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COMPARATIVE STUDY ON DISTRIBUTION OF LOAD AND STRESS ON NATURAL TOOTH AND PERIODONTIUM IN RELATION TO DIFFERENT TYPES OF RESTORATIVE CROWN MATERIALS – A PHOTOELASTIC STUDY

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ABSTRACT

Background: The selection of restorative materials for fabrication of crown and bridge which delivers less amount of stress to the periodontium is a challenging job for successful dentist. The resiliency of crown material plays a pivotal role in delivering stress to the periodontium and supporting structures.
Aim: To evaluate the amount of stress transmitted to tooth and periodontium with different restorative crown materials with different magnitude and direction of load.
Materials and method: Stress distribution is studied on seven different types of restorative crown materials on the natural tooth mounted on the photoelastic model.
Results: In photoelastic study the stress distribution is assessed by fringe order and fringe value. The highest stress inducing crown materials have highest fringe value. The study result shows metal ceramic restoration exhibits highest stress distribution followed by nickel chromium, silver palladium, gold, IPS empress 2, targis vectris. The least stress transferred to the periodontium was by acrylic resin.
Conclusion: The heat cure acrylic resin and the modified resin targis vectris have found to be the material of choice for complete coverage as far as stress concentration on the supporting structures is concerned.
Keywords: Fringe Order, Load Transfer, Photoelastic Study, Stress Distribution.

INTRODUCTION

The restoration of tooth irrespective of its vitality is found to be an attractive treatment in the modern era of dentistry. Attention should be focused on conserving the health of supporting structures in this kind of restorative management. The metallic and non metallic restorative material used in full coverage restoration exhibit their minimum, moderate and maximum influence on the supporting structure of the teeth. The stress developed during masticatory function is transmitted on the supporting structures through roots [1,4,7].

The amount of stress induced has a close relationship with factors such as magnitude of occlusal load, direction of load and type of restorative material employed and the resiliency of reastoration[31]. Periodontal health is one of the important determinants in the longevity of restoration. Factors that hamper the health of periodontium include torque forces, restorative materials with high modulus of elasticity and by the occlusal forces which go beyond the adaptive capacity of periodontium [16,5,10,12].
It is of vital importance to use restorative material which possess all the basic requirements and physical properties without compromising the

periodontium. Experimental biochemical models such as photoelastic models have been employed to determine the bone response to external load on restorative materials. The photoelastic method is a recognized engineering method of stress analysis and was first applied in dentistry in 1949 by Noonan[9].

In this study the application of photoelastic method to analyse the stress distribution to the periodontium with different restorative materials have been proposed in the models on various load transfer.

AIM AND OBJECTIVES

1. To evaluate the amount of stress transmitted to the supporting structures by loading the natural teeth restored with different restorative materials
2. To evaluate the stress distribution with different magnitude of load transfer
3. To evaluate the stress distribution with different direction of load transfer-vertical loading, oblique loading
4. To evaluate the resiliency of various restorative materials
5. To compare the resiliency exhibited by different types of materials selected in this study

MATERIALS AND METHODS

This study was conducted to analyse the stress distribution on the supporting structure of the natural tooth with complete veneer crowns of different restorative material existing in current clinical practice[1]. The crowned natural teeth with different restorative materials were fixed in a photoelastic study model to perform a two dimensional study to obtain fringes [9,14]. These crowned teeth were subjected to different magnitude of loading and in different direction of loading to simulate the masticatory load transmitted during function[8,15].

Restorative materials used in the fabrication of crown were

1. Non precious alloy nickel chromium alloy
2. Palladium silver alloy
3. Precious alloy Type III gold
4. IPS Empress 2
5. Targis Vectris
6. Feldspathic porcelain – (ultra low fusing)
7. Tooth colored heat cure acrylic resin

Materials used to prepare the photoelastic study models

1. Dentulous typhodont models
2. Two natural teeth) lower molar)
3. Flowable silicone
4. Irreversible hydrocolloid impression material
5. Modeling wax
6. Epoxy resin with hardener

Armamentarium:

1. Hand piece
2. Torpedo chamfer
3. Flat end tapered diamond
4. Long needle diamond
5. Fine grit round tipped tapered
6. Inlay casting wax
7. PKT instrument

Seven different restorative materials were selected for this study and for each restorative material five test samples (crowns) were prepared. Totally 35 test samples were prepared.

Restorative materials used for this study were grouped as follows

S.No	Groups	Material name	Commercial name	Manufacturer
1	I	Type III Gold	Design -98	Williams Ivoclar
2	II	Nickel chromium	CD 80	Sankin
3	III	Palladium silver	Design – 53	Williams Ivoclar
4	IV	Metal ceramic	4 – All, Design Porcelain	Ivoclar
5	V	Heat cure acrylic resin	DPI	Dental Products of India
6	VI	Modified tooth colored resin	Targis Vectris	Ivoclar
7	VII	Pressable ceramic Empress -2	IPS – Empress 2	Ivoclar

Preparation of photoelastic study model

A photoelastic model was fabricated with natural tooth by following techniques

Preparation of wax models: A study model of a lower dentulous typhodont was duplicated in wax using irreversible hydrocolloid impression material. The modeling wax was melted to liquid state and poured into alginate impression. Right half of wax model was cut at premolar level, to create a single segment wax model.

