A Comparison of Aluminum to Ceramic Lap Tools in Optical Lens Surfacing

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A Comparison of
Aluminum to Ceramic Lap Tools
In Optical Lens Surfacing

Submitted to the Department of
Occupational and Technical Studies
of
Old Dominion University
In Partial Fulfillment of the Requirements for
The Degree of Master of Science of
Occupational and Technical Studies

DEREK M. WALLS
1999
This research paper was prepared by Derek M. Walls under the direction of Dr. John M. Ritz in OTED 636, Problems in Occupational and Technical Studies. It was submitted to the Graduate Program Director as partial fulfillment of the requirements for the Degree of Master of Science in Occupational and Technical Studies.

APPROVED BY: Dr. John M. Ritz
Graduate Program Director
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Figure 1 - 4 and 6- 8 were obtained from the Naval Ophthalmic Support and Training Activity’s web page at: http://nos40.med.navy.mil

Figure 5 was obtained from Optical Works Corporation’s web page at: http://www.opticalworks.com
CHAPTER I

INTRODUCTION

In the optical field, metal and ceramic lap tools are the two main choices used in the fining and polishing of a plastic lens. Metal lap tools have been used for years and were the only practical choice while lenses were made with glass. With the introduction of plastic lenses the old cast iron lap tools proved to be detrimental for amongst other reasons, they rusted and the rust particles, though not harmful to glass, scratched the delicate plastic lenses. Aluminum lap tools had been used for several years with special fining pads on glass lenses. With a change of fining pads they worked well with the plastic lenses.

Unfortunately aluminum lap tools are still cumbersome. In an attempt to combat the weight of these lap tools, other materials have been employed, such as ceramic. The fear, however, is that ceramic lap tools will not last as long and will not be as accurate as the aluminum lap tools.

STATEMENT OF THE PROBLEM

The purpose of this study was to determine if ceramic lap tools produce as high a quality of optical lenses as aluminum lap tools during the surfacing process in eyeware manufacturing, if ceramic lap tools are easier or harder to work with than aluminum lap tools, if ceramic lap tools last as long as aluminum lap tools, and if ceramic tools are as cost effective as aluminum lap tools.
RESEARCH GOALS

To answer the research problems, the following goals were established.

1. To determine if the power of the lap tools becomes inaccurate over time. If so, to establish a predictable lifespan of ceramic and aluminum lap tools, and to determine if the lower cost of ceramic tools is economical if they have a significantly shorter life span.

2. To determine if there was a significant difference between any inaccurate power in both the aluminum and ceramic lap tools.

3. To discover if there is a significant difference in the speed and ease of the transition between the fining and polishing processes using ceramic lap tools as compared with aluminum lap tools.

4. To determine if there was a significant difference between the actual power of the lenses produced and what the prescribed power was when using ceramic as compared with aluminum lap tools.

BACKGROUND AND SIGNIFICANCE

For many years the process of fining an optical lens had been accomplished only with cast iron lap tools. The glass was placed directly on the lap tool to fine out the marks and scratches made in the generation of the glass lens. With the introduction of metal pads that were placed directly on the lap tool’s surface, the lap tool could be manufactured from lighter material such as aluminum, as long as the lens never touched the lap tool itself.
With the introduction of the plastic lens, the use of cast iron lap tools became impractical. One problem with the cast iron lap tools was that the rust particles they produced would scratch the delicate plastic lens. Additionally the cumbersome weight of the cast iron lap tool slowed production and could be ergonomically harmful to carry in large numbers and hazardous if dropped on one's foot.

Aluminum is a good alternative. It can be used with plastic or glass lenses provided the right fining pad is placed on it. Some key advantages to the aluminum lap tools are that they will not rust, they are not as heavy as the cast iron lap tool, they can be trued quicker and easier on a lap cutter, and they conduct heat away from the lens in the fining and polishing process which keeps plastic lenses from melting and warping. However there are some disadvantages. First, if no pad was placed on the aluminum lap tool, or if it fell off, the lap tool could quickly wear down in an uneven fashion and produce lenses with odd and inaccurate powers. Second, although not as heavy as the cast iron lap tool, the aluminum tool is still quite cumbersome. The weight of the aluminum lap tool may diminish the lifespan of the machinery that it is placed on, can be ergonomically harmful when many are carried, and hazardous to toes when dropped.

