective Eyewear usage per week:

1	2	3	4	5	6	7	8	9	10	11

3. Number of working hours per day the protective eyewear is worn:

4. Reason for not using protective eyewear:

1	2	3	4	5	6	7	8	9	10	11

1	2	3	4	5	6	7	8	9	10	11

   1.Scratches 2.Stained 3.Broken

   4.Others

5. Any injury following provision of Protective Eyewear:

1	2	3	4	5	6	7	8	9	10	11

   1. Yes 2. No

   a. Were protective eyewear worn when injured

1	2	3	4	5	6	7	8	9	10	11

   1. Yes 2. No

   b. Number of injuries

1	2	3	4	5	6	7	8	9	10	11

c. Injury as

1. Direct 2. Byestander

1	2	3	4	5	6	7	8	9	10	11

d. Eye involved

1. Right

1	2	3	4	5	6	7	8	9	10	11

2. Left 3. Both

e. Type

1	2	3	4	5	6	7	8	9	10	11

1. Superficial foreign body

2. Corneal tear 3. IOFB

4. Others

f. Treatment taken

1	2	3	4	5	6	7	8	9	10	11

1. Self Treatment 2. Traditional Practitioner

3. Medical Shop 4. General Practitioner

5. Ophthalmologist

6. Vision Following Injury:

1. Right 2. Left

1	2	3	4	5	6	7	8	9	10	11

7. Eye findings on examination

1	2	3	4	5	6	7	8	9	10	11

1. Scar 2. Linear Scar 3. Others

8. How do you rate the eyewear

1	2	3	4	5	6	7	8	9	10	11

1. Bad 2. Average 3. Good 4. Very good

9. Is the eyewear a burden for you

1	2	3	4	5	6	7	8	9	10	11

1. Yes 2.No

10. The comfort level of the eyewear

1	2	3	4	5	6	7	8	9	10	11

0 1 2 3 4 5 6 7 8 9 10

0. Very uncomfortable

10. Very comfortable

11. Is it interfering with your work

1	2	3	4	5	6	7	8	9	10	11

1. Yes 2.No

12. Would you like to wear the eyewear?

1	2	3	4	5	6	7	8	9	10	11

1. Yes 2.No

13. Do you feel it is necessary for us to come here every month

1	2	3	4	5	6	7	8	9	10	11

1. Yes 2.No

INSPECTION OF THE PROTECTIVE EYEWEAR

1. OK 2.Scratches

1	2	3	4	5	6	7	8	9	10	11

3.Spots on the eyewear

4. Interfering with Vision

Appendix II: Data Coding

1. **Serial**

2. **Cluster**

3. **Name**

4. **Age**

5. **Sex**
   1 = Male
   2 = Female

6. **Fmilyinc: Family Income**
   1 =< Rs.1000
   2 = Rs.1000 – Rs.2000
   3 =>Rs.2000

7. **Educatn: Education**
   1 =Illiterate
   2 = upto 6^{th} Std.
   3 = 7^{th} – 10^{th} Std.
   4 =>10^{th} Std.

8. **Visrtun: Vision unaided (Right Eye)**
9. **Visrtpin: Vision Pinhole (Right Eye)**
10. **Visltun: Vision Unaided (Left Eye)**
11. **Visltpin: Vision Pinhole (Left Eye)**

Vision
1 =6/6 – 6/18
2 = > 6/18 – 6/60
3 = >6/60 – 3/60
4 = >3/60 – 1/60
5 = > 1/60 - P_L
6 = No P_L

12. **Worktype: Type of Work (Breaking Stones)**
    1 = Large Stones
    2 = Small Stones
    3 = Loading

13. **Workdur: Number of years of work in the quarry.**

14. **Workdays: Number of days of work/week.**

15. **Numempl: Number of family members work in the quarry.**

16. **Familinj: Number of family members with eye injury.**

17. Apinjnum: Any eye injuries in the past

1 = Yes
2 = No

18. Aeyeinvo: Eye involved

1 = Right Eye
2 = Left Eye
3 = Both Eyes

19. Aoutcome: Outcome in the past

1 = Asymptomatic
2 = Impaired Vision
3 = Lost Vision

20. Tpinjnum: Any eye injury in the past three months

1 = Yes
2 = No

21. Teyeinv: Eye involved in the past three months

1 = Right Eye
2 = Left Eye
3 = Both Eyes

22. Injuryas: Injury as in three months

1 = Direct
2 = Bystander

23. Injuryty: Type of Injury

1 = Foreign Body (Superficial)
2 = Corneal Tear
3 = Intraocular Foreign body
4 = Others