Preparation of site for molar tooth: Using a hot spatula wax was removed from the first molar tooth to a depth so as to accommodate a molar tooth.

Fixation of molar tooth in wax model: The mandibular first molar natural tooth was placed in the prepared site of the wax model. The interface between the tooth and the wax is smoothened with hot instrument.

Impression procedure: Impression of the wax model with the tooth was made with flowable silicone and allowed to set. The wax was eliminated by boiling out technique leaving behind the mould with the natural molar tooth.

Preparation of Photo elastic material: An epoxy resin and hardener (Araldite, Cy230, HY 951, CIBAGEIGY) in the ratio of 10:1 were mixed in an aluminium container for 15 min. The material was then poured into a mould along its sides again to ensure that no air bubble was incorporated, the material was allowed to set for 48 hrs at room temperature curing to obtain photoelastic models with natural tooth in position.

Preparation of natural tooth to receive complete veneer crown in the photoelastic model: Two identical photoelastic models were fabricated with natural teeth in position. Tooth preparation was carried out based on the bio mechanical principles on both the natural tooth embedded in photoelastic model. Chamfer and shoulder finish lines were given to them respectively.

Preparation of wax pattern: The wax pattern is the precursor of the finished cast restoration that will be placed on the prepared tooth. For all metal restoration, the wax pattern thickness was 1.5mm. For all ceramic and resin restoration, the overall wax pattern thickness was 2.0mm. The wax pattern was invested, casted, finished and polished by the conventional casting technique.

Two dimensional photo elastic technique: The photo elastic study is an well recognized engineering method of stress analysis. The technique involves construction of a model of the structure to be investigated from a photoelastic material[9,14]. The temporary double refraction under stress of photo elastic materials is utilized for photo elastic analysis. The ray of light is resolved into two rays which travel at different velocities along the principle plane of the material and emerge retarded with each other. The amount of retardation is directly proportional to the difference between the principle stress and is measured using a polariscope. The coloured fringes obtained are used to determine the stress distribution.

The models were loaded with 30.60 and 90 pounds and the resultant stress were calculated from the amount of fringes which have been photographed.

Loading photoelastic model: The single molar crown was cemented on the prepared molar tooth of the photo elastic model and the model was placed in the photoelastic straining frame. Vertical and oblique forces of 30 lbs, 60 lbs, and 90 lbs were applied on the occclusal surface of the various crown within the straining frame. The resultant stresses transmitted to the bone were photographed for each load application and the fringe pattern was recorded. All photographs were evaluated visually for stress induced fringes. This procedure was repeated for all the five samples of seven restorative materials taken up for this study.

RESULTS

Interpretation of results for vertical loading :

Under 30, 60, 90 pounds Group V exhibited minimum stress distribution, and Group IV exhibited maximum stress distribution. The stress distribution in descending order is as follows Group IV > II > I > III > VI >VII > V

Interpretation of results for oblique laoding :

Under 30, 60, 90 pounds Group V exhibited minimum stress distribution, and Group IV exhibited maximum stress distribution. The stress distribution in descending order is as follows Group IV > II > III > I >VII > VI > V

Under 30 pounds Group I and Group VII exhibited equal stress distribution.

Under 60 pounds Group II and Group IV exhibited equal stress distribution.

Color patterns of the internal stress in the photoelastic materials indicate the relative magnitude and distribution of stress that result from the force applied. The total numbers of isochromatic fringes observed were directly proportional to the magnitude of the force and areas of high stress concentration are represented by how close the fringes are to each other. Fringe order is based on the fringe color position in the color sequence namely as the colors become brighter {fringe order Black, Gray, white, yellow, orange red, blue, green}. Higher stress are indicated as said by Dally in his experimental stress analysis 1985.

DISCUSSION

Restorative materials of metallic, non metallic and combination of both are commonly used in clinical practice to fabricate restorations. These restorative materials are selected based on several factors to fulfill the requirements of the clinician and the demands of the patient.

Biomechanical factors such as heavy biting forces and grinding forces deliver vertical, oblique and horizontal load. These forces are of different magnitude and act in different direction on the periodontium causing damage to the supporting tissues along with the local factors already present in the oral cavity. Under these situations, the rigidity of the restoration could act as a potential factor to increase the magnitude of force resulting in excess stress concentration on the supporting structures beyond the physiological tolerance[3,13]. Hence this study was conducted to find out the quantum of stress concentration on the supporting structures on the tooth restored with commercially available restorative materials in current clinical practice.