Ceramic lap tools are lightweight which makes them more ergonomically sound, and may add to the lifespan of the surfacing machines they are used on. The ceramic lap tools are also less expensive. One concern is that in clamping the lap tool into the machine, the pressure will cause the lap tool to temporarily become
inaccurate. Another concern is that the ceramic lap tool might wear out quicker than the aluminum lap tool and unlike the aluminum lap tool ceramic lap tools are difficult if not impossible to true again. Once they are warped or disfigured, the tool is of little or no use. Therefore the question becomes, is the cost of the ceramic lap tools economical considering their shorter lifespan?

LIMITATIONS

This study was limited to a random selection of ceramic and aluminum lap tools, of various sizes, from two separate labs. One lab predominately used aluminum lap tools and the second lab used ceramic lap tools more. The lap tools were measured with a segometer and a lens-clock. The two labs were chosen to determine what percentage of the predominately used lap tools would be worn down to the point of no longer being within standards.

Using only lap tools that had passed the accuracy test, a total of 200 lenses were surfaced. One hundred lenses were surfaced using ceramic lap tools and 100 lenses were surfaced using aluminum lap tools.

ASSUMPTIONS

Ceramic lap tools are half the weight of aluminum lap tools and are therefore ergonomically sound\(^1\). It is assumed that this lightness

\(^1\) Average of twenty aluminum lap was .65 lbs compared to .32 lbs average for twenty ceramic lap tools of the same powers.
will make it easier to pull the lap tools off shelves and will add years to the life of the surfacing machinery simply by causing less wear due to weight.

Due to operator and mechanical error in any one of the many surfacing processes a certain number of lenses may be manufactured inaccurately. It is assumed however, that the numbers of faulty lenses made with ceramic and aluminum lap tools, will be similar.

METHODS AND PROCEDURES

The first task was using a segometer and lens-clock to test the lap tools for accuracy, ensuring that a broad range of randomly selected lap tools was obtained. The two labs used in this experiment had both ceramic and aluminum lap tools. In the first lab, aluminum tools were primarily used, with ceramic lap tools used as a back up if the number of aluminum lap tools were running low in a certain power. In the second lab, ceramic lap tools were primarily used with aluminum lap tools as a back up. The test was to measure 100 lap tools of each type in each lab.

By measuring the different tools the researcher could compare the well used ceramic lap tools to the slightly used ceramic lap tools. This is to determine if over time the ceramic lap tools lose their accuracy and if so, how often they must be replaced. The same could be determined by comparing the aluminum tools. The well used aluminum tools were then compared with the well used ceramic tools.
to determine if there were similarities in the power differences in the tools, and if the differences were significant.

The next test was to measure ceramic and aluminum lap tools in the fining and polishing machines to determine if they were still true under pressure. This was done with 25 randomly selected aluminum and 25 randomly selected plastic lap tools of various sizes that were accurate. This was to determine if there were significant differences in what power the tool was supposed to be and what it actually was once clamped in the machine, and if there were significant differences between aluminum and ceramic lap tools.

The next test was to run the machines fining 100 lenses with ceramic lap tools and 100 lenses using aluminum lap tools. An effort was made to ensure that the lenses were blocked correctly by the blockers and cut out correctly in the generators. Once all the lenses were fined and polished they were inspected for accuracy and to ensure that they were within standards. The percentage of lenses not within standards were then calculated to determine if there was a significant difference in accuracy between aluminum and ceramic lap tools.

The next test was to determine the ease with which the crossover from fining to polishing was made. Once the lap tool is taken out of the finer, the fining pad must be taken off, the lap tool dried and a polishing pad placed on it. The concern was that the ceramic lap tool would not dry as rapidly, slowing production. The task was to determine if production was slower and if so, how significantly. To determine this the crossover was observed and timed.
The last test was the vulnerability of the lap tools. This was to determine if pealing the pads, dropping the lap tool, and other such shop wear would significantly damage the tools, and what it would take to repair or replace the damaged lap tool. This was done by taking five ceramic and five aluminum lap tools and dropping them from various increasing heights, then inspecting and measuring them after each fall to determine if any damage had occurred. This was also done by observing the original tools (measured in the two shops) for any signs of damage due to pealing and other shop wear.