24. Injtime: Time of Injury

1 = Morning
2 = Afternoon
3 = Evening

25. Outcome: Outcome of the injury in the past three months

1 = Asymptomatic
2 = impaired Vision
3 = Low Vision

26. Primtr: Primary Treatment

1 = Self Treatment
2 = Traditional Practitioner
3 = Medical Shop
4 = General Practitioner
5 = Ophthalmologist

27. Ophconsl: Ophthalmologist Consultation

1 = Yes
2 = No

28. Injtrgap: Interval between time of injury & treatment in hours

29. Trcost: Total Cost of Treatment

1 = < Rs.200
2 = Rs.200 – Rs.500
3 = Rs.500 – Rs.1000
4 = > Rs.1000

30. Injnatur: Nature of Injury

1 = Not Vision Threatening
2 = Vision Threatening

31. Rteyefin: Right Eye Findings

32. Rtscarnu: Right Eye Scar Number

33. Lteyefin: Left Eye Findings

34. Ltscarnu: Left Scar Number

Eye Findings

1 = Non-linear Scar
2 = Linear Scar
3 = Linear and Non- Linear Scar
4 = Normal

35. injuryas2:

36. injuryty2

37. injtim2

38. outcom2

39. primtr2

40. ophcons2

41. injtrgp2

42. trcost2

43. injnatur2

44. rteyefin2

45. rtscarnu2

46. lteyefin2

47. ltscarnu2

Note: The expansion and coding for Column Nos. 35 to 37 is same as for column Nos. 22 to

34. 2 represent the happenings of 2nd time.

Prefix of 3 represents at 3 months

48. 3uspreye: Using Protective Eyewear

1 = Yes
2 = No

49. 3npweek: Number of days of usage of protective eyewear per week

50. 3nphday: Number of working hours per day the protective eyewear is worn

51. 3rnupeye: Reason for not using protective eye wear

1 = Scratches
2 = Stained
3 = Broken
4 = Others

52. 3inj1:

53. 3wninjpg1

54. 3injas1

55. 3eyeinv1

56. 3type1

57. 3treat1

58. 3vnflinR1

59. 3vnflinL1

60. 3oer1

61. 3rscarnu

62. **3oel1**
63. **3lscarnu**
64. **3inj2**
65. **3wninjpg2**
66. **3numinj**
67. **3injas2**
68. **3eyeinv2**
69. **3type2**
70. **3treat2**
71. **3vnflinR2**
72. **3vnflinL2**
73. **3oer2**
74. **3oel2**
75. **3pgrate**
76. **3pgburd**
77. **3pgcomf**
78. **3pginf**
79. **3pglike**
80. **visit3**
81. **pginsp1**
82. **pginsp3**
83. **6uspreye**
84. **6npweek**
85. **6nphday**
86. **6rnupeye**
87. **6inj1**

88. 6wninjpg1

89. **6numinj**
90. **6injas1**
91. **6eyeinv1**
92. **6type1**
93. **6treat1**
94. **6vnflinR1**
95. **6vnflinL1**
96. **6oer1**
97. **6rscarnu**
98. **6oel1**
99. **6lscarnu**
100. **6inj2**
101. **6wninjpg2**
102. **6injas2**
103. **6eyeinv2**
104. **6type2**
105. **6treat2**
106. **6vnflinR2**
107. **6vnflinL2**
108. **6oer2**
109. **6oel2**
110. **6pgrate**
111. **6pgburd**
112. **6pgcomf**
113. **6pginf**
114. **6pglike**