The load applied on the prepared restoration is 30 pounds, 60 pounds and 90 pounds to simulate the masticatory load exerted by various types of restorations such as complete denture against natural tooth, removable partial denture against natural tooth and fixed partial denture against natural tooth respectively[7,15]. Loads were applied in two different directions, the axial direction simulating maximum biting force and the oblique loading simulating the grinding force. The oblique load was applied at an angle of 65 to the long axis of the tooth.

In this study 7 different restorative materials were selected which are the common materials used in the fabrication of restoration like complete veneer crown.

The metal ceramic crown exhibited maximum stress concentration followed by nickel chromium, palladium silver, gold, IPS Empress 2 and Targis vectris crowns. The least stress distribution was exhibited by acrylic resin.

Metal ceramic restoration is not a stress absorbing material due to its high rigidity. Although esthetically pleasing, it is highly detrimental to the periodontium especially during masticatory function. The oblique force was found to be more damaging when compared to the vertical force[5,10,12].

Following metal ceramic restoration the nickel chromium, silver palladium and gold restorations transmit more stress respectively[11]. All these alloys exhibit less or no resilience to minimize the stress distribution due to high Young's modulus value as far as these alloys are concerned. The gold alloys exhibit minimum stress concentration than niti is because of its low elastic modulus along with its ductility and malleability. Hence gold alloy may be suitable choice to restore the posterior teeth where esthetic demand is negligible.

Among the non metallic restorative materials, the all ceramic restoration Empress 2 exert more force and resulting in higher stress concentration over the supporting structure. Now all ceramic material have gained the highest popularity among the tooth colored restorative material of choice for complete coverage although illusion effect, color stability, longevity of material is found to be extremely good to fulfill the estheticand functional demands of the individual. But its rigidity is high according to Young s modulus. Although wear resistence of ceramic is very high it tends to wear off the opposing tooth.

Targs vectris modified resin and heat cure acrylic resin exhibit low stress concentration particularly the heat cure acrylic resin is the least one[2,3,6]. The acrylic resin has shock absorbing property due to their resiliency so it will dampen the impact forces that are exerted on the tooth through the restoration. So the stress distribution to the bone by the acrylic restorations is less when compared to all the other materials evaluated in this study.

CONCLUSION

The metal ceramic restoration exhibited maximum stress distribution and The acrylic resin restoration exhibited lower stress to the bone under 30,60 and 90 pounds on vertical and oblique loading. Among the metallic restorative material the gold alloy exhibits less stress concentration. Among the non metallic restorative material the heat cure acrylic resin exhibit the least stress concentration and all ceramic restotation exhibited maximum stress concentration.

Comparing all the restorative materials under two types of directions and three types of loading, the decreasing order of stress concentration is as follows: metal ceramic > nickel chromium crown>palladium silver crown>gold crown>empress 2>targis vectris> acrylic resin.

The decreasing order of resiliency of the seven restorative materials is as follows: acrylic resin > targis vectris>empress 2> gold crown > palladium silver>nickel chromium> metal ceramic

From the above study it can be concluded that the heat cure acrylic resin and the modified resin targis vectris have found to be the material of choice for complete coverage as far as stress concentration on the supporting structures is concerned. When comparing and evaluating other physical properties they are very low and could not compete with metal ceramic and all ceramic materials.

Hence an elaborate research and study have to be conducted to improve the physical properties of resin based restorative materials without compromising their resiliency.

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RESULT: VERTICAL LOADING
TABLE - I

S.No	*Load applied*	*Restorative materials*	*Fringe order*	*Fringe colour*	*Fringe value*
1	30Lbs	Group I	First	Green Yellow	1.39
2	30Lbs	Group II	First	Orange	1.63
3	30Lbs	Group III	First	Rose Red	1.82
4	30Lbs	Group IV	First	Purple	2.00
5	30Lbs	Group V	Zero	Purple	1.00
6	30Lbs	GroupV I	First	Deep Blue	1.08
7	30Lbs	Group VII	First	Blue Green	1.22

TABLE - II

S.No	***Load applied***	***Restorative materials***	***Fringe order***	***Fringe colour***	***Fringe value***
1	60Lbs	Group I	Second	Green Yellow	2.50
2	60Lbs	Group II	Second	Red	2.65
3	60Lbs	Group III	Second	Red	2.65
4	60Lbs	Group IV	Second	Red Green	3.00
5	60Lbs	Group V	First	Green Yellow	1.39
6	60Lbs	GroupV I	First	Purple	2.00
7	60Lbs	Group VII	First	Green	2.35

