Pins in a Composite : Their Effects on the Strength of the Material

Milton Latoni-Camarena

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PINS IN A COMPOSITE . . . THEIR EFFECT
ON THE STRENGTH OF THE MATERIAL

by

Milton Latoni-Camarena

A Thesis in Partial Fulfillment
of the Requirements for the Degree
Master of Science in the Field of Restorative Dentistry

June 1972
Each person whose signature appears below certifies that he has read this thesis and that in his opinion it is adequate, in scope and quality, as a thesis for the degree of Master of Science.

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DEDICATION

To my dear wife, Orpha Rosado de Latoni, for her help in copying and proofreading this manuscript.
ACKNOWLEDGMENTS

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Left side: Fracture of the cylindrical disc in vertical orientation

Right side: Fracture of the cylindrical disc in horizontal orientation

10. Fracture of the dumbbell specimen with the 0.022 inch diameter pin
CHAPTER I

INTRODUCTION

During the last few years the field of dentistry has been sated with many materials for anterior dental restorations. One class of materials, namely the composites, look very promising in this field. As a substitute for siliceous cements and acrylics the composites have been used mainly for anterior fillings of simple design. Lately their use has been directed to restorations which require the replacement of incisal fractures of anterior teeth and in posterior proximal cavities.

A tooth restored with composite will be more esthetic and longer lasting than when restored with the siliceous cements or acrylics. This is due to improved physical properties. Handling characteristics are relatively comparable to their predecessors, a factor which has resulted in their popularity.

Their use in restoring incisal fractures has become relatively popular. These Class IV restorations (incisal corners) need additional and stronger retention compared with most of the other restorations. This factor has led into the use of pins for additional retention in composites for the placement of Class IV restorations. However, no investigation has been done to determine their effect upon the
composite material. It is the purpose of this study to determine the influence of pins on the compression and tensile strength of a composite material.
CHAPTER II

HISTORICAL BACKGROUND

Requirements of a restorative material for anterior teeth are:

1. It should be placed directly in the prepared cavity without difficulty.
2. Such a material should have less solubility than silicates and be resistant to abrasion. Thereby it would be more durable.
3. Dimensional stability should be greater than that of the direct filling resins.
4. Its brittleness should be less than that of the silicates.
5. It should have color stability as well as an adequate range of shades.

A material of this type has long been desired by the dental profession.

Attempts in the early 1950's were made to improve the physical properties of the acrylic. In one attempt, about 30 percent inert fillers were added to acrylic resin. Fillers, including diamond, glass fiber, alumina or silicate, added singly or in combination, produced very slight improvements to the abrasion resistance of the acrylic.
A new experimental resin filling was used by Bowen\textsuperscript{1} in 1962. In this investigation he found that 70 percent organic polymer plus ceramic filler had tensile strength values between those of dentin and enamel. The strength depended on the surface treatment given to the particles of filler.

Bowen\textsuperscript{2}, in 1963, described the properties that a silica-reinforced polymer should have for dental restorative purposes. Bowen surface-treated the silica powder with a 10 percent aqueous solution of trisvinylsilane. One-half percent of the silane was used per weight of the fused silica. This treatment made the silica powder organophylic. A cross linking comonomer solution consisting of bisphenol and glycidil methacrylate was prepared to serve as the organic binder for the silica reinforcement. He mixed 70 percent of the treated silica powder with 30 percent of the liquid comonomer to obtain a practical consistency of the material. After three minutes the material hardened. It was then subjected to tests of solubility and water sorption, thermal tests, as well as tests for coefficient of expansion and tensile strength. This investigation demonstrated that the vinylsilane coating on the particles increased the strength of the material and decreased the water sorption and solubility of the composite. The silica reinforcement presented several properties which resembled enamel and dentin structures of the teeth.

The work of Bowen\textsuperscript{2} led to the development of a new reinforced
material which was made available by the trade name of Addent 35. This material contained about 70 percent inorganic fillers, composed primarily of glass beads and rods.

In England, McLean\textsuperscript{3} conducted studies to determine whether the introduction of glass or ceramic fillers would improve the marginal seal and abrasion resistance of acrylic restorations.