DEFINITION OF TERMS

The following terms are defined to assist the reader in their review of this study.

**Block** - That which is attached to the surface of the lens in order to hold it in place during the surfacing or edging process.

**Blocker(s)** - The device used to place a block on the lens in order to hold the lens in place during the surfacing process.

**Chucking** - In this case, locking down a block into a machine.

**Fining** - The process of bringing a generated lens surface to the smoothness needed so that it will be capable of being polished.

**Fouling** - Causing impurities, full of impurities; polluted. Very disagreeable or displeasing; horrid. Clogged or obstructed; blocked.

**Generating** - The process of rapidly cutting the desired surface curvature onto a semifinished lens blank.
**Generator** - The machine used for generating.

**Lap cutter** - A machine used to cut a lap tool to its correct curvature.

**Lap tool** - A tool having a curvature matching that of the curvature desired for a lens surface. The lens surface is rubbed across the face of the tool and, with the aid of pads, abrasives, and polishes, the lens surface is brought to optical quality. The tool must have the identical curvature to that of the lens it is for; that is, if the lens surface is concave the tool is convex to the same power.

**Lap tool, aluminum** - lap tool made from aluminum alloy.

**Lap tool, cast iron** - lap tool made from cast iron; with glass a fining pad is not needed, the lens surface is rubbed directly on the lap tool.

**Lap tool, ceramic** - A plastic like tool made up of many composites.

**Marks, generator** - A lens surface defect caused by the generator that cuts the lens to the desired curves. These marks must be fined and polished out to achieve optical quality.

**Marks, swirl** - A lens surface defect that indicates an abrasive particle was trapped between the pad and the lens surface causing swirl marks.

**Optical Center** - The point in an optical lens that there is no prism effect manifested. Should sit directly in front of the pupil.

**Power** - (focal, refractive power) - A measure of the ability of a lens to change the verging of entering light rays. The value that accurately describes the ability of a lens to converge or diverge light. For the purposes of this paper, refers to the ability of the tools to create the right curvature so that the power of the lenses will be correct.
**Pealing** - The act of removing a fining or polishing pad from a lap tool. Often done by using a knife or scraping device.

**Prism** - The part of an optical lens that deviates the path of light.

**Segment** - An area of an optical lens with power differing from that of the main portion. Bifocals, usually for reading.

**Segometer (lens clock, lens gauge, sag gauge)** - an instrument for measuring the surface curvature of a lens, lap tool, or other curved surface.

**Surfacing** - The process of creating the prescribed refractive power and prism on a lens by generating the required curves and bringing the surface to a polished state.

**Tray** - Optical labs use small box-like trays to keep the components of a pair of eyeware together (e.g. The prescription, lenses, and frame).

**True** - Accuracy. The accuracy of a tool or, to make a tool accurate. In this case a surfacing lap tool.

**Trueing** - To make accurate. See true.

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**OVERVIEW OF CHAPTERS**

This chapter has covered the nature of the problem, the goals that are to be obtained, the need for a study of this type, the background and significance of the research, the limitations of the research, the assumptions of the author, the methods and procedures to be used, and the definitions and explanations of certain terms.

Chapter II will review the literature associated with this topic.
Chapter III will discuss in more detail the methods and procedures that were utilized to obtain data and the findings to formulate conclusions. Chapter IV will report in detail the findings obtained by the research process. Finally, Chapter V will contain a summary of the paper, the conclusions made, and the researchers recommendations for change and implementations.
CHAPTER II

REVIEW OF LITERATURE

This chapter will be used to describe what needs to take place before a lens can be surfaced, the steps in surfacing a lens, and what happens after a lens is surfaced. This is provided to give the reader a better understanding of the process in manufacturing a lens.