TABLE - III

S.No	***Load applied***	***Restorative materials***	***Fringe order***	***Fringe colour***	***Fringe value***
1	90Lbs	Group I	Third	Green	3.00
2	90Lbs	Group II	Third	Pink	3.65
3	90Lbs	Group III	Third	Pink	3.10
4	90Lbs	Group IV	Third	Pink Green	4.00
5	90Lbs	Group V	First	Purple	2.00
6	90Lbs	GroupV I	Second	Green	2.35
7	90Lbs	Group VII	Second	Red Green	2.65

TABLE - IV

S.No	***Load applied***	***Restorative materials***	***Fringe order***	***Fringe colour***	***Fringe value***
1	30Lbs	Group I	First	Green Yellow	1.39
2	30Lbs	Group II	First	Rose Red	1.82
3	30Lbs	Group III	First	Orange	1.63
4	30Lbs	Group IV	Second	Green Yellow	2.50
5	30Lbs	Group V	Zero	Purple	1.00
6	30Lbs	GroupV I	First	Deep Blue	1.08
7	30Lbs	Group VII	First	Green Yellow	1.39

TABLE - V

S.No	***Load applied***	***Restorative materials***	***Fringe order***	***Fringe colour***	***Fringe value***
1	60Lbs	Group I	Second	Green Yellow	2.50
2	60Lbs	Group II	Third	Green	3.10
3	60Lbs	Group III	Second	Red	2.65
4	60Lbs	Group IV	Third	Green	3.10
5	60Lbs	Group V	First	Green Yellow	1.39
6	60Lbs	GroupV I	First	Purple	2.00
7	60Lbs	Group VII	First	Green	2.35

TABLE - VI

S.No	***Load applied***	***Restorative materials***	***Fringe order***	***Fringe colour***	***Fringe value***
1	90Lbs	Group I	Third	Green	3.10
2	90Lbs	Group II	Third	Pink Green	4.00
3	90Lbs	Group III	Third	Pink	3.65
4	90Lbs	Group IV	Fourth	Green	4.15
5	90Lbs	Group V	First	Purple	2.00
6	90Lbs	GroupV I	Second	Red	2.65
7	90Lbs	Group VII	Second	Red Green	3.00

TABLE - VII

S.No	Type of Restorative Materials	Fringe Value
1	Group I	1.39
2	Group II	1.63
3	Group III	1.82
4	Group IV	2.00
5	Group V	1.00
6	GroupV I	1.08
7	Group VII	1.22

TABLE - VIII

S.No	Type of Restorative Materials	Fringe Value
1	Group I	2.50
2	Group II	2.65
3	Group III	2.65
4	Group IV	3.00
5	Group V	1.39
6	GroupV I	2.00
7	Group VII	2.35

TABLE - IX

S.No	Type of Restorative Materials	Fringe Value
1	Group I	3.10
2	Group II	3.65
3	Group III	3.65
4	Group IV	4.00
5	Group V	2.00
6	GroupV I	2.35
7	Group VII	3.00

TABLE - X

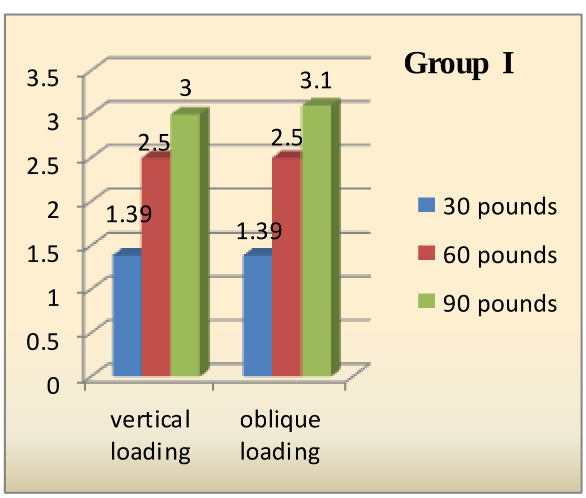
S.No	Type of Restorative Materials	Fringe Value
1	Group I	1.39
2	Group II	1.82
3	Group III	1.63
4	Group IV	2.50
5	Group V	1.00
6	GroupV I	1.08
7	Group VII	1.39