McLean\textsuperscript{4} in his clinical and physical appraisal of some composites divided them into three groups.

Group I (TB-71) was composed of an acrylic polymer plus inorganic fillers. This was not considered a true composite since the filler used was not coated with silane.

Group II, of which P-Cadurit and Addent 35 were examples, contained glass beads dispersed in a liquid resin. Addent 35 contained 70 percent inorganic filler composed mainly of soda glass beads and rods with a small quantity of siliceous material. These materials were silane-treated before being added to the liquid part of the resin.

Group III was represented by TD-71. Filler of alumino silicate was pretreated by a double process, using first a silane primer, followed by the application of a uniform coating of polymer.

The results of this investigation showed that Group I (TB-71) was very inferior to Addent 35 with regard to abrasion resistance.

Group II (P-Cadurit) revealed a number of defects, primarily lack of color stability and loss of surface contour. Physical testing
established a similarity in mechanical properties between Addent 35 and Group III (TD-71).

A composite resin is a compound consisting of an inorganic substance such as glass beads, fibers, lithium aluminum silicate, or quartz, which is treated with a vinylsilane coupling agent to obtain a better bond with the organic binder which is generally an ether of bisphenol A. Polymerization is activated by benzoyl peroxide. The composites are 70 to 80 percent inert fillers by weight.

The development of the composite materials is still in progress. Presently many of the previously introduced materials have been improved and there is little doubt that new ones will be developed.

The physical and mechanical properties of composite materials have been investigated by many authors.

Bowen\textsuperscript{5} studied the effect of particle shape and size distribution in a reinforced polymer. His investigations demonstrated that the strength properties of the material correlated better with the average particle size than with the percentage of resin in composite. Increased reinforcement to resin ratio was obtained with use of spheroidal particles and with the use of intermittent grading. Broader distribution of sizes in composites with small average size particles produced higher tensile and compressive strength values than did a composite with a narrow distribution but with larger particles.

Macchi\textsuperscript{6} in his comparison of Addent 35 and 12 with an unfilled
resin observed several interesting differences. The composites tested showed a better dimensional stability over the unfilled resin, both in setting and thermal changes. Surface roughness tended to increase when the composites were polished, while the unfilled resin maintained its original surface. Most of the composites tested showed a higher compressive and tensile strength than did the unfilled resin.

The physical properties of four thermosetting restorative resins were studied by Lee. He observed that the values for compression strength of the composites were lower than that of tooth structure. Tensile strength was within the values given for dentin. Tests of tooth structure have been reported as follows:

1. Compressive strength for tooth structure—33,000 to 44,000 psi.
2. Tensile strength
   a. Enamel—1,500 psi.
   b. Dentin—7,500 psi.

Values for some mechanical properties of the composite resins were superior to those of the conventional resins as pointed out by Phillips. Some of the advantages he reported were as follows:

1. Greater tensile and compressive strength.
2. Superior hardness and abrasive resistance.
3. Less polymerization shrinkage.
4. Less coefficient of thermal expansion.
Hollenback\textsuperscript{10} in his investigation found composites to be very hard and abrade very slowly. The clinical significance of these values in many cases may be a disadvantage since the composite might unduly abrade opposing tooth enamel and dentin.

Composites differ somewhat in their properties. The values of the physical properties vary from one brand to another and possibly from one batch to another. Several popular composites with their pertinent properties, as shown by two investigators, are listed. See Table I\textsuperscript{10} and Table II\textsuperscript{11}.

Composite resins are used primarily for restorations in anterior teeth. Although controversial, composite resins are being used by many dentists in Class II restorations in posterior teeth.

Investigations\textsuperscript{12, 13} as to the clinical performance of composites were initiated about three years ago. Observations for one year on a composite resin for Class II restorations by Phillips\textsuperscript{14} compared favorably with amalgam restorations. The resin restoration had a lower incidence of marginal failure than did the amalgam. The contour of the resin, however, showed signs of wear, particularly in the area of the marginal ridges. Also a slight color change was noticed.