BEFORE SURFACING A LENS

A prescription is needed before any other step can take place. In order to get a prescription the patient will first see an ophthalmologist or an optometrist. "An ophthalmologist is a doctor of medicine who has also completed several years of postgraduate study in eye care." The ophthalmologist diagnoses and treats eye disease, performs surgery, and prescribes visual aids. "An optometrist is one who practices optometry, a health care practitioner trained to examine and prescribe non-surgical treatment." Either an ophthalmologist or an optometrist can write a prescription for eyeware. This prescription is given to an optician who interprets the prescription to determine lens specifications and measures the patient's facial contours to determine the size and shape of frames best suited for the patient. The prescription can then be filled by that optician or sent to other opticians that work specifically in the manufacturing of eyeware (Moorhead, 1991, p. XII-30).
STEPS IN SURFACING A LENS

In order to manufacture a lens, the prescription must be received by the lab that will do the work. At large labs specializing in the production of customized eyewear, the prescriptions can be received by mail, E-mail, fax, or hand delivered. The prescription received must be calculated using mathematical formulas so that the lab can produce the lenses ordered. Traditionally this mathematical process was done by the optician using a worksheet. Today however, most labs use a computer to perform this task. A printout of the information can then be made. Additionally the prescription information and calculations can be stored in a database so that the prescription can be tracked through the lab process. In one of the labs that this research was performed in the database was networked to the fabricating equipment so that the information was automatically sent there.

Stock personnel are responsible for making certain that the proper stock is pulled for each prescription. A semi-finished lens blank is pulled for each eye and the correct frame is selected. "The semi-finished lens blank is a plastic lens that already has a finished front surface curve" (Moorhead, 1991, p. XI-2). The back side of the lens is left blank so that the back of the lens can be generated, fined, and polished to the prescribed power.

To surface a lens, the lens blank needs to be blocked. "The word blocking is used to describe the fastening of a lens blank to a metal body
known as a block. The block provides support to the lens while generating, fining, and polishing the surface" (Moorhead, 1991, p. XI-7). The block also helps to protect the finished surface of the lens as it goes though the surfacing area of a lab.

There are two prominent methods to attach a block to a lens blank. The first uses a wax-like material called "freebond" to bind a metal block to the surface of the lens blank. Freebond must cool sufficiently in order to hold the lens firmly enough to be generated. To help hold the block to the surface of a lens better, each block has different curves that fit to the front surface of the lens.

The second method utilizes a rubber pad that has an adhesive surface on both sides. This pad is placed between a flexible block and the lens surface. Using this method the lens blank can be chucked and generated right away.

In order to cut a surface of the lens, the lens is chucked in the generator. The generator has blades that spin at high rates of speed traveling in a curved pattern slowly across the lens. "The generator removes the surplus material and cuts the rough curves" to the prescribed power of the lens (Moorhead, 1991, p. XI-8). In a modern lab this information has already been entered in the database. Once the generation has taken place the lens has the correct curvature but is pitted and marked by the blades in the generator. In order to have a smooth surface the lens must have these marks fined out.
To fine and polish the lens, the correct lap tool for the job is selected by matching the surface of the lens with the surface of the tool. Prefabricated lap tools are used for the majority of surface jobs but occasionally a temporary customized lap tool is cut for a specific special job. The lap tools can be stored on shelves, in drawers, or in special racks designed for lap tools. Shelves are easy to design for ergonomics but can take up a large amount of room. Drawers are handy and adequate if only using a small amount of tools in a particular lab, however lap tools are easily misplaced and it is difficult to keep them in order. Racks utilize space very well, but the turning racks put strain on the arms when starting and stopping them from spinning, especially when the racks contain aluminum lap tools. The lap tool needed is pulled from storage, placed in the work tray with the generated lenses, and taken to the finers.

"The purpose of fining is to remove all the pits, scratches, etc., and to set the prescribed curves as required to obtain the desired prescription. The lens surface must be completely free of any defects" (Moorhead, 1991, p. XI-10). The steps in fining a lens are: 1) a fining pad is affixed to the lap tool (a pad that has a sandpaper-like surface on the front side and a self-adhesive surface on the back), 2) the lap tool is clamped into a machine called a finer, 3) the lens is placed on the lap tool and held down by a mechanical or pneumatically pressured arm, 4) water is sprayed around the lens to act as a lubricant, 5) the finer moves in a fast and complex motion to fine the generator marks, pits, and scratches out of the
entire lens surface. The end result is a very smooth but highly opaque back surface on the lens. The fining pad is removed from the lap tool and the tray with the lenses and lap tools is sent on to the polishers.

