SOME ASPECTS OF POSTERIOR RESIN RESTORATIONS: AN IN VIVO AND IN VITRO STUDY.

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VOLUME I

CONTENTS:

VOLUME I

	PAGE
TITLE	i
CONTENTS	ii
ABSTRACT	xviii
DECLARATION	xx
ACKNOWLEDGEMENTS	xxi
PREFACE	xxii
CHAPTER 1 : INTRODUCTION	1
1.1 Historical Backround	2
1.2 Structure of Posterior Composites	2
1.3 Properties of Posterior Composites	4
1.4 Clinical Aspects of Posterior Composites	7
CHAPTER 2 : LITERATURE REVIEW	8
2.1 Colour change on curing	8
2.2 Opacity and reflectance	9
2.3 Polymerisation Contraction	10
2.4 Depth of cure	12
2.5 Porosity	18
2.6 Clinical techniques	20
2.6.1 Acid-etch/Bonding techniques	20
2.6.2 Microleakage	22
2.6.3 Depth of Cure and Incremental Build-up	22
2.6.4 Wear	23
2.6.5 Finishing	30
2.6.6 Fracture resistance: teeth	33
2.6.7 Fracture resistance: composite resin	33

CHAPTER 3 : OBJECTIVES 35

CHAPTER 4 : COLOUR CHANGE ON CURING 37

4.1 Introduction 37
4.2 Materials and methods 40
4.3 Results 50
4.4 Discussion 53
4.5 Conclusion 53

CHAPTER 5 : OPACITY AND REFLECTANCE 54

5.1 Introduction 54
5.2 Materials and methods 54
5.3 Results 59
5.4 Discussion 76
5.5 Conclusion 80

CHAPTER 6 : DEPTH OF CURE 82

6.1 Introduction 82
6.2.1 Investigation of a suitable depth of cure standard 85
6.2.1.1 Materials and methods 85
6.2.1.2 Results 93
6.2.2 Discussion and conclusions 106

6.3 Depth of cure: clinical influences. 112
6.3.1. Introduction. 112
6.3.2.1 Materials and methods ; Matrix band influence 115
6.3.2.2 Materials and methods; Light TransmittingWedges 124
6.3.2.3 Results: Matrix bands 135
6.3.2.4 Results: Light Transmitting Wedges 148
6.4 Discussion 155
6.5 Conclusion 156

CHAPTER 7 : POROSITY 157

7.1 Introduction 157
7.2 Materials and methods 157
7.2.1 Vacuum packaging of materials. 157
7.2.2 Incremental placement of resins. 161
7.2.3 Pins. 165
7.2.4 Line angles. 170
7.2.5 Effects of instrument placement. 173
7.2.6 Matrices. 182

7.3 Results 183

7.3.1 Vacuum packaging of materials. 183
7.3.2 Incremental placement of resins. 183
7.3.3 Pins. 183
7.3.4 Line angles. 186
7.3.5 Effects of instrument placement. 191
7.3.5.1 Pushing down on the resin 191
7.3.5.2 Lifting an instrument off the resin 191
7.3.5.3 Cutting the resin with a plastic 192

7.3.6 Matrices. 219

7.4 Discussion 226
7.5 Conclusion 226

CHAPTER 8. POLYMERISATION CONTRACTION 227

8.1 Introduction 227
8.2 Materials and methods 232
8.3 Results 232
8.4 Discussion 239
8.5 Conclusion 240

CHAPTER 9. WEAR: IN VIVO PILOT STUDY. 241

9.1 Introduction 241
9.2 Materials and methods 241

9.2.1 Materials 241
9.2.2 Methods - Class II Posterior resins 248
9.2.2.1 Preparation of the tooth 248
9.2.2.2 Cavity form 249
9.2.2.3 Sandwich Technique 256
9.2.2.4 Resin placement 257
9.2.2.5 Curing 262
9.2.2.6 Finishing 262

9.2.3 Methods - Class II Glass ionomer 275
9.2.4 Methods - Class II Amalgam 275

9.3 Assessment Method 276

9.4 Observed clinical failure: case report 277

9.5 Results 277

9.6 Discussion 296

9.7 Conclusion 298

VOLUME II

APPENDICES. 298

APPENDIX A. 299
Essay:
Aspects of posterior resin restorations
J. G. Ironside 1986

APPENDIX B. 393

List of Restorative Resins used in this research project.

APPENDIX C. 395

Case Report; Clinical notes.

APPENDIX D. 400

Australian Standard1278 - 1982
Resin based dental restorative materials.
Method for determining depth of cure.
Depth of Cure AS 1278 - 1982 Data

APPENDIX E. 403

Opacity tests:
Graphic displays and tables of
Individual results

APPENDIX F. 428

Reflectance tests:
tables and graphs of
Individual results

APPENDIX G. 442

Clinical protocol

APPENDIX H. 449

Replication Method

APPENDIX I. 450

Conical Diamond: Technical Information.

APPENDIX J. 458

Statistical comparison of disc thicknesses.

BIBLIOGRAPHY. 459

LIST OF FIGURES, TABLES AND GRAPHS.

FIGURES

4.2.a Expanded diagram for the apparatus used to produce the flat resin sample. 43

4.2.b Diagram of the cured resin sample, where a contrasting uncured resin specimen has been placed in the centre of the washer. 45

4.2.c Colour Change: Occlusin light grey photographed against a black backround, showing the change from opaque white to a more translucent grey-white. 47

4.2.d Colour Change: Herculite Syringeable photographed against a black backround, showing the change from opaque white to a more translucent grey-white. 49

6.2.1.b Resin specimen being measured according to AS 1278-1982. The uncured resin has been gently scraped away leaving only composite which has shown some degree of cure. 90

6.2.1.c Stainless steel mould of 4mm diameter with a resin specimen in situ. 92

6.2.1.2.a. Scanning electron micrograph of scratch from the conical diamond, where the resin matrix appears to be normal. The scratch is uniform, and there do not appear to be any tears through the matrix. The scratch appears to be about 23 microns across at this point. 97

6.2.1.2.b. Scanning electron micrograph of scratch from the conical diamond, where the resin matrix appears to have failed due to inadequate cross-linking. This photograph was taken near the middle of the specimen where the resin matrix is starting to show signs of tearing. Distinct filler particles can be seen lying in the surface of the cracks. 99

6.2.1.2.c. Scanning electron micrograph of scratch from the conical diamond, where the resin matrix appears to have failed due to inadequate cross-linking. This photograph was taken near the end of the specimen where the uncured resin had been gently scraped away and represents the point termed "catastrophic failure". 101

6.2.1.2.d. Scanning electron micrograph of Knoop Hardness indentations in resin sample adjacent to scratch where the resin matrix appears to be normal. 103

6.2.1.2.e. Scanning electron micrograph of Knoop Hardness indentations in resin sample adjacent to scratch where the resin matrix appears to have failed due to inadequate cross-linking 105

6.2.3.a. Diagram and photograph of the shape of the cured specimen from the depth of cure mould used in AS 1278-1982. **109**

6.2.3.b This photograph shows two resin depth of cure specimens produced according to As 1278-1982, with the exception that separators were used in the middle of the mould apparatus, as demonstrated in figure 6.3.2.1.a. The top specimen had a clear plastic separator and the bottom specimen had a stainless steel separator. **111**

6.3.1.a Photograph of a light transmitting Hawe-Luciwedge. (Side View)

114

6.3.1.b Photograph of a light transmitting Hawe-Luciwedge. (Top View)

114

6.3.2.1.a Diagram of apparatus used to simulate the effect of matrix strips on the quality of surface cure in the interproximal box. **117**

6.3.2.1.b Photograph of apparatus used to test the effect of matrix strips on the quality of surface cure in the interproximal box. **119**

6.3.2.1.c Diagram of apparatus used to simulate the effect of the clear mylar strips on the quality of surface cure in the interproximal box for the premolar specimen. **121**

6.3.2.1.d Photograph of apparatus used to test the effect of the clear mylar strips on the quality of surface cure in the interproximal box for the premolar specimen. **123**

6.3.2.2.a Diagram of the system used to measure the enhancement of depth of cure by the use of light transmitting/reflecting wedges. **126**

6.3.2.2.b Photograph of the system used to measure the enhancement of depth of cure by the use of light transmitting/reflecting wedges.