At the end of a two-year period, after examining the same restorations, Phillips\textsuperscript{15} and others were less optimistic about the restorations. The bonding effect afforded by the silane coating was
### TABLE I. A Comparison of Some of the Physical Properties of Some Commercially Available Composite Restorative Resins

<table>
<thead>
<tr>
<th>Material</th>
<th>Compressive Strength 24 hr. psi*</th>
<th>Tensile Strength psi</th>
<th>Wear in cu. mm/hour Silex Slurry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptic</td>
<td>31,800</td>
<td>7130</td>
<td>0.11</td>
</tr>
<tr>
<td>Blendant</td>
<td>29,500</td>
<td>3650</td>
<td>0.60</td>
</tr>
<tr>
<td>Concise</td>
<td>29,800</td>
<td>4950</td>
<td>0.37</td>
</tr>
<tr>
<td>D.F.R.</td>
<td>25,900</td>
<td>6700</td>
<td>0.21</td>
</tr>
<tr>
<td>Addent XV</td>
<td>29,200</td>
<td>5800</td>
<td>0.21</td>
</tr>
</tbody>
</table>

*Specimens stored at room temperature*
TABLE II. A Comparison of Some of the Physical Properties of Some Composite Restorative Resins

<table>
<thead>
<tr>
<th>Material</th>
<th>Compressive Strength 24 hr. psi*</th>
<th>Abrasion** (percent wt. loss)</th>
<th>Knoop Hardness 24 hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptic</td>
<td>28,000</td>
<td>1.2</td>
<td>49</td>
</tr>
<tr>
<td>Blendant</td>
<td>23,000</td>
<td>1.3</td>
<td>28</td>
</tr>
<tr>
<td>D.F.R.</td>
<td>25,000</td>
<td>0.4</td>
<td>45</td>
</tr>
<tr>
<td>Addent 35</td>
<td>20,000</td>
<td>0.4</td>
<td>28</td>
</tr>
<tr>
<td>Addent 12</td>
<td>24,000</td>
<td>0.5</td>
<td>32</td>
</tr>
<tr>
<td>Dakor</td>
<td>18,000</td>
<td>0.6</td>
<td>20</td>
</tr>
</tbody>
</table>

* Specimens stored at room temperature

** One hour brushing in a mechanical toothbrushing machine with a slurry of CaCO₃.
not as strong as it had been believed. Christensen\textsuperscript{16} and Going\textsuperscript{17} observed similar deficiencies in their investigations.

Cavity preparation for composites requires the same care that is necessary for any other type of restoration. A good cavity design with adequate retention is essential. The mixing, handling, placement, and finishing are also factors to be considered for a successful restoration.

Finishing of the restoration is best achieved by a well adapted matrix since the material does not lend itself very well to mechanical polishing.

Various techniques\textsuperscript{18, 19} for finishing the composite restoration are recorded in the literature. Abrasive discs, diamond stones, and twelve-bladed burs are recommended. Chandler\textsuperscript{20} recommends using flexible paper discs impregnated with diamond particles (1 to 5 microns diameter); although quite effective, these discs do not seem to be commercially available. Better finishes seem to be produced by the use of the twelve-bladed burs.

Several investigators\textsuperscript{21, 22, 23} have warned that, biologically, composite resins cause pulpal irritation and a suitable liner is recommended.

I. PINS IN COMPOSITE RESINS

Pins used for retention can be traced back to the 19th century.
Evans\textsuperscript{24} described a method used by Littig, where pins were used to fasten a restoration on a tooth.

The retention of amalgam restorations with pins was used by Markley\textsuperscript{25} in 1951. In his technique a 0.025 inch diameter iridium-platinum pin was cemented into a prepared pinhole made by a No. 1/2 round bur.

Another technique, described by Markley\textsuperscript{26} in 1955, used threaded stainless steel wire in pinholes prepared by a No. 1/2 round bur. After the pinholes were prepared the pins were cemented.

In 1958 Markley\textsuperscript{27} used threaded stainless steel pins of 0.025 inch diameter and prepared the pinholes with a 0.027 inch diameter twist drill (Spirec Bohrer). "Lentulo-Spirals" were used to carry the cement into the holes.