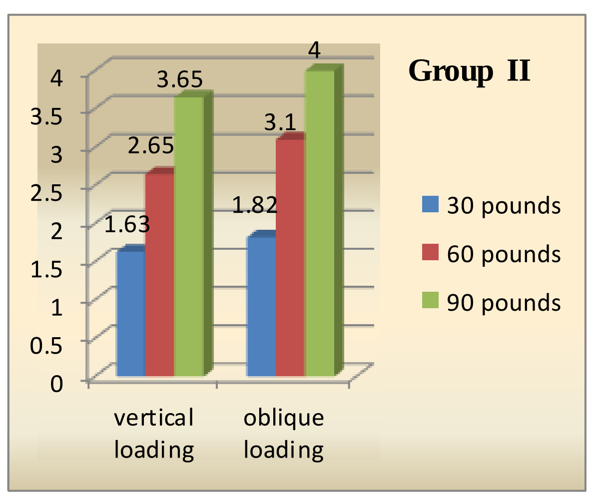
TABLE -XI

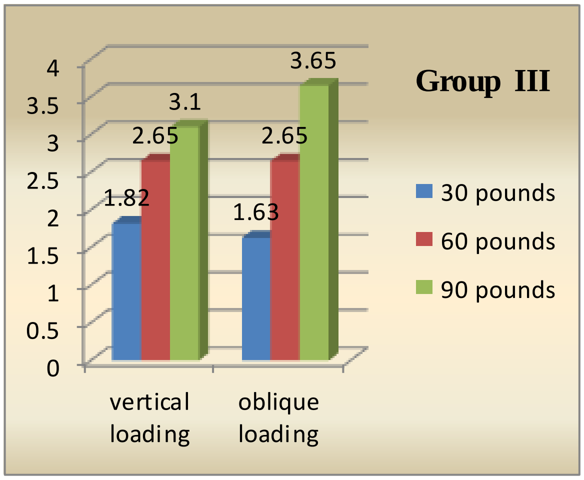
S.No	Type of Restorative Materials	Fringe Value
1	Group I	2.50
2	Group II	3.10
3	Group III	2.65
4	Group IV	3.10
5	Group V	1.39
6	GroupV I	2.00
7	Group VII	2.35

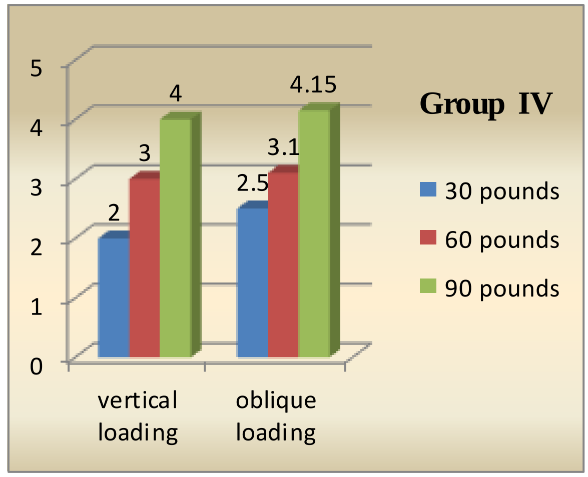
TABLE -XII

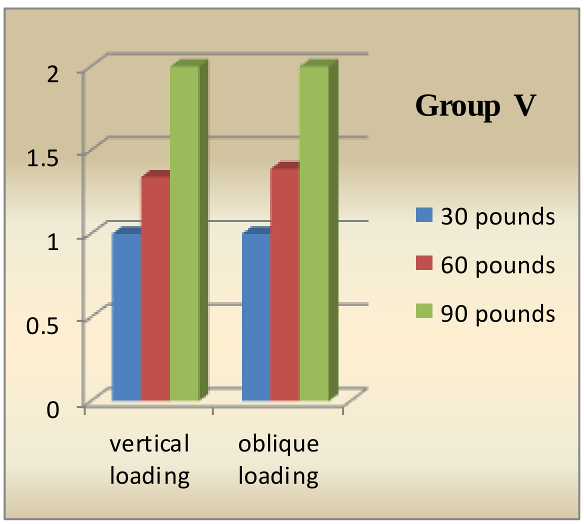
S.No	Type of Restorative Materials	Fringe Value
1	Group I	3.10
2	Group II	4.00
3	Group III	3.65
4	Group IV	4.15
5	Group V	2.00
6	GroupV I	2.65
7	Group VII	3.00