To remove the opaqueness and produce an optically clear lens, the lens must be polished. This is accomplished using the same lap tool that was used in fining, but instead of the fining pad, a soft velvet-like pad with a self-adhesive back, called a polishing pad, is placed on the lap tool. The polishing machine is the same kind of machine as the finer but instead of water it sprays a milky white polish to coat the lens as it is polished. "Upon completion, the lens is completely smooth and crystal clear, albeit dirty from the polish" (Moorhead, 1991, p. XI-11). The polishing pad is removed from the lap tool and the lap tool is cleaned and placed back in storage.

At this point the block is separated from the lens by a deblocking device that uses pneumatic pressure to slightly bend the plastic lens, causing the lens to pop free from the block and freebond. The lenses are then cleaned of the polishing compound and freebond residue and the lens is ready for inspection. The freebond that is removed is placed back in the blockers and reused and the blocks are cleaned and returned to the blockers for future use as well.

Inspection ensures that the process has been done properly and the final results are those desired. When inspecting a lens for accuracy the first step is to look at the lens against a light source to ensure that the lens is not cracked or broken, that all the generator marks have been fined and polished out, that the lens is free of scratches, and that there
is no visible aberration or irregularities.

The lens is then placed in a lensmeter to make certain that the lens is the prescribed power and within standards. If there is prescribed prism in the lens, that is checked for accuracy and if it is within standards. If there is a segment, the lens axis is verified for accuracy, the segment is checked for proper power and to see if it is the correct distance from the optical center of the lens. The last step is to determine thickness, that the edge and center of the lens is not too thin.

If one or the other of the lenses fail inspection an attempt is made to determine what went wrong. If possible, the problem is corrected and the lenses are fixed or new lenses resurfaced. If both lenses pass inspection the job is sent to the finishing section.

AFTER A LENS IS SURFACED

The finishing of the eyeware is as involved a process as surfacing, however it will only be briefly discussed, since the topic of this research involves the surfacing aspect of optical fabrication.

To complete the eyeware the paperwork is again verified to make certain the right lenses and frame are with the right tray. The single vision lenses (lenses with no segments) are placed in a lensometer to verify accuracy, aligned on their axis, and marked on the optical center and axis. The lens is then placed on a finishing blocker and decentered the prescribed amount (decentering moves the optical center of the lens to the location where the center of the pupil is in relation to the frame prescribed). In segmented lenses, the segments are decentered, the
height is moved to the desired placement, and the lens is then blocked. The block is used to hold the lens in the edger. The edger cuts down the edge of the lens so it will match the exact size and shape of the frame prescribed. Once the lens is edged and safety beveled to remove any sharp edges left by the edgers, it is then placed inside the frame. The axis or segments are aligned to match the prescription. The finished eyeware is then inspected to ensure that every part is as it should be and the prescription is accurate.

SUMMARY

At first glance it may not seem to matter if a lap tool is ceramic or aluminum, but closer investigation reveals that the lap tool is an important aspect in the surfacing of a lens. If the lap tool cannot be relied upon for accuracy, then accurate lenses cannot be produced. If a lap tool cannot hold up and needs to be replaced more often, it will disrupt production and cost the lab money in replacement costs. If the lap tools are too heavy, then they are ergonomically unsound. If there is a significant increase in the time of transition from fining to polishing, then this delay will hinder the process. Therefore it can be quite important to know which tool is overall superior.
CHAPTER III

METHODS AND PROCEDURES

This chapter will explain the various components that are involved in the methods and procedures of this research. This includes the variables involved in the research, the use of the instruments, the lab procedures, the methods used for data collection, and the analysis used to compile the data.

RESEARCH VARIABLES

In this study the variables studied were the aluminum lap tools, the ceramic lap tools, and the lenses that they produced. More specifically one hundred aluminum and one hundred ceramic lap tools were randomly selected, then they were measured with a segometer and lens clock for accuracy. Additionally, twenty-five aluminum and twenty-five ceramic lap tools were selected for comparison, then they were locked into the finers and polishers to see if they changed in accuracy. In the test of actually fining and polishing lenses, a hundred accurate aluminum and a hundred accurate ceramic lap tools were selected. They were used to produce the two hundred plastic lenses that were analyzed for quality. The variables between the aluminum and ceramic lap tools, were evaluated to determine which produced superior lenses within economical constraints.
INSTRUMENT USE

The instruments used were the segometer and lens clock that measure the curvature of an object. These were used to determine the curvature of the lap tools that underwent the test. A lensometer was used to determine the power of the lenses once they were produced in this process. All instruments were carefully calibrated before the tests were done.