128

6.3.2.2.c Photograph of the cured resin sample following a 40 second application of the Translux CL light. **130**

6.3.2.2.d Diagram of the system used to produce a test surface at the top of the wedge, parallel to the base, at points that would approximate the centre of the interproximal region. **132**

6.3.2.2.e Photograph of the system used to produce a test surface at the top of the wedge, parallel to the base, at points that would approximate the centre of the interproximal region. **134**

6.3.2.3. h. Photograph of the in vitro interproximal surface of a specimen produced by the method shown in diagram 6.3.2.1.c and then scratch tested as shown in figure 6.3.2.1.d **145**

6.3.2.3.i S.E.M. Photomicrograph of the in vitro interproximal surface of a specimen produced by the method shown in diagram 6.3.2.1.c and then scratch tested as shown in figure 6.3.2.1.d 147

6.3.2.4.b. Diagram of the flat specimen of resin cured by light transmitted through the wedge only. 152

6.3.2.4.c Photograph of flared scratches from a resin sample, where the only light allowed to cure the specimen was transmitted through the wedge. 154

7.2.1.b. Diagram of the compressed and exploded views of the apparatus used to produce thin sections of composite resin for the study of porosity inclusions incurred during manufacture. 161

7.2.1.cPhotograph of the very thin section produced to observe the presence of porosities in vacuum packed posterior resin restoratives. 163

7.2.3.a Occlusal view of specimen before grinding back. 167

7.2.3.b Occlusal view of specimen after grinding back, with red representing the remains of the pins. 167

7.2.3.c Buccal view of specimen after grinding back, with red representing the remains of the pins. 167

7.2.3.d Mesial view of specimen after grinding back, with red representing the remains of the pins. 167

7.2.3.e Photograph of the exposed pins and voids after the specimen was ground back. 169

7.2.4.a Diagram of the temporary line angle formed between the cavo-surface margin and the matrix band. 172

7.2.5.c. Method of patting down resin with a flat ended plugger, diameter 1mm. 177

7.2.5.d. Method for cutting the resin increment from the delivery tube with a plastic instrument. 179

7.2.5.e. Method for pushing a stilletto type of instrument into the resin to manipulate the material into the cavity. 181

7.3.1.a Sub-micron porosity in vacuum packed resin. 185

7.3.1.b Sub-micron porosity in vacuum packed resin. 185

7.3.4.a Porosity at the artificial line angle produced at the intersection of the gingival floor and the matrix strip. 188

7.3.4.b Microporosity seen at the intersection of the axial walls of the proximal box and the matrix strip. 190

7.3.5.1.a Conical shaped sample of a sticky resin after the instrument had been pushed down and then lifted off. **194**

7.3.5.1.b Ridges left after pressing down on a highly filled resin. **196**

7.3.5.1.c Microscopic view of long resin tags in a less highly filled posterior resin following condensation by a flat instrument. **198**

7.3.5.1.d Microscopic view of short resin tags in a highly filled resin after condensation by the same flat instrument. **200**

7.3.5.1.e Stiletto marks in a less highly filled resin. **202**

7.3.5.1.f Stiletto marks in a highly filled resin. **204**

7.3.5.2.a S.E.M. micrograph of a very sticky resin surface following removal of an instrument. **206**

7.3.5.2.b S.E.M. micrograph of a very sticky resin surface following removal of an instrument. **208**

7.3.5.2.c S.E.M. micrograph of a less sticky resin surface following removal of an instrument. **210**

7.3.5.2.d S.E.M. micrograph of a less sticky resin surface following removal of an instrument. **212**

7.3.5.3.a Diagram and photograph of wave form following the cutting of a resin increment from the end of the delivery tube. **214**

7.3.5.3.b S.E.M. view of wave form created by cutting an increment off the delivery stream. **216**

7.3.5.3.c Polarised dark field view of wave form created by cutting an increment off the delivery stream. **218**

7.3.6.a. Porosity of approximately 100 microns diameter on the surface of a small particle posterior composite. This surface was covered with a clear matrix band during polymerisation. **221**

7.3.6.b. Micro-porosity in the resin rich surface layer of posterior composite resin. This photograph was taken by dispersed phase contrast light microscopy, with a magnification of 420 times. **223**

7.3.6.c. Micro-porosity in the resin rich surface layer of posterior composite resin. This section was cut at right angles to the proximal surface and photographed in bright field incident light at 420 times magification. **225**

8.1.a Diagram of self-curing resin undergoing polymerisation. The contraction forces are towards the centre and the top surface has been drawn down form the original dotted line to replace the lost volume. **229**

8.1.b Volumetric contraction pattern during curing of a photo-initiated resin. The contraction, (black arrows), is towards the visible curing light, (blue arrows). 231

8.3.1.a Photograph of the contraction gap formed at the gingival margin during curing from the occlusal, using a metal matrix band. The contraction gap is actually formed by the disruption of the glass ionomer-dentine bond. 236

8.3.1.b Photograph of the bond between the glass-ionomer and the restorative resin from the same specimen as that shown in figure 8.3.1.a. Note that the bond is not broken. 238

9.2.1.a Mesio-distal sectional diagram of a molar with a 3 surface Class II cavity with an amalgam restoration. 243

9.2.1.b Mesio-distal sectional diagram of a molar with a 2 surface Class II cavity a glass-ionomer restoration. 245

9.2.1.c Mesio-distal sectional diagram of a molar with a 3 surface Class II cavity and "Sandwich Technique" posterior resin restoration. 247

9.2.2.2.a Cavity outline form: mesial view, showing rounded line angles and butt style cavo-surface margins in areas of high stress or difficult access. 251

9.2.2.2.b Cavity outline form: buccal view, showing rounded internal line angles, with a butt style gingival margin in the proximal box. 251

9.2.2.2.c Cavity outline form: occlusal view, showing rounded internal line angles, with a butt style gingival margin on the proximal box axial walls. 251

9.2.2.2.d Pear shaped diamond bur used for the main cavity outline form. The diameter is 1.2mm. 253

9.2.2.2.e Tungsten carbide bur for finishing main cavity outline form. The diameter is 1.2 mm. 255

9.2.2.4.a The gingival floor is covered by a Ketac-Fil base, (shown here in red), which is about 1 mm thick. 259

9.2.2.4.b The first vertical/oblique resin incrument, (shown in blue). 259

9.2.2.4.c The second vertical/oblique resin incrument, (also shown in blue). 259

9.2.2.4.d The final incrument (also blue), is placed to finish the occlusal. 259

9.2.2.4.e The gingival floor is covered by a Ketac-Fil base, (shown here in red), which is about 1 mm thick. **261**

9.2.2.4.f The first increment is a horizontal layer, covering the glass ionomer base. This is cured only from the gingival, via the light transmitting wedge, to ensure maximum conversion of monomer components to the polymer at the gingival margin to provide the best seal.

9.2.2.4.g The first vertical/oblique resin increment, (shown in blue). **261**

9.2.2.4.h The second vertical/oblique resin increment, (also shown in blue). **261**

9.2.2.4.i The final increment (also blue), is placed to finish the occlusal. **261**

9.2.2.6 a Photograph of a coarse "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used. **264**

9.2.2.6 b Phase contrast photomicrograph of the surface of the resin specimen shown in figure 9.2.2.6.a following the application of the coarse disc. **264**

9.2.2.6 c Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.a. Magnification 20 times. **264**

9.2.2.6 d Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.a. Magnification 200 times. **264**

9.2.2.6 e Photograph of a medium "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used. **266**

9.2.2.6 f Phase contrast photomicrograph of the surface of a resin specimenfollowing the application of the medium disc. **266**

9.2.2.6 g Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.e. Magnification 20 times. **266**

9.2.2.6 h Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.e. Magnification 200 times. **266**

9.2.2.6 i Photograph of a fine "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used. **268**

9.2.2.6.j Phase contrast photomicrograph of the surface of a resin specimen following the application of the fine disc. **268**

9.2.2.6 k Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.i. Magnification 20 times. **268**

9.2.2.6 l Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.i. Magnification 200 times. 268

9.2.2.6 m Photograph of a super fine "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used. 270

9.2.2.6 n Phase contrast photomicrograph of the surface of the resin specimen shown in figure 9.2.2.6.m following the application of the super-fine disc. 270

9.2.2.6 o Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.m. Magnification 20 times. 270

9.2.2.6 p Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.m. Magnification 200 times. 270

9.2.2.6 q Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.a. 272

9.2.2.6 r Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.e. 272

9.2.2.6 s Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.i. 272

9.2.2.6 t Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.m. 272

9.2.2.6.u, top Phase contrast photomicrograph of the surface of a resin specimen shown following the application of the Shofu Quasite finishing point. Note that the surface of the disc is beginning to smear over. The collection of debris in the open porosities is concentrated. Magnification 420 times. 274

9.2.2.6.v, bottom left Scanning electron micrograph of the same specimen surface photographed shown in figure 9.2.2.6.u. Magnification 20 times. 274

9.2.2.6.w, bottom right Scanning electron micrograph of the same specimen surface photographed in figure 9.2.2.6.u. Magnification 200 times. 274

9.2.5.a. Photograph of a recording impression from which a replica was made in Araldite D. 279

9.5.1.a, top view. This restoration is seen at the six month recall. It is a P-30 MOD restoration. The surface and margins have started to stain. 282

9.5.1.b, middle view. The same restoration as above, at the twelve month recall. The surface and margins are stained even further. 282

9.5.1.c, bottom view. The eighteen month recall for the same restoration as above, with even further deterioration. There is however no bulk failure or any other clinical signs or symptoms to indicate failure of this restoration. 282

9.5.1.d, top view This series of restorations is taken at the polishing appointment after insertion. The 27 (obscured) has had a MO Ketac-Silver restoration, the 26 has a MODL Dispersalloy restoration, the 25 and 24 have MOD Herculite restorations. The six month recall did not show any significant deterioration. 284

9.5.1.e, middle view. This composite photograph was taken at the twelve month recall of the same restorations as above. 284

9.5.1.f This photograph was taken at the eighteen month recall. As with the previous photograph, the Dispersalloy of the 26 has deteriorated, but the surfaces of the 24 and 25 are still good. The 25 does however have some small occlusal wear marks, (figure 9.5.1.o). 284

9.5.1.g, top view. This photograph was taken at the polishing appointment after insertion of the restorations in this quadrant. The 27 was restored with a MO Ketac-Silver, the 26 was restored with a MODL Dispersalloy amalgam and the 25 was restored with a MOD herculite posterior composite. 286

9.5.1.h, middle view. This photograph is taken of the same series as above at the twelve month recall. The area outlined in red appears in the scanning electron micrograph in figure 9.5.1.j. 286