More recently, in 1966, Markley\textsuperscript{28} used a 0.020 inch diameter pin. This small diameter pin was suitable for use in small teeth and large gingival third amalgams.

Goldstein\textsuperscript{29} in his article described a technique developed by Baker. In this technique a pin of 0.022 inch diameter was driven into a 0.021 inch diameter hole in the dentin which took advantage of the elasticity of the dentin to retain the pin.

Following the introduction of the friction lock pin, the self-threading stainless steel pin (T.M.S.\textsuperscript{*}) was introduced by Weissman\textsuperscript{30}. In this technique the pins were screwed into the dentin after preparing

\textsuperscript{*}Thread Mate System, Whaledent Co.
a pinhole with a twist drill of a smaller diameter. These pins are available in three different sizes, 0.031, 0.023, and 0.019 inch diameter.

Investigations were made to determine which one of the three types of systems for placing the pin provided the best retention. Dilts in 1968 and Moffa in 1969, testing these three types of systems, established that the greatest retentive values were obtained with the self-threading pin.

More extensive use of pins with other direct filling materials became popular. Some practitioners used the pins for retention in gold foil restorations; others used them in acrylic resin and later on in the composite restorative materials.

A controversy over the influence of pins in the physical properties of amalgams became apparent.

Markley and Wright claimed that pins increase the compressive and tensile strength of amalgam. Contrary to their findings, Wing and Welk concluded that compressive strength of amalgam was reduced with the use of pins. Going and Cecconi showed that the tensile strength of amalgam was reduced with the use of pins.
CHAPTER III

METHODS AND MATERIALS

The effect of pins on the compressive and tensile strength of samples of composite direct filling material was measured. Three different shapes of Teflon molds were used:

1. A cylindrical rod
2. A cylindrical disc
3. A dumbbell shape

The molds were designed to facilitate removal of the samples and to provide a smooth sample surface.

Initially the molds were lubricated with shaving soap; but it was found that those samples gave low values of compressive strength. Thereafter all samples were made without the use of a lubricating medium.

The materials used to make the samples were: three Teflon molds, two glass slabs to form smooth ends (sides) to the samples, a cylindrical rod and plunger to extrude the hardened specimens, endodontic pliers to insert the pins, plastic instruments to fill the molds and composite with mixing pad supplied by the manufacturer.

The composite resin used throughout the experiment was
Adaptic, manufactured by Johnson and Johnson Co. This material was kept at all times under refrigeration except for the period of time that it was in use. Before using the composite it was allowed to warm to room temperature. The Adaptic composite resin was homogenized and did not need stirring prior to its use. The stainless steel pins used were both threaded and non-threaded.

Compression and diametral compression (tensile) strength tests were done using headless threaded pins with different diameters in cylindrical samples. Non-threaded pins were used for the tensile strength tests using a dumbbell-shaped sample.

I. COMPRESSION STRENGTH TEST

The effect of compression strength was measured on cylindrical samples 8 mm long and 4 mm in diameter. The compression strength was calculated by dividing the maximum compressive load by the cross sectional area of the cylinder.

\[
\text{Compression strength} = \frac{\text{force}}{\text{area}}
\]

Control and experimental samples were made.

The composite was mixed for 30 seconds. The cylindrical Teflon mold (Figures 1A, 2) was placed over a glass slab and loaded with a plastic instrument using normal packing pressure. A threaded pin of 0.031 inch diameter and 7 mm long was inserted in vertical position in the center of the mold.
A. Dimensions of the mold for the cylindrical rod

B. Dimensions of the mold for the cylindrical disc

C. Dimensions of the dumbbell-shaped tensile specimen

Figure 1.
Figure 2. Teflon mold for cylindrical rod-shaped specimen.
Endodontic pliers were marked with a small notch so that the pin could be placed half a millimeter from the bottom end of the mold. Immediately another glass slab was placed over the filled mold. This allowed the pin to be covered with composite resin to a thickness of half a millimeter on each end.