LAB PROCEDURES

The first task was to randomly select fifty aluminum and fifty ceramic lap tools and, using a segometer, test the lap tools for accuracy. Using the accurate randomly selected lap tools, twenty-five aluminum and twenty-five ceramic, the next test was measuring the lap tools once they were chucked into the fining and polishing machines. A segometer and lens clock were used to determine if they were still true under that pressure.

Next, two hundred lenses were produced. One hundred lenses were made using ceramic lap tools and one hundred lenses using aluminum lap tools. The lenses were checked to see that they were blocked correctly in the blockers and were correctly generated by the generators. Once all the lenses were fined and polished they were inspected with a lensometer to see how accurate they were and to determine if they were within standards.

The next test determined if the crossover from fining to polishing was made more difficult using ceramic as compared to aluminum lap
tools. When the lap tool is taken out of the finer, the fining pad must be taken off, the lap tool dried and a polishing pad placed on it. If the pad is more difficult to remove from the ceramic lap tool as compared to the aluminum lap tool this could slow production down. To determine this, the crossover was observed and timed while the test comparing the two lap tools was performed.

The vulnerability of the lap tools was also tested. This was done by taking five ceramic and five aluminum lap tools and dropping them from various increasing heights, then inspecting them and measuring them for accuracy after each fall to determine if any damage had occurred.

METHODS OF DATA COLLECTION

When measuring the one hundred aluminum and one hundred ceramic lap tools for accuracy, the tools were selected by obtaining the tool number randomly off a computer. The tools selected were then pulled off the shelf and measured with a segometer and a lens clock. The actual power of the tool was then written next to what the tool's power was supposed to be. The tool is allowed to be off .06° in either direction.

Next, of the tools that passed the first test, twenty-five of each type were locked into the finers and then the polishers to determine if there was any significant change in their power. The changed power was then written next to the actual power.

Then one hundred accurate aluminum lap tools and one hundred accurate ceramic lap tools were used to fine and polish two hundred
lenses. The lenses were checked to ensure that they had been blocked and generated correctly before the test. The lenses were then polished starting with the aluminum and switching to the ceramic after the first twenty, then back to the aluminum after twenty, and so on. The lenses were then cleaned and inspected using a lensometer. Each lens is supposed to be a certain power. The actual power was recorded next to what the power was supposed to be. Separate lists were used for those lenses that were fined and polished by aluminum and ceramic lap tools.

STATISTICAL ANALYSIS

In this study the percentage of aluminum lap tools that did not meet standards was compared to the percentage of ceramic lap tools that did not meet standards.

The percentage of passing lenses produced using ceramic lap tools was compared to the percentage of passing lenses produced by aluminum lap tools.

SUMMARY

In this chapter the methods and procedures used in this research study were discussed as were the research variables, the lab procedures, the methods of data collection, and the statistical analysis.

In Chapter IV, the findings of this study will be reported and in Chapter V, the summary, conclusions, and recommendations for change and implementations will be made.
CHAPTER IV
FINDINGS

In this chapter the findings of the research will be presented. The purpose of this study was to determine if ceramic lap tools produce as high a quality of optical lenses as aluminum lap tools in the surfacing of lenses for eyewear, if ceramic lap tools are easier or harder to work with than aluminum lap tools, if ceramic lap tools last as long as aluminum lap tools, and if ceramic tools are as cost effective as aluminum lap tools.

FINDINGS

In this study the following goals were established to answer the research problems.

1.) To determine if the power of the lap tools becomes inaccurate over time. If so, to establish a predictable lifespan of ceramic and aluminum lap tools, and to determine if the lower cost of ceramic tools is economical if they have a significantly shorter life span.