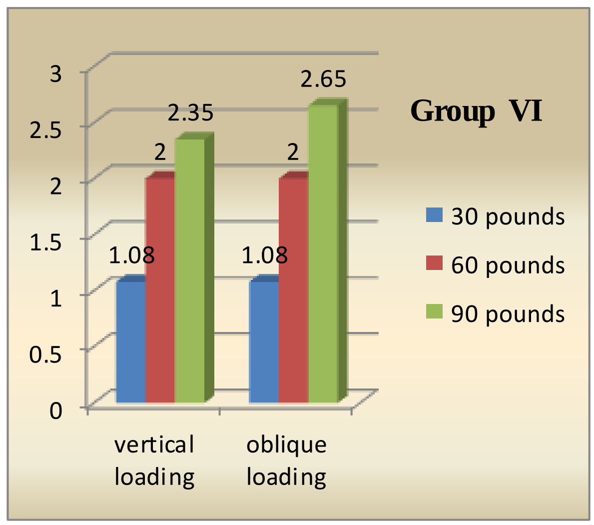


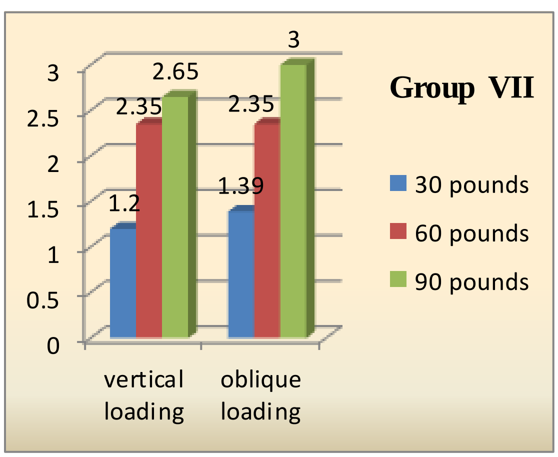


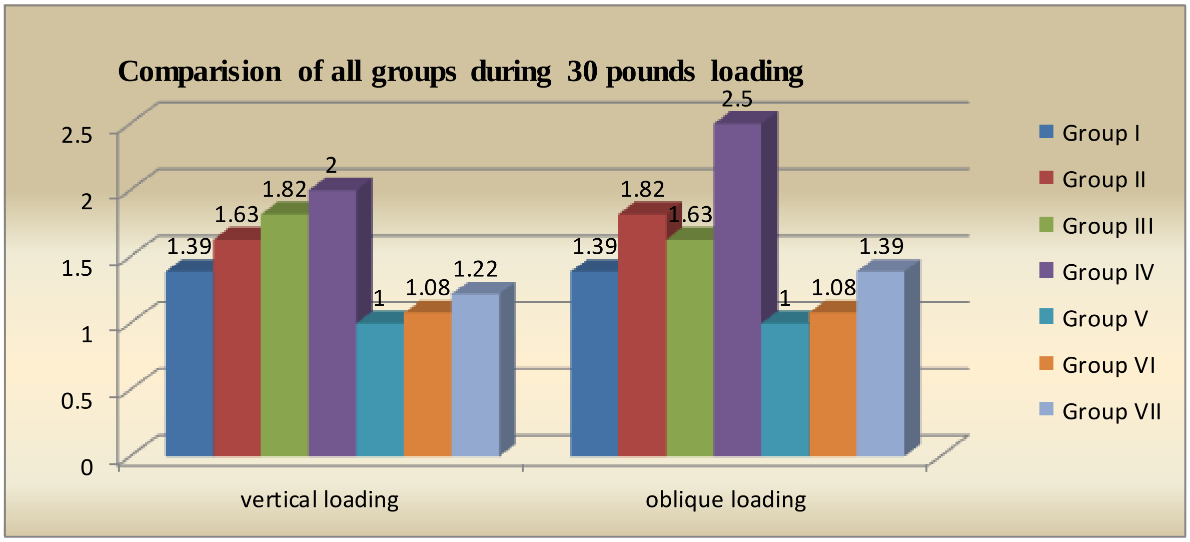

Group III
4
3.5
3
2.5
2
1.5
1
0.5
0
1.82
2.65
3.1
1.63
2.65
3.65
vertical loading
oblique loading
30 pounds
60 pounds
90 pounds

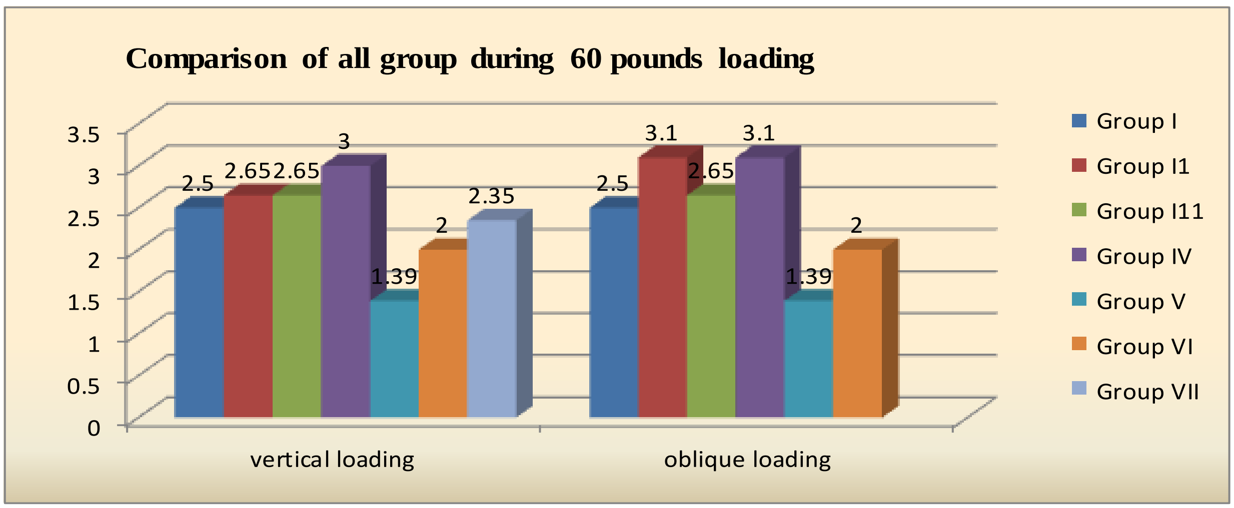

Group IV
5
4
3
2
1
0
2
3
4
2.5
3.1
4.15
vertical loading
oblique loading
30 pounds
60 pounds
90 pounds