9.5.1.i, bottom view. This photograph is taken of the same series as above, but at the eighteen month recall. 286

9.5.1.j, top view. Fractured and abraded amalgam margin of the 26. This photomicrograph was taken from the area outlined in red in figure 9.5.1.h. at the twelve month recall. Magnification : X 80. 288

9.5.1.k, bottom view. Scanning electron micrograph of the fractured distal marginal ridge from the 26 shown in figure 9.5.1.i, taken at the eighteen month recall. Magnification : X 20. 288

9.5.1.l, top view. Scanning electron micrograph of the mesial marginal ridge of the 25, (figure 9.5.1.i), taken at the eighteen month recall. Magnification : X 10. 290

9.5.1.m, bottom view. Scanning electron micrograph of the mesial marginal ridge of the 25, (figure 9.5.1.i), taken at the eighteen month recall. A higher powered view of the fracture seen in the figure above. Magnification : X 50. 290

9.5.1.n Scanning electron micrograph of the margin of the P-30 restoration seen in figure 9.5.1.a, b and c. Magnification : X 100. 292

9.5.1.o, top view. Scanning electron micrograph of the surface of the Herculite restoration in the 25, seen previously in figure 9.5.1.f. Magnification : X 10. 294

9.5.1.p, bottom view. Scanning electron micrograph of the surface of the Herculite restoration in the 25. Magnification : X 100. 294

TABLES

1.3.a Physical properties of composite resins. 6

4.2. Resins tested for colour change on curing 39

5.2.1 Resins investigated for opacity and reflectance variations as a result of different exposures to the same curing light. 58

5.3.4 Results for the reflectance tests conducted on individual resins.

6.2.1.a Results of Depth of Cure tests according to AS 1278-1982. 88

7.2.1.a Resins tested for porosity inclusions during manufacture 159

7.2.5.a Resins observed by S.E.M. for porosity following instrumentation 173

7.2.5.b Resins observed by polarized dark field microscopy and macro-photography for porosity following instrumentation 175

8.3 Results for testing the effect of the direction of application and the type of matrix band on the integrity of the gingival margin seal. 234

9.5 a Results of the in vivo pilot study for the behaviour of Dispersalloy, P-30, Herculite and Ketac Silver. 280

9.5.b Results for staining and loss of anatomic form 280

GRAPHS

4.3. Results of colour change. 52

5.3.1.a. Graph of opacity results for all resins at 0, 24 and 48 hours. Values represent the mean for the combined results. 61

5.3.1.b. Graph of opacity results showing the changes that occur between uncured samples and those given 20 second exposure, 40 second exposure and 60 second exposures respectively. 63

5.3.2.a - n Graphs for individual resin opacity changes. * * *

5.3.3.a Reflectance results for all resin 66

5.3.3. b Graph for the reflectance values of the uncured specimens listed in table 4.2. 71

5.3.3. c Graph for the reflectance values of the specimens cured for 20 seconds, listed in table 4.2. 71

5.3.3. d Graph for the reflectance values of the specimens cured for 40 seconds, listed in table 4.2. 73

5.3.3. e. Graph for the reflectance values of the specimens cured for 60 seconds, listed in table 4.2. 73

5.3.3. f. Graph for the reflectance values of the Occlusin specimens, listed in table 4.2. 75

6.2.1.a Depth of Cure using AS 1278-1982. This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. 95

6.3.2.3.d Depth of Cure using AS 1278-1982. This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. The test mould had a metal separator strip to divide the sample into two halves. 129

6.3.2.3.e Depth of Cure using AS 1278-1982. This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. The test mould had a black plastic separator strip to divide the mould and specimens into two halves.

131

6.3.2.3.f Depth of Cure using AS 1278-1982. This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. The test mould had a clear plastic separator strip to divide the sample into two halves. 133

6.3.2.3.g Comparison graph to demonstrate the differences in the depth of cure results between different matrices. 135

6.3.2.4.a Graph representing the depth of cure measurements from the transmitting light wedge. 142

ABSTRACT.

The recent advocation of resin restorative materials for use as conservative Class I & II restoratives has prompted considerable investigation with regard to their suitability. A larger concern is the advocation for even wider use in the posterior region. During this investigation a number of different aspects of resin behaviour were observed in order to study the following objectives.

a. To show colour and opacity change on curing.

b. To compare the Australian Standard for depth of cure to a Scratch Hardness test.

c. To show porosity internally and at the surface.

d. To look at polymerisation contraction in relation to the gingival margin of the "Sandwich" technique.

e. To observe wear patterns of "P-30", "Herculite", "Ketac-silver" and "Dispersalloy" in vivo.

Colour change on curing was reviewed for a variety of resins/resin shades. Most posterior resins tested undergo a degree of change, with most becoming darker, and a few lighter.

Most resins undergo a degree of opacity change, which is related to the length of time that the curing light is applied and the time delay, (0, 24 or 48 hrs.), before measuring the opacity change. In general, the longer the curing time, the less the opacity change at the later measuring intervals. This would indicate a higher level of conversion in the resin matrix with a

longer application of the curing light. Uncured resins briefly exposed to laboratory light and stored in darkness until the next measurement do show a slight degree of conversion.

The comparison between the Australian Standard for depth of cure for restorative resins and the scratch test, using a conical diamond, has revealed a change in conversion rate after only 50 - 60 % of the depth accepted by that standard. The AS 1278-1982 system is very reliable and readily reproducible.

Porosity in posterior resins has been found in a wide variety of situations, from undisturbed vacuum packed resins as a result of manufacturing processes, to the final restoration. Porosity is induced with almost every maneouvre or attempt at placing the resin in a cavity. This includes methods of direct placement by syringe, or using specially constructed or coated instruments. Porosity and/or voids are also present at line angles, increment lines and around pins. Immediate subsurface porosities are opened by finishing proceedures.

The results demonstrate that all resins shrink to varying degrees. The degree is dependent on monomer composition and filler particle density. The best method to reduce the effects clinically, is to cure smaller increments of resin sequentially, and use directional curing with the light.

The in vivo study shows that conservatively placed Class II polymer restoratives will withstand the functions demanded of them. Those placed under direct occlusal loading show more wear than those in an enamel protected occlusion. In contrast to this initial finding, "Ketac-silver" is not a good Class II restorative.

DECLARATION

This research report is submitted in partial fulfilment for the Degree of Master of Dental Surgery.

The research is of original material and work and contains no material previously published or written by another person except where due reference is made in the text.

No part of this work has been submitted for any other degree or diploma in any University.

This research report may be made available for photocopying and loan if applicable if accepted for the award of the degree.

James G. Ironside

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Where the research findings of other workers are described, mentioned or discussed, due reference has been made and included in the bibliography.

PREFACE

This report was written with the aim of providing some insight to the behavior of resin restoratives used in Class I & II situations. Several aspects of resin behaviour have been observed to determine whether trends exist. As it was not the aim to go into great depth with such trends, large specimen ranges for statistical analysis were not employed. The identification of several changes that occur has been achieved and it will require extensive additional work to determine the degree and effects of these findings.

CHAPTER 1. INTRODUCTION

The needs of modern man have become an interesting and diverse collection of physical and mental demands. No less has the dental area suffered the same fate. The advent of modern dentistry has evolved around an increasingly sophisticated group of sciences; numbered are the days of empirical treatments. The battery of restorative materials is now changing at such a rate that it is common for posterior composite materials to be withdrawn from the market before they have reached the American Dental Association acceptance target of five years satisfactory service for product accreditation.

This trend is particularly evident in the adhesive resin based restoratives. Within this research field there are some areas which are open to contention and not yet studied with common techniques. Examples of these are; depth of cure for photo-activated composites, porosity and its relevance to wear in the clinical situation, some physical properties both in vivo and in vitro, and changes to optical properties on curing, including colour change and opacity.

The essay "Aspects of Posterior Resin Restorations" (Ironside, 1986[1]) is used as a general backround and literature review in conjunction with this report. Specific areas used in this report are supported with more recent publications.

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[1]IRONSIDE, J.G., Aspects of Posterior Resin Restorations : An essay, M.D.S. Programme, the University of Adelaide, Dept. of Dentistry, 1986.

1.1 HISTORICAL BACKROUND

The term posterior composite is used to refer to materials used for Class I and II cavities. The first material commercially available for such purpose was Addent 12[2], (Makinson, 1986). Since that time a variety of materials have been used for this purpose. Some are claimed by manufacturers to be specifically formulated for posterior use, for example, "P-30"[3], whilst others, such as the traditional composite "Adaptic"[4], were simply used for this purpose.

1.2 STRUCTURE OF POSTERIOR COMPOSITES.

The resin research over this period has evolved around the basic aim to produce the "perfect resin restorative" both for anterior and posterior use. The research areas centered on the composition of the resin itself, the coupling of the resin matrix to the filler content, the nature and quantity of the filler fraction and the different needs of composite resins for different applications. The resin restorative or "composite resin" as it is more commonly called, was defined by Bowen in 1972 as:

"A combination of two chemically different materials with a distinct interface separating the components and having properties which could not be achieved by any of the components acting alone."

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[2]Addent 12 : Dental Products Division/3M, 225-1S-09 3M Center, St. Paul, MN 55144. U.S.A.

[3]P-30; Dental Products Division/3M, 225-1S-09 3M Center, St. Paul, MN 55144. U.S.A.