- Only one percent of the lap tools tested was the desired power. Of those that were not, only 12 percent of aluminum and 14 percent of ceramic lap tools fell within the standards set in this research (see table 1). A predictable life span could not be established since the tools in one lab ranged in age from 15 years to present and 10 years to present in the other lab.
2) To determine if there was a significant difference between any inaccurate power in both the aluminum and ceramic lap tools.
   • Of the tools tested, 86% ceramic and 88% aluminum were not within the standards set by this research paper.

3.) To discover if there is a significant difference in the speed and ease of the transition between the fining and polishing processes using ceramic lap tools as compared with aluminum lap tools.
   • The aluminum lap tool took an average of 2.4 seconds to dry under air flow and the ceramic lap tool took an average of 6.3 seconds to dry.
   • The fining and polishing pads took an average of 4.5 seconds to remove from the aluminum lap tools and 5.2 seconds to remove from the ceramic lap tools.
   • Fining and polishing pads adhered to an aluminum lap tool less than satisfactory, but did not adhere to a ceramic lap tool at all.

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**TABLE 1**

<table>
<thead>
<tr>
<th></th>
<th>CERAMIC</th>
<th>ALUMINUM</th>
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</thead>
<tbody>
<tr>
<td>NUMBER OF LAP TOOLS TESTED AT LAB 1</td>
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<td>50</td>
</tr>
<tr>
<td>NUMBER OF LAP TOOLS TESTED AT LAB 2</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>TOTAL NUMBER OF LAP TOOLS TESTED</td>
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<td>100</td>
</tr>
<tr>
<td>NUMBER OF ACCURATE LAP TOOLS</td>
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<td>1</td>
</tr>
<tr>
<td>NUMBER OF LAP TOOLS WITHIN STANDARDS</td>
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<td>12</td>
</tr>
<tr>
<td>NUMBER OF LAP TOOLS OUT OF STANDARDS</td>
<td>85</td>
<td>87</td>
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</table>
4.) To determine if there was a significant difference between the actual power of the lenses produced and what the prescribed power was when using ceramic as compared with aluminum lap tools.

- Of the lenses, 5% of the lenses fined and polished by ceramic lap tools and 4% by aluminum lap tools did not meet standards.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>CERAMIC LAP TOOL</th>
<th>ALUMINUM LAP TOOL</th>
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</thead>
<tbody>
<tr>
<td>NUMBER OF LENSES WITHIN STANDARDS</td>
<td>95</td>
<td>96</td>
</tr>
<tr>
<td>NUMBER OF LENSES OUT OF STANDARDS</td>
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<td>4</td>
</tr>
<tr>
<td>TOTAL NUMBER OF LENSES PRODUCED</td>
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</tr>
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</table>

SUMMARY

In this chapter the findings of this research study were presented. In Chapter V, the summary, conclusions, and recommendations for change and implementations will be made.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter will contain the summary of the complete study, conclusions made from the research, and the recommendations made based on the findings of this study.

SUMMARY

Lap tools are used in the fining and polishing of a plastic lens in the optical field. The two main choices of surfacing lap tools are aluminum and ceramic. Aluminum lap tools had been used for several years for fining glass and plastic lenses, unfortunately aluminum lap tools are cumbersome. In an attempt to combat the weight of lap tools, other materials have been employed, such as ceramic. The fear, however, is that ceramic lap tools will not last as long and may not be as accurate as the aluminum lap tools.

The purpose of this study was to determine if ceramic lap tools produce as high a quality of optical lenses as aluminum lap tools during the surfacing process in eyewear manufacturing, if ceramic lap tools are easier or harder to work with than aluminum lap tools, if ceramic lap tools last as long as aluminum lap tools, and if ceramic tools are as cost effective as aluminum lap tools.

The disadvantages of aluminum lap tools is that if no pad is placed on the aluminum lap tool, or if it fell off, the lap tool could quickly wear down in an uneven fashion and produce lenses with odd
and inaccurate powers. Also aluminum lap tools are cumbersome, and the weight of the aluminum lap tool may diminish the lifespan of the machinery that it is placed on.

Ceramic lap tools are lightweight and may add to the lifespan of the surfacing machines. They are also less expensive. However, as with the aluminum lap tools, if no pad is placed on the ceramic lap tool it will quickly wear down and a concern was that the ceramic lap tool might wear out quicker than the aluminum lap tool. Unlike the aluminum lap tool, ceramic lap tools are difficult if not impossible to make accurate again. Once they are warped or disfigured, the tool is of little or no use. Therefore, the question is whether the cost of the ceramic lap tools is economical if they have a shorter lifespan.