The loaded mold was allowed to set for five minutes. The glass slabs were removed and the specimens were pushed from the mold with a three millimeter diameter plunger. The specimens were stored in water at a temperature of 37° C for a period of one week.

Similar samples were prepared using 0.023 inch diameter pins 7 mm long. To differentiate the samples, red and blue pencil marks were made respectively on the specimens containing the 0.031 and the 0.023 inch diameter pins.

Control samples were made using the same procedure but without pins.

A minimum of ten specimens were made for each of the three samples tested. Each individual sample was tested for compression strength using a Tinius Olsen Electromatic Universal Testing Machine. The samples were loaded at a rate of 0.025 inch per minute and the load in pounds of force indicated by the machine was recorded.

II. TENSILE STRENGTH TESTS

The diametral compression and the conventional dumbbell tensile tests were used.
Diametral Compression Test

The diametral test was accomplished by compression loading a cylinder across its diameter. In this position the maximum tensile stress is perpendicular to the compression or applied load axis. The ultimate tensile strength was calculated from the maximum load and sample geometry as described by Going37.

\[
\text{Tensile strength} = \frac{2 \times \text{compressive load}}{\pi \times \text{diameter} \times \text{length}}
\]

Control and experimental samples 8 mm long by 8 mm in diameter were formed in a Teflon mold (Figures 1B, 3).

The composite was mixed and loaded into the mold similarly to the compression test specimens. A threaded pin of 0.031 inch diameter and 7 mm long was inserted in the center of the mold.

Endodontic pliers marked with a small notch were used to place the pin in the center of the mold. The pin was covered with composite. A thickness of half a millimeter of composite covered each end of the pin facing the walls of the mold.

The loaded mold was allowed to set for five minutes. The glass slabs were removed and the specimens pushed from the mold with a three millimeter diameter plunger. The specimens were stored in water at a temperature of 37° C for a period of one week.

Similar samples were prepared using 0.023 inch diameter pins 7 mm long. To differentiate the samples and to identify the direction
Figure 3. Teflon mold for cylindrical disc-shaped specimen.
of the pin, red and blue pencil marks were made respectively on the 0.031 inch and 0.023 inch specimens.

Control samples were made using the same procedure but without pins.

A minimum of twenty specimens were made for each of the three samples tested.

Each of the samples with pins was tested for tensile strength by applying compressive force with a Tinius Olsen Electromatic Universal Testing Machine (Figure 4). Half of the samples were tested with the pin in a vertical orientation and the other half in a horizontal orientation. The samples were loaded at a rate of 0.025 inch per minute and the load in pounds was recorded.

Conventional Dumbbell Test

The effect of tensile stress was measured on dumbbell-shaped samples obtained from a mold (Figure 5) with a 0.30 inch gauge length and 0.125 inch cross section. Total length of each specimen was 0.75 inch (Figure 1C).

Control and experimental samples were made. The composite was mixed and loaded as explained before and a non-threaded pin 0.022 inch diameter by 17 mm long was inserted along the length of the loaded mold. Threaded (T.M.S.) pins were not used since they were not available in the required length for the dumbbell samples.
Figure 4. Application of the diametral compression test.
Figure 5. Teflon mold for the dumbbell-shaped specimen.
Endodontic pliers were used to place the pin halfway into the thickness of the experimental sample. The loaded mold was allowed to set for five minutes. The glass slabs were removed and the specimens were pushed from the mold using a metal rod 2 mm in diameter by 17 mm long. The specimens were stored in water at a temperature of 37°C for a period of one week.

Control samples were made using the same procedure but without the use of the pin.

A minimum of ten specimens were made for each of the two sets of samples tested.

The tensile specimens were pulled in the direction of their long axis at a rate of 0.02 inch per minute by an Instron Testing Machine. The ends of the dumbbell shape were friction fit into two aluminum grip plates (Figure 6) which in turn were placed between the jaws of gimbled grips (Figure 7). This minimized the chance of non-axial loading with resulting complex stresses. The maximum load was recorded and the tensile strength calculated by dividing the load by the area:

\[
\text{Tensile strength} = \frac{\text{load}}{\text{area}}
\]
Figure 5. Aluminum grip plates to hold the dumbbell-shaped specimen.
Figure 7. Dumbbell-shaped specimen held by gimbaled grips for applying tensile load.
CHAPTER IV

RESULTS

A total of 110 specimens were tested in this investigation. Seventy of them contained pins and the remaining were used as controls. The specimens were subjected to compression or tensile forces to measure their maximum load capacity.