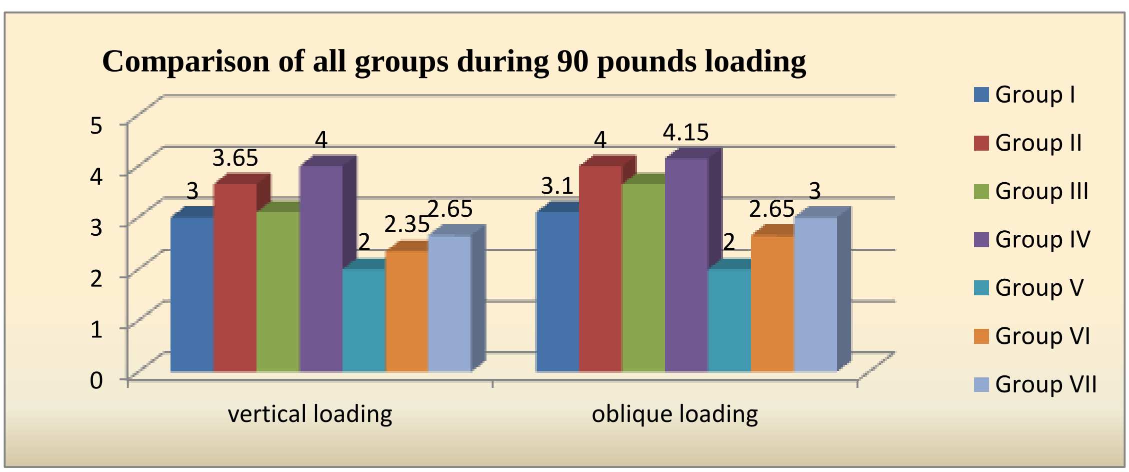

Group V
2
1.5
1
0.5
0
vertical loading
oblique loading
30 pounds
60 pounds
90 pounds


Group VI
3
2.5
2
1.5
1
0.5
0
1.08
2
2.35
1.08
2
2.65
vertical loading
oblique loading
30 pounds
60 pounds
90 pounds


Group VII
3
2.5
2
1.5
1
0.5
0
1.2
2.35
2.65
1.39
2.35
3
vertical loading
oblique loading
30 pounds
60 pounds
90 pounds


Comparision of all groups during 30 pounds loading
2.5
2
1.5
1
0.5
0
1.39
1.63
1.82
2
1
1.08
1.22
1.39
1.82
1.63
2.5
1
1.08
1.39
vertical loading
oblique loading
Group I
Group II
Group III
Group IV
Group V
Group VI
Group VII


Comparison of all group during 60 pounds loading
3.5
3
2.5
2
1.5
1
0.5
0
2.5
2.65
2.65
3
1.39
2
2.35
2.5
3.1
2.65
3.1
1.39
2
vertical loading
oblique loading
Group I
Group I1
Group I11
Group IV
Group V
Group VI
Group VII


Comparison of all groups during 90 pounds loading
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4
3
2
1
0
3
3.65
4
2
2.35
2.65
3.1
4
4.15
2
2.65
3
vertical loading
oblique loading
Group I
Group II
Group III
Group IV
Group V
Group VI
Group VII