This study chose a random selection of ceramic and aluminum lap tools, of various powers, from two separate labs. The lap tools were then measured with a segometer and a lens-clock. This was done to determine what percentage of lap tools would be worn down to the point of no longer being within standards.

Both types of lap tools were also placed in the fining and polishing machines to determine if they were still true under pressure. Then the lenses were surfaced to determine if both types of lap tools produced similar results. It was also determined which tool was easier to work with in the crossover from fining to polishing. Finally the vulnerability of the lap tools was tested. This was to determine if pealing the pads, dropping the lap tool, and other such shop wear would significantly damage the tools.
CONCLUSIONS

From the goals established to answer the research problems, the following conclusions were made.

1.) To determine if the power of the lap tools becomes inaccurate over time. If so, to establish a predictable lifespan of ceramic and aluminum lap tools, and to determine if the lower cost of ceramic tools is economical if they have a significantly shorter life span.

Only one percent of the lap tools tested were the desired power. Of those that were not, only 12 percent of aluminum and 14 percent of ceramic lap tools fell within the lowest of standards set in this research. A predictable life span could not be established since the tools in one lab ranged in age from 15 years to present and 10 years to present in the other lab. It is interesting to note that while the percentage of lap tools that are out of power is high, the number for rejected lenses for each lab is between 5-15 percent.

2) To determine if there was a significant difference between any inaccurate power in both the aluminum and ceramic lap tools.

There was no significant difference between the aluminum and ceramic lap tools. Of the lap tools tested, 86% ceramic and 88% aluminum were not within the standards set by this research paper. The major difference is that ceramic lap tools are fixed, that is they are the curvature they are, whereas aluminum lap tools can be machined to be brought back to the curves they are supposed to be.
of the transition between the fining and polishing processes using ceramic lap tools as compared with aluminum lap tools.

There was a significant difference in the handling of the lap tools. The ceramic lap tools are lighter which makes them much easier to pick up and carry. However, the ceramic lap tool took an average of 6.3 seconds to dry whereas the aluminum lap tool took an average of 2.4 seconds to dry under air flow. In a large production lab these seconds add up and could slow production down significantly. Additionally, if a lap tool is slightly damp, the fining and polishing pads will adhere to the aluminum lap tool more readily than the ceramic which, when damp, the pads would not adhere to at all. Once the lap tool is completely dry however, the fining and polishing pads adhere better, which makes them harder to remove once done with them.

4.) To determine if there was a significant difference between the actual power of the lenses produced and what the prescribed power was when using ceramic as compared with aluminum lap tools.

When comparing lenses produced by aluminum and ceramic lap tools there was no significant difference in the power of the lenses. Five percent of the lenses fined and polished by ceramic lap tools and four percent by aluminum lap tools did not meet standards.

The vulnerability of the lap tools was also tested. Ceramic and aluminum lap tools were dropped from various heights. When inspecting them and measuring them for accuracy after each fall no change to the lap tools curvature or other damage had occurred.
RECOMMENDATIONS

The following recommendations are made based on the findings of the research.

1.) All aluminum lap tools in both labs should be measured for accuracy and if not accurate, the lap tools should be machined.

2.) Test ceramic lap tools for accuracy and if inaccurate, they need to be relabeled to reflect their true curvature.

3.) Until a ceramic lap tool is made that is more durable, or can be machined, it would be advantageous to purchase aluminum lap tools.

   If access to machining equipment is not available, ceramic lap tools would be of value so long as they are tested and relabeled periodically.

4.) In military optical field units, the bulk of lenses used are pre-manufactured, the surfacing of lenses is less common. If a lens must be surfaced the lighter weight of the ceramic lap tool would be a factor. However, individual foam lap tools could be cut for one time use. This saves storage room, the need to carry an assortment of lap tools, and considerable weight (whether the lap tool is ceramic or aluminum).

5. It is suggested that future studies may be able to determine a predictable lifespan of lap tools if the lap tools are marked as soon as they are placed into use and tracked for several years.
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