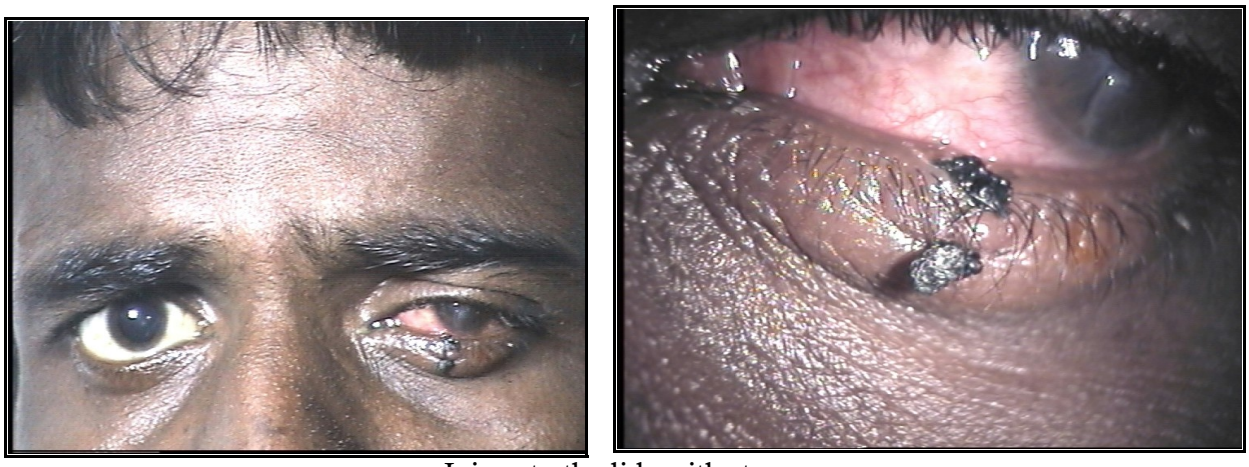
115. 6visit

116. **pginsp6**

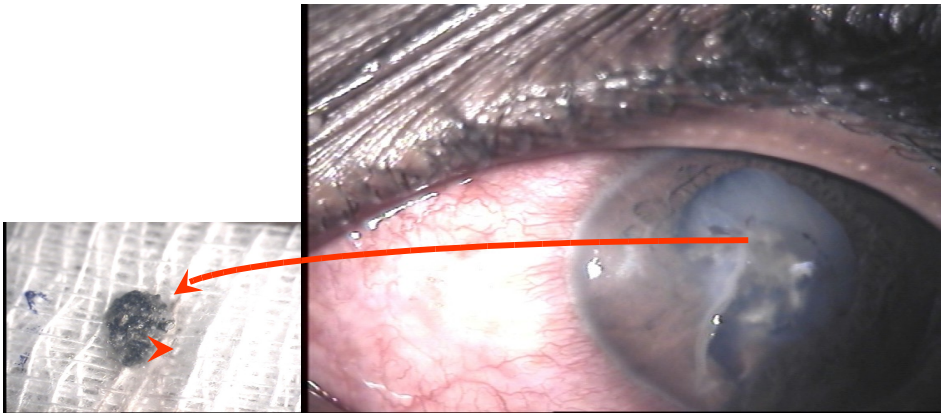
117. **3lost**

118. **6lost**

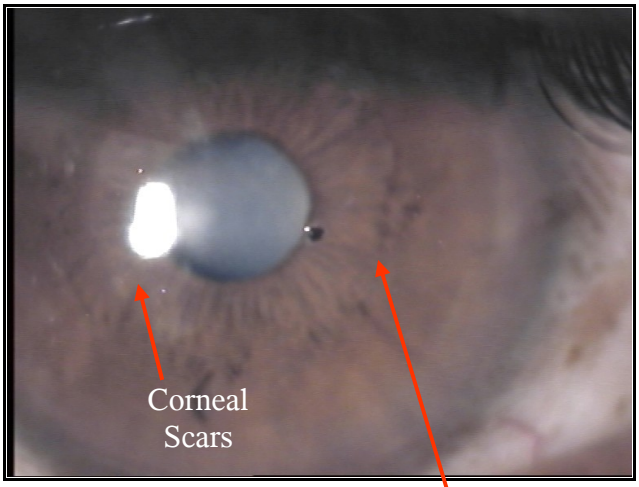
Appendix III: Vision Threatening Ocular injuries with stone seen in our hospital