Figure 1

Photoelastic polariscope with straining and loading frame

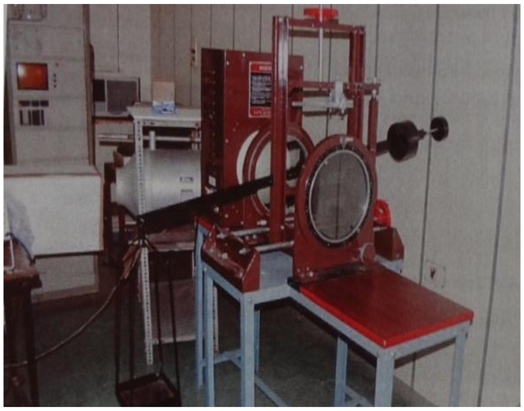

Figure 2

Fringe orders

Figure 3: on vertical loading 30, 60,90 pounds

Figure : 4 On oblique loading Group I 30, 60, 90 pounds

Figure : 5 On oblique loading Group II 30, 60, 90 pounds

Figure : 6 On oblique loading Group III 30, 60, 90 pounds

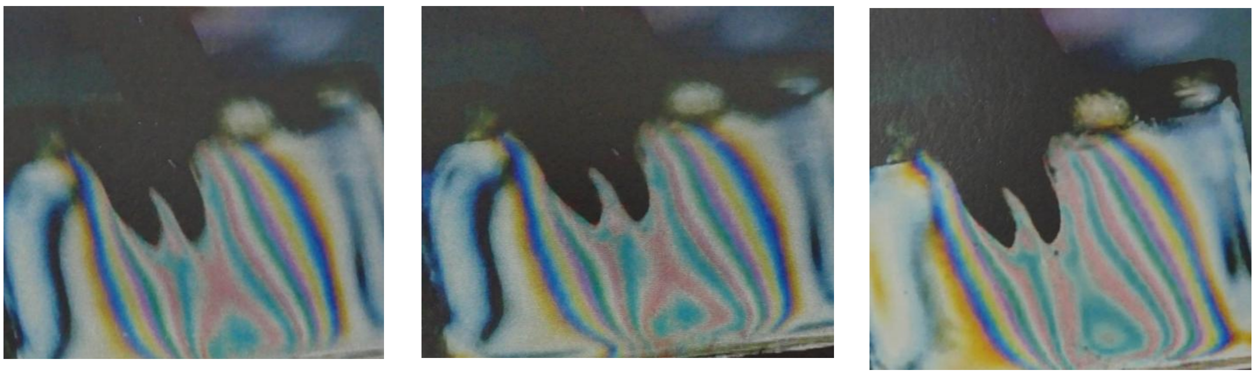

Figure : 7 On oblique loading Group IV 30, 60, 90 pounds

Figure : 8 On oblique loading Group V 30, 60, 90 pounds

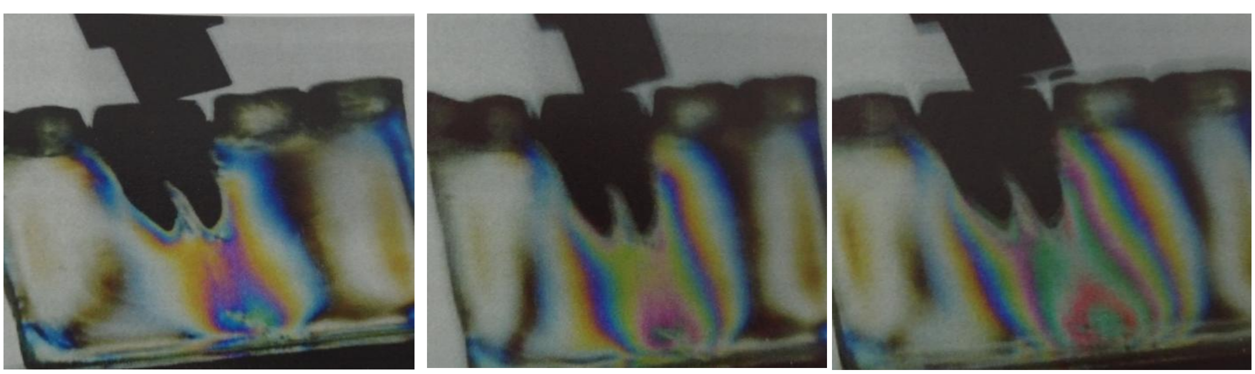

Figure : 9 On oblique loading Group VI 30, 60, 90 pounds

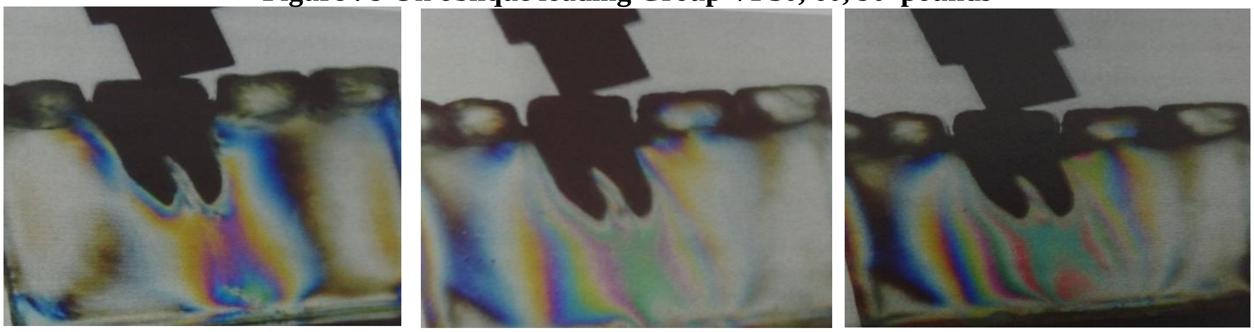

Figure : 10 On oblique loading Group VII 30, 60, 90 pounds