[4]ADAPTIC; Johnson and Johnson Dental Products Company, 20 Lake Drive, CN 7060, East Windsor, N.J. 08520

The basic ingredients in composite restorative materials include:

monomers,

dilutants,

polymerisation stabilisers,

colour stabilisers,

polymerisation initiators,

polymerisation accelerators,

inorganic reinforcing fillers and

coupling agents.

It has generally been agreed, [Vanherle et al., 1985 and Jendresen 1985], that the ideal characteristics of posterior composites should include the following:

1. Biocompatibility.
2. Wear resistance like amalgam.
3. Ease of manipulation with simple conventional working techniques.
4. Absolute form stability.
5. Perfect and impermeable marginal adaptation.
6. Radiopacity.
7. Quick, exact and non-tooth destructive finishing proceedures.
8. Good aesthetics.

In order to achieve these ends the manufacturers of recent times have placed considerable emphasis on the development of their resin systems for posterior restorations. New developments have focussed on the type, size and quantity of filler, the blend of different monomers, improved silane coupling and aesthetics. Most manufacturers have incorporated a variety of shades to allow greater aesthetic flexibility. A recent addition to the market, "Herculite XR"[5] has dentine shades and enamel shades which according to the manufacturer, allow more lifelike restorations.

1.3 PROPERTIES OF POSTERIOR COMPOSITES.

The physical properties of posterior restoratives vary widely with manufacturers trying to produce very tough materials based on laboratory tests. The table 1.3.a. is an attempt to present current information.

Correlation between the constituents of the restorative and its in vitro performance are then used to give an indication of performance. However, when in vivo and in vitro results are compared the true performance of the material is often far below the manufacturers predictions.

[5]Herculite XR; Kerr, Romulus, Michigan, 48174 U.S.A.

Table 1.3.a.

Physical properties of composite resins

(after Smith, 1985)

Table 1.3.a

Property	Posterior	Conventional	Microfill
Compressive strength (MPa)	300-380	250-300	190-260
Compressive Modulus (GPa)	15-20	7-14	3-5.5
Tensile Strength (MPa)	45-70	40-60	25-40
Tensile Modulus (GPa)	15-20	15-20	4-6
Bending Strength (MPa)	120-150	110-135	60-80
Water sorption (wt. %)	0.2-0.6	0.2-0.8	1.2-2
(vol. %)		1.5-2	2-3
Thermal Expansion Coefficient (10^{-6} / ^{o}C)	22-35	25-35	45-70
Mineral Content (% wt.)	60-86	70-80	35-50

1.4 CLINICAL ASPECTS OF POSTERIOR COMPOSITES

The clinical considerations for the use of posterior composites are centered around the need for aesthetics and conservative restorations. The resins are generally shaded to match the existing tooth colour. Direct bonding to the remaining tooth structure, particularly the enamel, diminishes the need for removal of additional tooth structure to create retention and resistance form.

A considerable literature collection concerning mercury toxicity has been directed towards the general public. This has resulted in some cause for concern on the public's behalf. Whilst this may or may not be the case, particularly with the low corrosive amalgam alloys available today, there is an increasing demand for resin restoratives in lieu of amalgam. A section of the public have also begun to demand the replacement of good amalgams with unproven resins. It is also interesting to note that gold as an alternative is not promoted despite its biocompatibility and exceptional clinical record over a long period of time.

CHAPTER 2. LITERATURE REVIEW

There is no intention for this literature review to be an overview for the whole field of composite resins.

A literature review in the form of an essay entitled "Aspects of Posterior Resin Restorations" has been presented as part of this programme. It included material published up to November 1986. This essay appears as Appendix A at the end of this report. However, further developments have occurred in the period up to December 1987 and relevant aspects from the essay and subsequent literature, are included now in this review.

2.1 COLOUR CHANGE ON CURING.

The colour of the resin is influenced by the amount of camphoroquinone within its make-up. Camphoroquinone on its own is used as a photo-sensitizer to initiate the photo-polymerisation or may be used in conjunction with an adjacent reducing agent such as an amine to produce at least two free radicals and enhance the degree of cure. The addition of camphoroquinone to the base resin turns the material very yellow, (Taira et al., 1988).

The surface finish of the resin also has an effect on the perceived colour of the resin. A highly polishable resin reflects more light than a matt finished resin. Where more light is reflected, the surface takes on the colour of the incident light, whereas a matt finish produces diffuse reflection, allowing the colour of the reflector to come through, (O'Brien 1985). This is also an important factor when considering the reflectance of resins.

2.2 OPACITY AND REFLECTANCE.

The normal enamel-dentine-pulp complex of the human tooth has its own particular set of optical properties. These include opacity, translucency, reflectance and dispersion. Such properties combined with pigmentation, age and physical structure produce the colour characteristics of the tooth. The dentine is more opaque than the enamel, and both have a degree of translucency. Translucent objects will both reflect and transmit some light and therefore the human tooth may be regarded as translucent material, with wide variations according to which part is under observation, (Maclean, 1979). The surface structure and refractive index will determine the surface reflectance, (Groenhuis et al., 1984), regardless whether the material is enamel, resin or porcelain. Dental restorative resins are required to have similar properties to teeth, without deterioration or mis-match of shade.

When a beam of light strikes the boundary between two transparent media, there is both a reflected and a refracted beam. Whilst the laws of reflection and refraction could tell us the directions or angles of these beams, they cannot give an indicaton of their relative intensities. In addition, when a light beam strikes the interface between two transparent media, the fraction of the incident light that is reflected is called the reflectance and is dependent on two factors : (a) the relative refractive indices of the two media and (b) the angle of incidence. When light strikes the surface of a denser medium the reflectance increases as the angle of incidence increases to 90^{o}, but reflection never becomes total, (Shortley et al., 1965).

These factors will show marked differences in magnitude between resin systems placed in the same situation and will also have a marked effect on the efficiency of the depth of cure. Filler particle size and wavelength can combine to give maximum dispersion and reflectance with little transmission, overall combining to provide an opaque appearance.

2.3 POLYMERISATION CONTRACTION

During curing the resin matrix undergoes contraction and the amount and type of monomers and oligomers have a direct bearing on the magnitude of the contraction. The filler content has little effect on this contraction unless it is greater than 50% by volume, and clinically this shrinkage produces the so called "contraction gap". With most modern composites this contraction can be expected to be around 2-3%, by volume. However, with very low viscosity monomers such as methyl methacrylate it can be as high as 5%. The lowest value currently claimed is 0.6% by volume for a quartz filled posterior resin, "Visio-Molar"[6].

The effects of microleakage have been of concern to the dentist for a long time. When composite resins cure they contract, and if there is insufficient strength in the bond between the resin and the tooth, the adhesion of the resin to the tooth fails and a gap forms between the the restorative material and the cavity wall. The effect is to allow in bacteria and plaque. This results in secondary caries, pulpal sensitivity, and sometimes pulp infection and necrosis. Hygroscopic expansion of the resin in the first two weeks is often not enough to close this contraction gap, (Brannstrom, 1985).

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[6]Visio-Molar ; ESPE, Fabrik Pharmazeutischer, West Germany.

More recently it has been demonstrated that heat does not change the contraction width. Cold causes the gap to increase by up to 5 micrometers, (Torstenson et al., 1988).

The main area where microleakage is applicable in posterior resin restorations is the interproximal gingival margin, (Kidd, 1985), where there is little or no enamel to provide a sufficiently sound seal. Normally, the acid-etch enamel margins provide considerable resistance to micro-leakage, (Luescher et al., 1977 ; Hembree 1980). Unless particular steps are taken to prevent leakage at the gingival margin the restoration will fail, as irrespective of the material used, contraction gaps develop at the cervical margin. This gap varies in width from 7 to 22 micrometers and the use of dentine adhesive or recommended pretreatment proceedures for bonding do not markedly reduce the gap size, (Torstenson, 1986).

Sealing of the gingival margin can be achieved by the use of a post-operative sealing technique as described by Torstenson et al., (1985), where low viscosity resin is drawn into the gap by capillary force and allowed to set. The gingival margin can also be sealed by the use of dentino-enamel bonding agents, although their effectiveness is questionable if the curing shrinkage of the filled resin is allowed to cause a high tensile force on the bonding agent. The use of a glass-ionomer resin as a base extended to the gingival margin can also provide a seal.

Significant reduction of microleakage at the enamel margins can be achieved with a bevelled cavosurface margin, (Moore, 1986). At the gingival margin this reduction can be improved by the use of oblique incremental placement techniques and light-transmitting wedges, (Krejci and Lutz,1986).

2.4 DEPTH OF CURE

Depth of cure for light-activated resins has been reported by many to be dependent on a number of variables. Following the clinical use and observed failures of some Ultra Violet Light Cured (UVLC) applications there have been many articles written concerning what constitutes a cure, what affects the cure, and what is considered to be the proper depth of cure. Finally there are the problems of relating the observed in vitro behaviour to the realities of the clinical situation.

Numerous factors have been observed as having an effect on depth of cure. Considering both the in vivo and the in vitro situations, these include the following:

1. The mould material,
2. The mould size,
3. The exposure time,
4. The intensity of the photo activating light source,
5. The diameter of the light beam,
6. The age and condition of the light globe and reflectors,
7. The input voltage,
8. The condition and type of light transmitter between the source and the objective, and
9. The inherent factors of the composite itself, principally the transmission coefficient and the composition.