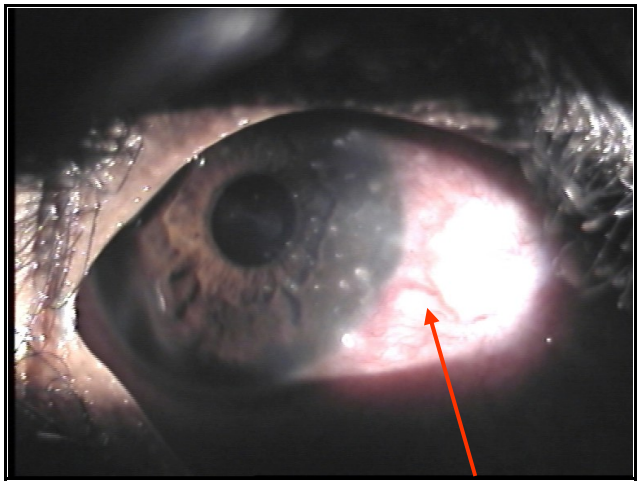
Injury to the lids with stone



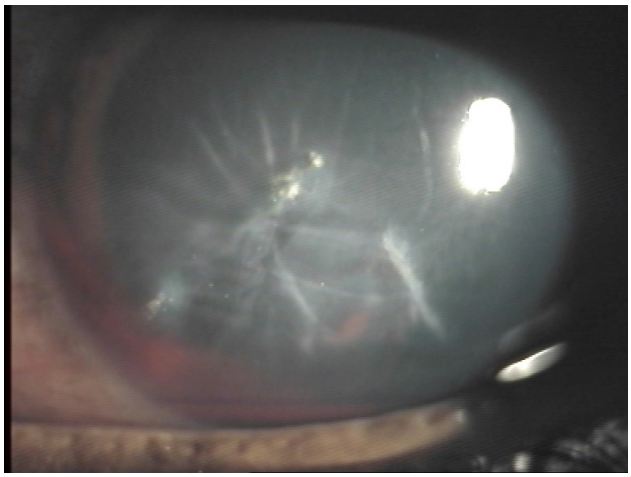
Corneal Tear with stone in the anterior chamber and Traumatic Cataract. Stone removed



Stone on the Cornea (Superficial), multiple corneal scars

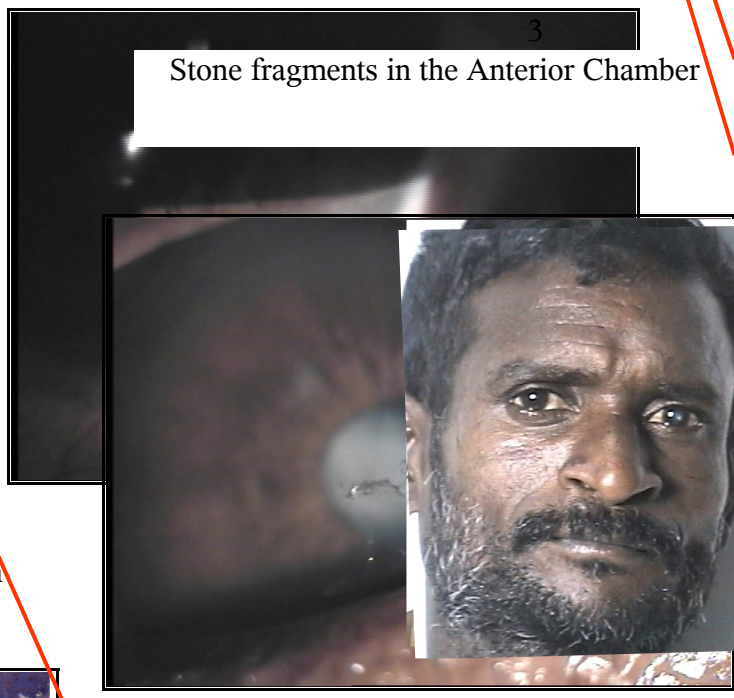


Multiple stone fragments on the Cornea



Stone fragment on the Cornea with multiple scars surrounding it.

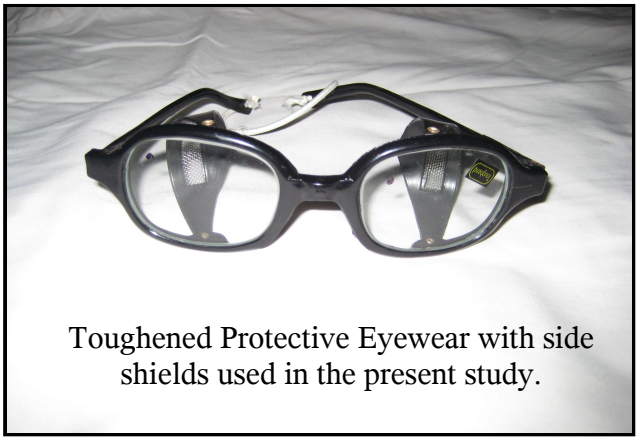
Stone fragments in the Anterior Chamber



Quarry Workers (Husband and Wife) with Ocular injuries

Stone Quarries

Education to the Quarry Workers



Protective Eyewear

Workers in the Quarry

Eye Safety At Work

Is Everyone's Business.

Use Protective Eyewear