I. COMPRESSION TEST

The tests on the cylindrical specimens showed that cracks formed and grew in directions of $45^\circ$ to the axis of the cylinder, independent of the use of pins. The applied load was along the cylinder axis. The $45^\circ$ was the direction of the maximum shear stress.

In the control samples and those containing the 0.031 inch diameter pin, the specimens cracked but did not break apart.

Even though the pattern of breakage in the cylinders with the 0.023 inch diameter pin was similar to the others, usually some composite material separated from the cylinder.

Of all the samples tested, it was observed that the specimens with the 0.031 inch diameter pin showed highest compression strength.
II. TENSILE STRENGTH TESTS

Diametral Compression Test

The control samples in these series broke along the diameter of the cylinder into two parts. The fracture was vertical and along the line of maximum compression; therefore the fracture was perpendicular to maximum tensile stress. This is a typical failure mode for brittle materials.

The samples with the 0.031 inch diameter pin in a vertical direction broke along the vertical diameter in the direction of the applied load. Most of the specimens tested fractured along the pin surface. The sample broke completely apart in two to three pieces (Figure 8A).

Samples with the same size pin in a horizontal direction showed a crack in the direction of the applied load. The crack was easily observed but the pieces of the specimen did not come apart (Figure 8B).

The same test was used on the samples with the 0.023 inch diameter pin.

Specimens with the 0.023 inch diameter pin in a vertical direction fractured vertically along both sides of the pin. This fracture left a square sheet of composite material 1 mm thick containing a pin (Figure 9A).

Samples with the same pin in a horizontal direction produced a very interesting result. The fracture occurred again along the vertical
Figure 8. Results of diametral compression test using the 0.031 inch diameter pin.

Left side: Fracture of the cylindrical disc in vertical orientation
Right side: Fracture of the cylindrical disc in horizontal orientation
Figure 9. Results of diametral compression test using the 0.023 inch diameter pin.

Left side: Fracture of the cylindrical disc in vertical orientation
Right side: Fracture of the cylindrical disc in horizontal orientation
diameter, breaking the specimen in two parts and severing the pin in half (Figure 9B).

Of all the 8 mm by 8 mm cylinder specimens tested, the cylinder with the 0.023 inch diameter pin in a vertical orientation produced the highest value of tensile strength. This higher value in the 0.023 inch specimen may suggest a strengthening effect. However, the statistical analysis of the data suggests that it may not be significantly higher.

**Conventional Tensile Test**

Dumbbell samples were the most difficult to test since samples of this geometrical shape tended to break very easily while being placed in the grips of the Instron Testing Machine. All dumbbell specimens, when tested, broke close to the center, i.e., away from the grips (Figure 10).

The dumbbell containing the pin showed much larger values than the control. This probably indicated that the pin increased the tensile strength.
Figure 10. Fracture of the dumbbell specimen with the 0.022 inch diameter pin.
CHAPTER V

CORRELATION AND DISCUSSION OF DATA

The mean stress of the control samples tested for compression strength showed lower values than the samples containing the larger size pin. Even lower values than for the control were obtained from the samples containing the smaller size pin (Table III). This would suggest that the large size pin increased the compression strength of the composite material.