The method for measurement of depth of cure has not been standardised internationally, and to date several systems have been tried. These include resistance to scraping, dye adherance (deGee et al., 1984), optical

distinction, hardness indentation profiles, and physical measurement by micrometer. There is also no concensus about absolute hardness value or the relative ratio of hardness between the top and bottom surfaces for a depth of cure criterion. Skeeters et al. (1983), defined depth of cure as the axial distance from the surface where the Knoop hardness dropped to less than 90% of the hardest value measured. The specimens for this definition were cylinders of composite material, 4 mm in diameter and 6.4 mm high. The specimens were produced in cylindrical split/brass moulds. During curing, the tip of the light source was placed in contact with a Mylar matrix strip that covered the base of the specimen cylinder.

There is little evidence to show that prolonged exposure to the curing light will eventually provide adequate depth of cure. The manufacturers suggest that if in doubt a longer exposure time should be used. Leung et al., (1982), demonstrated that extremely long exposure times (300 seconds) will improve the polymerisation. However, their study used top and bottom Barcol hardness measurements to guage the relative depth of cure.

When considering the previously mentioned factors some reasons for discrepancies can be seen. For example where the beam diameter is less than the internal mould diameter the depth of cure increases because the surrounding composite acts similarly to a translucent mould (Fan et al., 1984). Translucent moulds have often been cited as producing higher depth of cure values when compared with opaque metal molds. However, because metal moulds behave in a similar fashion to tooth structure their use has been substantiated (de Lange et al., 1980; Watts et al., 1984; and Ruyter, 1985).

The transmission coefficient is the indicator of the ability for the curing light to pass through the composite. The composition of the material will affect this value. For example, the small filler particles of the microfills cause more light scattering, which decreases the amount of light transmitted through the material giving a shallower depth of cure.

With regard to variations in curing lights, investigators generally agree that this is an area where considerable variations can occur. A number of articles (Blankenau et al., 1983; Watts 1984; Friedman et al., 1984; Fan et al., 1985; Cook 1985; and Christensen and Christensen, 1986), attempt to rank light sources according to their ability to provide adequate depth of cure. The rankings between the reports vary and several reasons given for this include:

1. Differences in between the measuring methods used and the instrumentation,
2. Variations in the relative performances of identical units, (i.e. units of the same brand),
3. Any variation in globe output,
4. The method and condition of the light transmission medium to the composite as previously mentioned,
5. The diameter of the emitting surface of the light source, and
6. The distance from the light source to the composite.

Globe output can vary with the age, subtle variations in the manufacture, or line voltage variations to the globe at the time of measurement.

The output of the lights in the 400-500 nm range also varies and it is this property that has more bearing on the effectiveness of the unit rather

than brightness as 470 nm is the optimum wavelength for free radical formation. Currently not enough is known concerning the quantum efficiencies of the various wavelengths for curing. The observation is that Visible Light Cure (VLC) units with higher quantities of ultra-violet light as well as high output in the 470 nm region are more efficient for curing. The actual light intensity recorded from a given unit is therefore not always an accurate indicator of its efficiency. Manufacturers have been increasing the radiant emittance of the lights in order to overcome this problem (Cook, 1985).

Several studies have shown specific problems associated with depth of cure. In 1984 deGee, ten Harkel-Hagenaar, and Davidson concluded from their dye staining of unreacted groups in the resin phase, that microfill resins have a more limited depth of cure than conventional resins, that the boundary between separately light activated layers in built up composites occasionally resulted in defective curing, and that in deeper areas of some light-activated microfills insufficient coupling between the prepolymerised filler particles and the matrix can be demonstrated.

The 1980 work of de Lange, Bausch and Davidson demonstrated the presence of three zones in photo- initiated composites. The first, zone A, showed physical properties comparable to those of the self-cured composites. The second, zone B, demonstrated an increased softness compared to zone A, and the third, Zone C showed no signs of cure at all. These results were based on Knoop hardness values. The tests also confirmed the work of Reinhardt and Vahl (1977) which showed that only unfilled resins had a time-dependent curing pattern. Other points that arose from their work were :

1. That it is possible that a second exposure after finishing the restoration has only a slight effect on the total curing depth,

2. That during finishing of a fresh photocured restoration, the best material with regard to bond conversion rates (i.e. the surface layer) may be removed.

A number of other reports have demonstrated that factors such as shade variation will have an effect on the depth of cure. The darker shades of several resin systems have been shown to require at least 40 seconds in order to achieve adequate hardness and presumably depth. Also darker shades show a definite loss in desired physical properties at between 1 and 2 mm in depth and little or no cure beyond 3 mm depth. This has led to recommendations of incremental build-up for deep and extensive restorations. However a more recent study suggests that the relationship between shade and depth of cure may be complex and that the depth of cure may be more dependent on factors such as the translucency of the components, e.g. opaque shades, (Swartz et al., 1983 and Ferracane et al., 1986). The discrepancies between different lights tends to be more pronounced when their ability to cure darker shades is compared (Friedman et al., 1984).

The position of the restoration within the tooth and accessability for the curing light also have a marked effect on the depth of cure. This is particularly important in Class II cavities with regard to the interproximal region. It has been shown that increased area of light transmission and lights of greater output can increase the hardness values for the resins, particularly the posterior composites (Watts et al.,1984). These researchers

also demonstrated that the curing profiles of a given material were different when activated by different light units.

Finally, it has been shown that prior or premature exposure of the material to some of the modern dental operating lights adversely affects the final properties of the restoration by premature curing, particularly during the manipulative time of placement. The complete extent and exact nature of this detrimental effect is not known, (Watts et al.,1984).

In an article by DeWald et al, (1987), four methods are compared with the conclusion that scraping and optical methods severely overestimate the true depth of cure or that depth to which optimal conversion has occurred. Infrared spectroscopy (IR), to determine conversion rate and Knoop hardness appear to have a good correlation. The degree of conversion as measured by IR seems to be the most sensitive method to determine depth of cure.

Curing by light does produce heat, which may be detrimental to the pulp. The overall conclusion by Lloyd et al., (1986), is that thinner sections of composite coupled with longer exposure times are more likely to produce damage to the pulp. The full extent of these effects are yet to be determined. However the conclusions of Stanford et al. (1986) are that longer curing produces the best cure and to avoid the heat build-up, shorter doses, repeated to give the same overall required curing time are just as effective as the same continuous long dose.

Fan et al., (1987) studied the effects of voltage fluctuations on different curing units relative to depth of cure. Their findings revealed that it was still not absolutely certain that the higher irradiance units were of benefit or that the lower units were inadequate. Most units demonstrated decreased performance with reduced input voltages and increased performance with increased voltage. One unit performed consistently at the optimum level over almost the entire range of voltages, while another unit decreased in performance after the correct voltage was increased.

2.5 POROSITY

There have been a number of reports concerning porosity, (Fischel et al., 1982; Reinhardt et al., 1982; and Jorgensen et al., 1983). Those concerning the self cured composites generally reported a porosity value of 1-2% by volume, that the porosity was greater when the materials were placed with an instrument than when injected, and that it could be markedly reduced by the application of pressure for a short time to the mixed composite, the extent of this reduction being a function of the viscosity of the mix.

The recent change to light-cured resins has altered porosity levels. These materials are vacuum packed and can be delivered to the cavity with minimal porosity, particularly when they come in the syringable form. The spatulation of the self-cured systems incorporated a number of porosities and this has now been eliminated. However, operator-induced porosity is possible through the mishandling of the VLC resins with hand instruments for placement where voids are created or air entrapped.

The use of VLC materials has led to only two essential variables for porosity formation. They are handling technique and the viscosity of the resin. As

previously mentioned direct injection of the material into the cavity produces the least porosity, but it is still not porosity free. Only when the inside of the syringe was wetted with a drop of monomer before loading the composite did a porosity free delivery take place, (Jorgensen et al.,1983). This may not be necessary for compules prepacked under vacuum. However it must be realised that manipulation of the syringed material by a hand instrument may still cause porosity formation as a result of entrapment of induced air bubbles.

It has been reported (Medlock et al., 1983) that syringe placement significantly reduces the pore area of composite resins compared to hand placement and that it can give total elimination of voids larger than 150 micrometers.

The placement of composite material without bonding resin has been studied by a number of researchers, (Jorgensen 1975, Asmussen 1977 and Hansen 1984). The main aim of most of these studies was to note the existence and assess the ability of the filler resin to produce tags of material which could penetrate the etched enamel and effect a satisfactory bond, and in fact a number agree that this is quite possible. However they also note that such an approach appears to be prone to porosity, and the use of a bonding monomer markedly reduces any porosities that may occur in the region of the restoration margin.

Larger porosities in the region of cavity irregularities were more prone to occur when a bonding resin was not used, (Hansen 1984). The diameter of the opening of the manufacturer's syringe had some bearing on porosity formation, as it was seen in work by Hansen (1984), that the larger the diameter the lower the incidence of porosity. His work also demonstrated

that it was probable that polymerisation of the bonding resin prior to placement of the filled restorative would adversely affect the ability of the bonding resin to help reduce porosity.

2.6 CLINICAL TECHNIQUES

2.6.1 ACID-ETCH/BONDING TECHNIQUES

The recent tendency in the literature is to advocate an etching time of 15-20 seconds with a continuous painting technique. This produces an etched surface with less debris and more spacing for thicker resin tags, (Baharav et al., 1987).

Recent availability of so called dentine bonding agents has led to a belief that in severely compromised teeth the need for additional retention with the inclusion of pins is not altogether necessary. A recent article by Federick, (1987), suggests that the need for pins is still very important if only for the fact that such bonding systems have not been subject to sufficient longterm studies to prove their efficacy.

Dentine bonding agents are often reported to have clinically significant strength, but the concern is that there is no standardised method for measurement and that they are dependent on technique variables, (Tyas, 1987). Clinical data by Tyas in the same report, suggested that the use of a glass ionomer as the dentine bonding agent produced a more successful result than several other dentine bonding agents. Many restorations demonstrated evidence of marginal leakage at the 12 month recall.

The use of air polishing devices, such as the Prophy-Jet[7], prior to using the acid-etch technique appear to significantly enhance bonding of resins to enamel, Scott et al. (1987).

The long held belief that the time for etching enamel surfaces with 37% ortho-phosphoric acid for 60 seconds has been disputed with the results of work by Barkmeir et al., (1986), demonstrating no significant difference between a 15 second etch and a 60 second etch when tested in shear. SEM photomicrographs of the surface demonstrated no difference in the morphology of the etched surfaces.

A recent article by Mixson et al., (1988), has demonstrated a relationship between the pressure, amount of water and duration of washing time to the bond strength. This research concluded that a flow of 25 ml. per 10 seconds was optimum, along with a water/air spray pressure of 0.27 MPa. If the washing time was increased to 60 seconds, a significant drop in bonding strength ocurred. An S.E.M. investigation of the etched surface after a sixty second wash, revealed that the enamel prisms had been damaged by the excessive water/air spray. The best washing duration was between 10 and 30 seconds.

Bonding between increments was the focus of an article by Tjan et al., (1988), where the major conclusions were that weak bonding occurred between urethane-dimethacrylate composite and BIS-GMA composite and that such combinations were to be avoided. Materials which were bonded to previous layers of the same type, produced the highest bond strengths, (Tjan et al., 1988).

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[7]Prophy-Jet: Component of the Cavi-Jet, Dentsply Int., York, Pa., U.S.A.

2.6.2 MICROLEAKAGE

The distinction between microleakage and dentine permeability is made at this stage. Microleakage, in the context of this report, relates to the flow of fluid and other entities, past the restorative to the dentine. Dentine permeability, relates to the ability of anything, once past the restorative, to pass through the dentine to the pulp. With this in mind, a number of agents, such as glass ionomer or bonding resin, may be used to prevent microleakage around the restorative to the dentine, but the use of those systems may in turn damage the pulp if there is insufficient dentine or it is highly permeable, (Jendressen et al., 1987).

The area below the cemento-enamel junction where a Class II cavity might have a gingival margin still presents concern. The evidence suggests that the use of a glass ionomer lining, which covers the dentine and is extended to the gingival cavosurface margin, significantly reduces the incidence of microleakage, (Kanca, 1987).

2.6.3 DEPTH OF CURE AND INCREMENTAL BUILD-UP.

Incremental build-up is advocated in clinical practice to over-come depth of cure limitations and the effects of polymerisation contraction. The conclusions from the work of Podshadley et al., (1985), concerning the viability of this method demonstrated that increments added immediately after the predecessor were adequately bonded, although filler particle size did make a difference to the final bond strength.

2.6.4 WEAR

Wear is still a major area for concern and research for the success of posterior composites.

Many attempts have been made to produce an in vitro system to measure wear of candidate posterior composites, which will give an accurate indication of how they will perform clinically. It has been realised by a number of researchers that a proper and accurate wear test may take as long as a proper clinical trial to carry out, and that to accelerate such tests may reduce the relevance of the test, (McKinney,1985). The evidence to date suggests that the wear itself is a product of abrasion, fatigue, adhesion loss at the resin/filler interface, and chemical disintegration, and that during wear there is a buildup of subsurface damage.

Wear mechanisms:

1. Occlusal contact areas
   - Fatigue, with adhesion loss and abrasion
   - Chemical disintegration
2. Contact-free occlusal areas
   - Abrasion
   - Chemical disintegration
3. Interproximal contact areas
   - Abrasion
   - Chemical disintegration

Factors which influence the wear of the posterior composite are; the nature and composition of the resin matrix, the filler loading and type, the effectiveness of the filler-matrix coupling, porosity, the effects of polishing and the ability of the composite to resist the environmental

factors in the mouth. The oral factors include the relationship of the restoration to the occlusion, the nature of the diet including abrasiveness of food particles and solubility parameters of ingested organic liquids, and other changes such as thermo-cycling and pH shifts.

In 1978, Draughn and Harrison pointed out that wear or more particularly abrasion rates are dependent on the size, hardness, and volume fraction of particles in the composite, and that the most abrasion-resistant composites available at the time, contained a high volume fraction of large hard particles.

Most writers in recent times agree that posterior composite restorations do not show the same ability to withstand wear as amalgams, (Phillips et al., 1973; Leinfelder et al., 1975; Kusy, 1977; and Leinfelder, 1981), although the more recent hybrid resins do show an improvement over the traditional composites which were first used for this purpose, (Pallav et al., 1986). The wear of posterior composites involves the breakdown of the resin matrix and its bond to the filler particles, and the eventual loss of those particles. This can occur from direct mechanical stress, or by chemical breakdown of the resin matrix, (Leinfelder,1981). Water plays an important role in wear, where stress corrosion and increased hydroxy ion concentration at the filler interface cause adhesion loss of filler, which explains in part why composite materials do not withstand wear and tend to change colour with time, (Soderholm, 1983).

Factors involved include the abrasiveness and chemical nature of the diet (e.g. frequent contact with alcohol increases the rate of breakdown of the matrix but has not been tested clinically), the presence of occlusal interferences and bruxism and the method of finishing the surface.

Until recently, surface wear was measured using the United States Public Health Service (USPHS) system which tended to suggest that the wear rate appeared to accelerate between the first and second year where occlusal stress was involved, (Leinfelder, 1985). However more recent work has shown that two thirds or more wear occurred during the first six months and that the relatively low rate initially observed in the USPHS system was due to the inability of the operators to detect the cavo-surface margin until it was exposed by as much as 100-150 micrometers, (Leinfelder,1985). Most researchers now agree with the fact that in vitro wear tests do not necessarily concur with in vivo tests, and cannot be used to give an indication of long-term in vivo performance, (Powers et al., 1983). Goldberg et al., (1984), demonstrated the inability of the USPHS system to establish statistically significant differences between composite formulations at three, nine, eighteen, and twenty-four month recalls. The technique of ranking models identified a statistical difference between the formulations at two years and the categorizing proceedure. Goldberg et al. (1984), identified significant differences at nine, eighteen, and twenty-four months. Yost et al., (1986) pointed out that where sufficient serial specimens were available differences between materials can be seen, and wear rates estimated.

The work of Jorgensen, (1980), has demonstrated some interesting aspects concerning the relationship of the resin formulation and wear. First, he points out that the abrasion of the matrix in a macro-filled composite will not occur when the distance between the particles is of the order of 0.1 micrometers or less, and he feels that although this phenomenon is not completely understood, it may be related to the corpuscular or cellular nature of human food. This work also pointed out that as wear did occur

with these resins, the increased friction produced by added surface-roughness led to a greater degree of surface abrasion and an increased wear rate. Porosity of the resin also increased the wear rate, (Jorgensen 1980).

When the surface of a composite restoration is periodically observed by the S.E.M. replica technique, the filler particles can be seen to become more and more exposed from the resin and eventually lost, leaving microscopic holes and exposing the matrix to direct abrasion. The work of Abell et al., (1983), estimated the rate of recession of the matrix to be from 0.08 to 0.16 micrometers per day in a quartz-filled composite in a class I cavity.

Toothbrushing has also been implicated in composite wear and the study of this factor has demonstrated some important information concerning the effects of abrasion on the surface of various types of composite, (Aker, 1982). The hybrid materials under SEM analysis generally were seen to have surfaces similar to the traditional composites after abrasion, although some were smoother than others. The surface characteristics were more attributable to the larger filler particles. The microfilled resins tended to retain a smooth surface. Both the hybrids and the microfills tended to be more abraded than the macrofills, the difference being up to six times, (Aker, 1982).

Chemical exposure to 1.23% APF gel increases the risk of wear. The gel has been shown to produce surface roughness and weight loss, (Kula et al., 1983). The filler particles are suggested to be the most likely sites for degradation but unpolymerised materials are also known to leach out. Phosphoric acid and hydrofluoric acid are constituents of the gel, (Kula et al., 1983). The effects differ according to the filler type, with the strontium

glass-filled resins being most affected, followed by the quartz-filled resins, and least affected are the pyrolytic silica filled resins, (Kula et al., 1983). Variations in the size, type, and percentage of filler particles can alter the severity of these effects.

In 1982 McKinney and Wu reported that chemical softening by ethanol was far more effective than water in producing increased wear in dental composites (in vitro study). They also observed light-cured materials to be initially more resistant than self-cured materials, and wear increased rapidly with decreasing surface hardness. Wear rates for strontium-glass-filled composites pre-conditioned in pure water were noticed to be enhanced considerably when compared to quartz-filled and micro-filled composites. In this situation the degradation was attributed to stress corrosion of the glass filler, (McKinney and Wu 1985).

The work of Lutz et al., (1984), demonstrated some important features concerning wear. They were able to show that vertical loss of substance in occlusal contact areas was more than double that in contact-free areas, and that the larger the restoration the greater the wear. This suggests that the resin restoration benefits from the protection offered by the surrounding enamel and therefore cavities should be as conservative as possible. Curing mechanism was shown to influence wear also; heat-cured resins had the least wear, followed by light-cured, and the greatest wear was associated with self-cured resins.