TABLE III. Compression Strength

<table>
<thead>
<tr>
<th>Pin Diameter (inches)</th>
<th>No. Samples</th>
<th>Mean Stress (psi)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>10</td>
<td>37,000</td>
<td>5140</td>
</tr>
<tr>
<td>0.023</td>
<td>10</td>
<td>36,100</td>
<td>4520</td>
</tr>
<tr>
<td>0.031</td>
<td>10</td>
<td>41,700</td>
<td>3190</td>
</tr>
</tbody>
</table>

A comparison of the three compression strength groups was made (Table IV). The control group, when compared to the group containing the large size pin, showed a significant difference at the 0.05 level. This difference was large enough to indicate that the large size pin significantly increased the compressive strength of the composite material.
TABLE IV. Compression Strength: Comparison of Groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Degrees of Freedom</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control vs. small</td>
<td>18</td>
<td>0.403</td>
<td>0.692</td>
</tr>
<tr>
<td>Control vs. large</td>
<td>18</td>
<td>2.435</td>
<td>0.026</td>
</tr>
<tr>
<td>Small vs. large</td>
<td>18</td>
<td>3.159</td>
<td>0.005</td>
</tr>
</tbody>
</table>

In the compression strength groups, the group containing the small size pin did not show significant difference from the control group. If the observed reduction in compression strength is real, it may be that the small pin was not strong enough to give mechanical support or that it flexed or bent, breaking off some of the composite and, therefore, weakening the cylinder. However, with the evidence shown, it cannot be said that the small pin tended to weaken the material.

The diametral tensile test showed no statistically significant evidence that any of the pins, independent of their orientation and size, would strengthen or weaken the material (Table V). However, the small size pin in the vertical direction showed higher average values than the same pin in the horizontal direction. The small pin in the horizontal direction showed lower values than the control group but had higher values than any of the large size pin specimens.

Although it is difficult to explain why the small size pin in the vertical direction showed higher strength values, it may be said that
the small pin had less surface area and therefore less probability of
initiating a crack. Possibly there was a competition between surface
nucleation of cracks and mechanical support from the pin and, therefore,
a small vertical mechanical support is most important. The large size
pin, having more surface area, would allow more crack initiation.

TABLE V. Diametral Tensile Test

<table>
<thead>
<tr>
<th>Pin Diameter (inches)</th>
<th>Orientation</th>
<th>No. Samples</th>
<th>Mean Stress (psi)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>----</td>
<td>20</td>
<td>5360</td>
<td>1010</td>
</tr>
<tr>
<td>0.023</td>
<td>vert.</td>
<td>10</td>
<td>5490</td>
<td>879</td>
</tr>
<tr>
<td>0.023</td>
<td>hor.</td>
<td>10</td>
<td>5270</td>
<td>603</td>
</tr>
<tr>
<td>0.031</td>
<td>vert.</td>
<td>10</td>
<td>5080</td>
<td>1290</td>
</tr>
<tr>
<td>0.031</td>
<td>hor.</td>
<td>10</td>
<td>5180</td>
<td>1010</td>
</tr>
</tbody>
</table>

A comparison of all the diametral tensile groups showed no
significant variations from the control (Table VI). Therefore, the pins
did not significantly affect the tensile strength of the material.

TABLE VI. Diametral Tensile Test: Comparison of Groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Degrees of Freedom</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control vs. sm. vert.</td>
<td>28</td>
<td>0.353</td>
<td>0.727</td>
</tr>
<tr>
<td>Control vs. sm. hor.</td>
<td>28</td>
<td>0.246</td>
<td>0.808</td>
</tr>
<tr>
<td>Control vs. lg. vert.</td>
<td>28</td>
<td>0.650</td>
<td>0.521</td>
</tr>
<tr>
<td>Control vs. lg. hor.</td>
<td>28</td>
<td>0.463</td>
<td>0.647</td>
</tr>
</tbody>
</table>
The conventional tensile test showed a very large difference in the mean stress values of the control samples and the group containing the pins (Table VII). There was a significant difference at the 0.05 level when the pin was used (Table VIII). This indicated that the tensile strength of the material is increased.