There are various reports that the microfilled posterior resins have shown very little wear. The work of Asmussen and Jorgensen (1982), has given a possible explanation where microfills have demonstrated higher fatigue strength at relatively-low stress. Clinically this would be possible where

the restoration was of a conservative nature with protection from the occlusion provided by surrounding enamel. However, microfills have also been shown to be the most stable material in a wet environment, with respect to crack formation; these composites leach less silicon than composites containing strontium and/or barium glasses, (Soderholm et al., 1984).

Materials with urethane-dimethacrylate/dibutyl-pthalate resin systems were inferior in vivo wear resistance in occlusal contact areas. This is thought initially to be a result of the measurable plastic deformations associated with these materials. Fractures from these deformations initiate the breakdown of the restoration. The inclusion of prepolymerised particles can help to provide an initial wear resistance. Asmussen et al 1982

The hybrid composites with a reduced average particle size (compared to the traditional composites), and sophisticated size distribution, more dense packing of their macrofillers, and direct admixture of microfillers to the organic matrix, are believed to have more wear resistance than the traditional or large particle filled composites, (Lambrechts et al., 1985). Their surface morphology is also superior to the traditional composites, and thus their abrasion resistance is better.

Lambrechts et al., (1985) point out that although there are five types of wear (abrasive, corrosive, fatigue, adhesive, and attrition), probably the most aggressive form is attrition. Attrition is seen as the ultimate wear consideration as it takes into account the effect of fatigue wear in centric stops in posterior teeth. The long-term effects of thermo-mechanical fatigue and cyclic stress have yet to be fully understood, as these effects

only show any destruction much later, despite any early favourable wear results.

Indirect evaluation methods report mean losses in the region of 163 micrometers for one system after three years, (Boksman et al., 1986). The determination of wear rates in vitro as a reliable precurser to placing new resins in service has always been of considerable interest. Wilson et al., (1987), used dynamic mechanical analysis to characterise polymeric restorative materials and assign them a glass transition temperature. The conclusions from their work included the findings that composites made by photopolymerisation can undergo marked changes in mechanical state in the oral environment, including becoming rubbery, leathery or glassy, and that variations in mechanical states are generally undesirable, particularly with reference to wear.

The use of fracture mechanics has been suggested as a useful method for predicting clinical wear in posterior composites, (Truong et al., 1987). In determining this, subsurface microcracking was studied by scanning electron microscopy, with evidence of separation between filler and matrix, as a result of stress release allowed by fluid uptake after curing.

The reliability of such methods for determining wear has been questioned by Pilliar et al., (1987), due to the wide variability in results from the same aging techniques, particularly where ethanol is used as the aging agent. This article suggested that the correlation between wear and fracture toughness, as measured by the stress intensity factor was very complex and not well understood.

Marginal integrity is defined as withstanding considerable repetitive compressive loads with little detriment to the enamel-composite bond, (Jendresen et al., 1987), although thin margins in areas where bevels have been applied and which are subject to repeated load, are prone to fracture, (Jendresen et al., 1987).

2.6.5 FINISHING

Considerable discussion has also been directed at this area, as reported by (Lambrechts et al.,1982). The aim of finishing is to produce appropriate contour and to redevelop a surface texture that will reflect light in a similar manner to that of tooth enamel. The final result should also be resistant to surface staining and abrasion. The main methods include the use of stones, tungsten-carbide finishing burs, aluminium oxide-coated flexible discs, fine and superfine diamonds, fine polishing pastes and rubber-mounted abrasives. The final finishing of composite resins involves gross finishing and contouring, fine finishing, and polishing. The time for final finishing needs to be considered, as it has been reported by various authors, (Hansen 1983), that the resins continue to polymerize after the curing light has been removed. Hansen also reported the importance of avoiding early contact with water where a possible detrimental effect may result.

Lutz et al. in 1983, demonstrated that fine and superfine diamonds (40 and 15 micrometers respectively) produced a better finish on the four types of resin they used than did green stones, white stones, or tungsten-carbide burs. They also pointed out that the flexible aluminium oxide discs produced an excellent finish but were only useful on accessable convex surfaces. However, these researchers and others were quick to point out that as usual

the best finish is obtained where the resin is polymerised against a matrix. But, this surface is usually rich in resin matrix and could present problems in an occlusal contact area. Where a matrix is not used, the outer layer polymerisation is inhibited by oxygen, resulting in a chalky, soft surface. Therefore the removal of this layer to expose potentially harder material is advised by Lutz et al., (1983).

The 1984 report of de Wet and Hardwick pointed out that the rubber mounted polishing instruments can cause smearing of the surface, and could leave debris attached to, or incorporated in the surface. It was also pointed out by Pearson and Messing, (1979), that both rubber mounted finishers and discs produce considerable amounts of heat when being used and, with the relatively low melting temperature of the resin, smearing can occur. This smearing covers the remaining exposed filler particles, which are left after the abrasive material chips away the surface. Where white stones and tungsten carbide burs are used the exposed filler particles are left protruding.

The work of Lambrechts and Vanherle (1982), has added further light to the effects of polishing. They point out that the smear layer exists in almost all composites they tested (14 altogether), and that it was caused by friction producing enough heat to melt and deform the matrix. The thickness of this layer can be as great as 100 nm. Another observation was that the finish of the hybrid materials was hampered by the unequal physical properties of the matrix and filler phases. Furthermore, it was observed that the grinding or polishing agent had to be harder than the hardest phase in the composite, and that these very hard and strong abrasive particles should not shatter but stick very well to the polishers. Loose abrasive grains tend

to roll over the composite surface instead of grinding it, causing the organic matrix to be worn away and roughness to appear. The loose particles also fill up any air bubbles and pores and any subsequent polishing removes these particles causing further scratching. Their final conclusions were that it was better to finish for a longer period with a fine grained disc than to go faster with a coarse disc which loses bigger grains and that all loose particles must be removed from the surface immediately and continuously because it is the bigger particles of former polishings that drift over the surface and prevent complete polishing by the ultra-fine grains. The micro filled resins polish better than the conventional resins, (Kanter et al., 1983).

More recent work by Smith et al., (1986) and Quiroz et al., (1986), demonstrated rubber-mounted abrasive points in the form of Shofu Quasite Midi-points[8] and Vivadent[9] polishing points to be the most effective in producing a smooth finish in posterior composite restorations. Considerable differences between the different brands of finishing systems were also detected. One brand of finishing diamonds was significantly better than the other tested. The same result occurred between the two disc systems tested, and the two rubber point systems.

Savoca and Felkner (1980), demonstrated that smoothness of composite resin after finishing is not a function of the time at which it is finished.

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[8] Quasite Midi Points ; Shofu Dental Products, Japan.

[9] Vivadent polishing points : Vivadent, Schaan, Liechtenstein.

There now appears to be some evidence that final finishing of posterior composites is best left for as long as possible post insertion. Wear resistance in abrasion and attrition sites appears to be significantly different , (Braem et al., 1986).

2.6.6 FRACTURE RESISTANCE: TEETH

One of the major arguments put forward for the use of posterior composites is the potential for increased resistance to the fracture of teeth with Class II cavities due to the adhesive nature of the restoration. However, as reported by Joynt et al., (1987), there was no significant increase in fracture resistance between teeth restored with amalgam and teeth restored with posterior composite resin using an enamel bonded acid-etch technique, for ClassII MOD cavities. This may be explained by Hood (1985), who feels that the relaxation of the cusps following matrix band removal may be enough to fracture the enamel bond, particularly when polymerisation contraction effects are added.

2.6.7 FRACTURE RESISTANCE: COMPOSITE

The relationship between filler content, conversion rate and fracture toughness of composites is the subject of an article by Ferracane et al., (1987). The conclusions of this article are that fracture resistance is increased by increased filler loading and better resin conversion rates, however, the higher the filler loading, the better the result, independent of the conversion rate.

Davis et al., (1987) tended to agree with those results, but add to the discussion with the information that changes in the stress intensity factor caused by altering the filler- matrix interface are small compared to the large increase produced by increasing the amount of filler. The nature of the matrix will influence the fracture toughness, with a brittle matrix requiring a rigid filler for increased toughness, particularly if the matrix-filler interface is poor. A ductile matrix shows a decrease in fracture toughness with an increase in filler rigidity as the filler prevents plastic deformation of the matrix, (Davis et al., 1987). The presence of water makes it easier for the resin to undergo plastic deformation, (Davis et al., 1987).

CHAPTER 3. OBJECTIVES

This project is divided into two sections, an in vitro section, dealing with the objectives (a),(b),(c) & (d) listed below, and an in vivo section dealing with objective (e).

The objectives are :

(a). To show colour opacity and reflectance changes on curing.

(b). To compare the Australian Standard for depth of cure to a Scratch Test.

(c). To show porosity internally and at the surface.

(d). To look at the polymerisation contraction in relation to the gingival margin of the "Sandwich" technique.

(e). To observe wear patterns of "P-30", "Herculite", "Ketac-Silver" and "Dispersalloy" in vivo.

Colour change was limited to objective observations of colour change in posterior resins on curing. A sample of eight different commercial posterior resins were chosen. Four of these resins were supplied in four shades, each of which was tested, giving a total of twenty different resins, (based on either shade or brand). See table 4.1 for the names and manufacturers. Each sample was cured for 40 seconds and then simply compared with an uncured sample of the same resin.

The objective for opacity and reflectance tests was to note the possibility of post-curing and whether increased curing time at the insertion would decrease this. Variations between shades of the same resin were also tested.