**TABLE VII. Conventional Tensile Test**

<table>
<thead>
<tr>
<th>Pin Diameter (inches)</th>
<th>No. Samples</th>
<th>Mean Stress (psi)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>10</td>
<td>4400</td>
<td>1030</td>
</tr>
<tr>
<td>0.022</td>
<td>10</td>
<td>6410</td>
<td>1310</td>
</tr>
</tbody>
</table>

**TABLE VIII. Tensile Tests Comparison**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Degrees of Freedom</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional with pins vs. without pins</td>
<td>18</td>
<td>3.809</td>
<td>0.001</td>
</tr>
<tr>
<td>Conventional without pins vs. diametral without pins</td>
<td>28</td>
<td>2.444</td>
<td>0.021</td>
</tr>
</tbody>
</table>

The control group in the conventional tensile test showed lower values in mean tensile strength than did the control group in the diametral test (Tables V, VII). Probably this was due to the grip on the dumbbell samples concentrating the stress. The dumbbell was more sensitive to surface condition and also had a different shape (longer and thinner).
Pins in the conventional tensile test strengthened the material but not in the diametral test. In the conventional test a significant difference was observed when the pins were used (Table VIII). This may have been due to the lack of threads on the pin which were not available to act as fracture starting points in the dumbbell sample. In addition, the dumbbell has a less complex stress pattern and there was no external compression. Lastly, the pin was longer and took up a greater percent of the total cross sectional area.

The results of this investigation may be clinically significant. Virtually every large restoration is subjected to both tensile and compressive forces in the mouth. Pins are used to anchor large amalgams, composites or cements to the tooth and during the chewing cycle will have a tendency to be deflected by horizontal and vertical forces directed against them.

Although the tensile force is approximately only fifteen percent of the compressive force, strengthening of any material against fracture from tensile or compressive forces is a desirable goal. From the standpoint of the restorative dentist, improvement of tensile values is more important than compressive, where composite resins are concerned.

The 10 percent increase in compressive strength shown by the used of a 0.031 inch diameter pin is probably not clinically significant. For large Class II restorations or for composite cores (build-ups) for crowns, an increase of this magnitude is not particularly important.
Inasmuch as the tensile strength (Table VII) is approximately 40 percent improved with the addition of a pin, it is felt that this increase is clinically significant.

Regardless of any strengthening factors, however, the major function of a pin is to attach the material to the dentin. This basic fact cannot be ignored.

Significant increases in strength have been documented in the results given. However, even in the results showing no significant increase, the use of pins produced no weakening effect in the material. Clinically, this fact indicates that the use of pins in composites could only help, not hinder, the dentist to achieve his goal for a long-lasting restoration.
CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine the effect of pins on the compression and tensile strength of a composite material. A series of tests were conducted on three differently shaped samples.

The compression test showed that the composite material was strengthened 10 percent by the use of a 0.031 inch diameter pin. The 0.023 inch diameter pin neither increased nor lowered the strength of the material significantly.

In the diametral compression test, the diameter or orientation of the pin showed no significant strengthening or weakening effects in the tensile values. The samples with the 0.023 inch diameter pin in the vertical direction showed higher values but the difference was not significantly large enough to indicate any strengthening effect.

The conventional dumbbell test demonstrated that there is a large significant difference when the 0.022 inch diameter non-threaded pin was used (Table VIII). The tensile strength of the composite material was increased by 40 percent.

The results of this investigation demonstrated that pins do not weaken composite material and large size pins, in general, will
increase compression strength. In simple tension, the pin used significantly increased strength. This is in contrast to previous results for amalgams.
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PINS IN A COMPOSITE . . . THEIR EFFECT ON THE STRENGTH OF THE MATERIAL

by

Milton Latoni-Camarena

An Abstract of a Thesis in Partial Fulfillment of the Requirements for the Degree Master of Science in the Field of Restorative Dentistry

June 1972
ABSTRACT

The influence of pins on the compression and tensile strength of a composite resin was measured.

Compression strength was measured in cylindrical samples 8 mm long and 4 mm in diameter, using different size threaded stainless steel pins. The tensile strength was determined by compression along the diameter of cylindrical samples containing different sizes and orientations of threaded stainless steel pins.

The conventional dumbbell tensile strength was measured by pulling the mounted specimens in the direction of their long axis, using non-threaded pins.

These tests demonstrated that the compressive strength of the composite was increased 10 percent when the large size diameter threaded pin was used. The diametral compression showed no significant increase or decrease of the tensile strength, while the conventional dumbbell test demonstrated an increase of 40 percent in tensile strength in the samples containing the non-threaded pins.