The comparison of the scratch test to Australian Standard 1278-1982 (Appendix D), for a more reliable for depth of cure is limited to demonstrating significant reductions in conversion rates within resin specimens which would otherwise be judged acceptable by that standard. This investigation then looks at different clinical methods to potentially improve conversion in difficult areas related to the placement of posterior composites in Class II cavities.

Porosity investigations are limited to demonstrating the presence of large and small porosities as a result of manufacturing processes and clinical manipulation. The effect of these porosities is high'lighted when they become involved in clinical finishing proceedures.

Polymerisation contraction investigations are limited to show the influence of different matrix and light curing applications on the integrity of the gingival margin of Class II cavities. The addition of composite retention pins as retention aids was also observed.

A pilot study to observe wear patterns and clinical technique was conducted and limited to observing wear patterns on a Scanning Electron Microscope. This study also provided valuable information, which, when used in conjunction with the in vitro studies, has led to modifications of the clinical technique.

CHAPTER 4. COLOUR CHANGE ON CURING

4.1 INTRODUCTION

The use of composite resin restoratives involves a degree of operator knowledge and skill in manipulating the material and achieving the desired result. A resin characteristic during the use of photo-cured resins is the amount of colour change which occurs on curing. This change along with the other inherent optical properties as mentioned in section 2.2 should result in the same translucent-opaque balance as found in the adjacent tooth. This can be a considerable distraction to the unwary operator as it involves a number of considerations and implications. These are:

1. The degree to which the resin changes colour on curing.
2. The degree to which post-curing polymerisation influences further colour change.
3. The variability between different resins.
4. The shade for the restoration may be difficult to determine.

The manufacturers of today's dental resins are therefore faced with the dilemma of producing a resin which in the unset form is close to the set form to make it relatively easy for the operator to restore the tooth in a predictable manner as far as aesthetics are concerned. It has often been the woe of operators to find that the cured restoration does not match either the rest of the tooth or even the shade guide.

Table 4.2 :

Resins tested for colour change on curing

Table 4.2

RESIN	MANUFACTURER	CODE
HERCULITE SYRINGEABLE	KERR MFG	
YELLOW		H-Y
UNIVERSAL		H-U
LIGHT		H-L
GREY		H-G
FULFIL	L.D.CAULK	FF
DISTALITE	JOHNSON & JOHNSON	DIST
VISIOMOLAR	ESPE	
STANDARD		VM-S
GREY		VM-G
BROWN		VM-B
LIGHT		VM-L
ADAPTIC II	JOHNSON & JOHNSON	A-II
OCCLUSIN	ICI	
XL (LIGHT)		OCC-XL
S (STANDARD)		OCC-S
DY (DARK YELLOW)		OCC-DY
LG (LIGHT GREY)		OCC-LG
P-30	3M	
XL (LIGHT)		P-30 L
U (UNIVERSAL)		P-30 U
Y (YELLOW)		P-30 Y
G (GREY)		P-30 G
ESTILUX POSTERIOR	KULZER	EST. P

It has been reported by Brodbelt et al., (1981), that dehydration of human enamel produces a decrease in translucency and rehydration similarly returns the value to normal. This is based on the knowledge that there is an increase in the difference of the refractive indices between the enamel and the surrounding media when the water is replaced by air. This phenomenon, as it might relate to resin, has not been investigated in this report. All the specimens were kept dry. However it would be interesting to note whether there is a difference in the range of change between enamel, resin and other aesthetic restoratives such as porcelain.

4.2 MATERIALS AND METHODS

In order to observe colour change in posterior resins on curing the following materials and methods were used. A sample of nine different commercial posterior resins was chosen. Four of these resins were supplied in four shades, each of which was tested, giving a total of twenty different resins, (based on either shade or brand). Only one specimen was made for each. See table 4.2 for the names, manufacturers and identification codes used here.

The resins were placed in the centre of fibre discs, (internal diameter approximately 7 mm, thickness 1 mm), and cured for 40 seconds Using a Translux CL visible light curing generator. Care was used to place the resins with a minimum of porosity and voids. The resin was squeezed into place by compressing the initial sample lump between two flat glass slabs, separated from the resin by clear plastic matrix strips, see the diagram in figure 4.2.a. The glass slabs were removed and the sample cured for 40 seconds. A 3 mm diameter hole was then cut in the centre of the hardened resin sample and filled with matching uncured resin, figure 4.2.b. The sample was photographed with electronic flash, on a black backround, figures 4.2 c & d for examples (Colour film, Kodachrome 64[10]).

The resulting slides were then graded on a fluorescent viewing screen, using rankings to determine colour change.

[10]Kodachrome 64 daylight film; Kodak (Australasia) Pty. Ltd., Melbourne Australia.

Figure 4.2.a

Expanded diagram for the apparatus used to produce the flat resin sample.

Yellow represents the resin lump prior to flattening.

Red represents the fiber washer.

Green represents the glass slides.

Blue represents the flat glass slabs.

Mylar strips are placed between the glass slides and the resin/washer assembly. The top glass slab was removed prior to curing. The mylar strips were removed following curing to enable a 3 mm hole to be drilled through the centre of the resin disk. This then allowed the placement of an uncured increment for comparison.

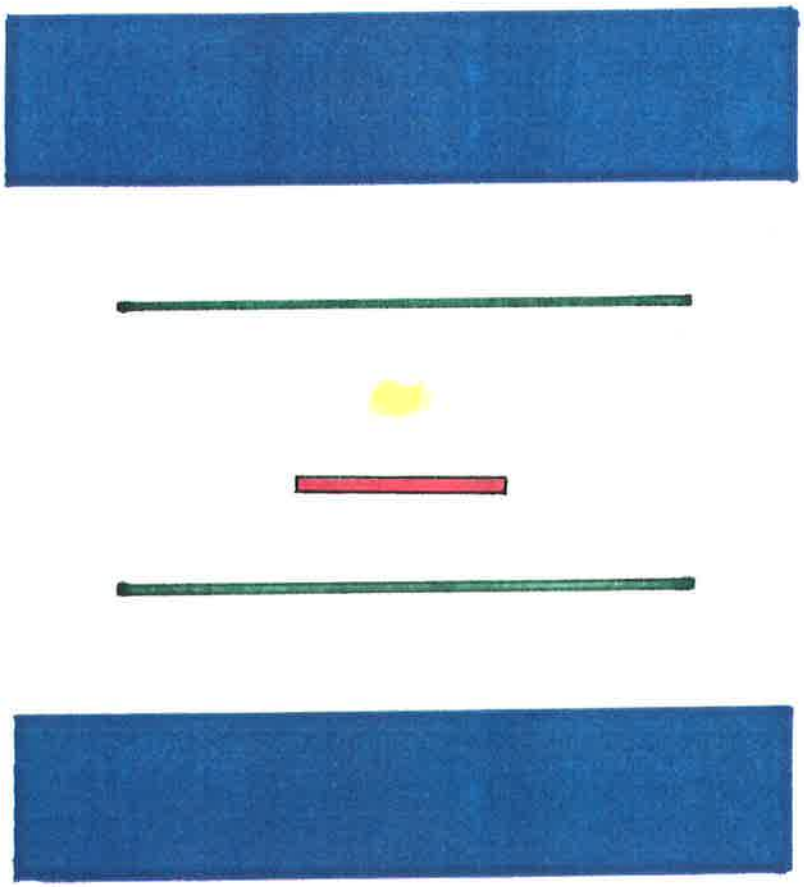

Resin
Fibre Washer
Microscope Slide
Glass Slab

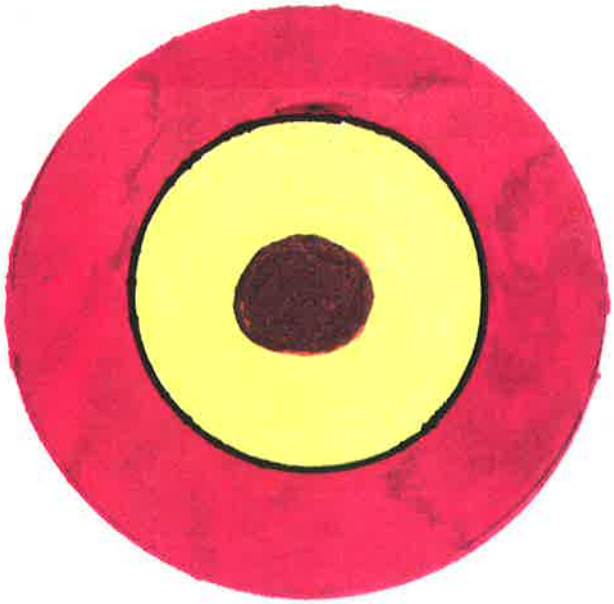
Figure 4.2.b

Diagram of the cured resin sample, where a contrasting uncured resin specimen has been placed in the centre of the washer.

The red ring represents the red fibre washer in which the disk shaped specimen is produced.

The yellow inner ring represents the cured disk of resin.

The brown centre represents the uncured resin used to enable a comparison between the two states to be made.



Uncured Resin

Cured Resin

Fibre Washer

Figure 4.2.c:

Colour Change

Occlusin light grey photographed against a black backround, showing the change from opaque white to a more translucent grey-white.

The white opaque centre is uncured resin.

The translucent grey-white outer resin ring surrounded by the red fibre washer is the cured resin.

The difference in colour is the result of curing the resin for 40 seconds.

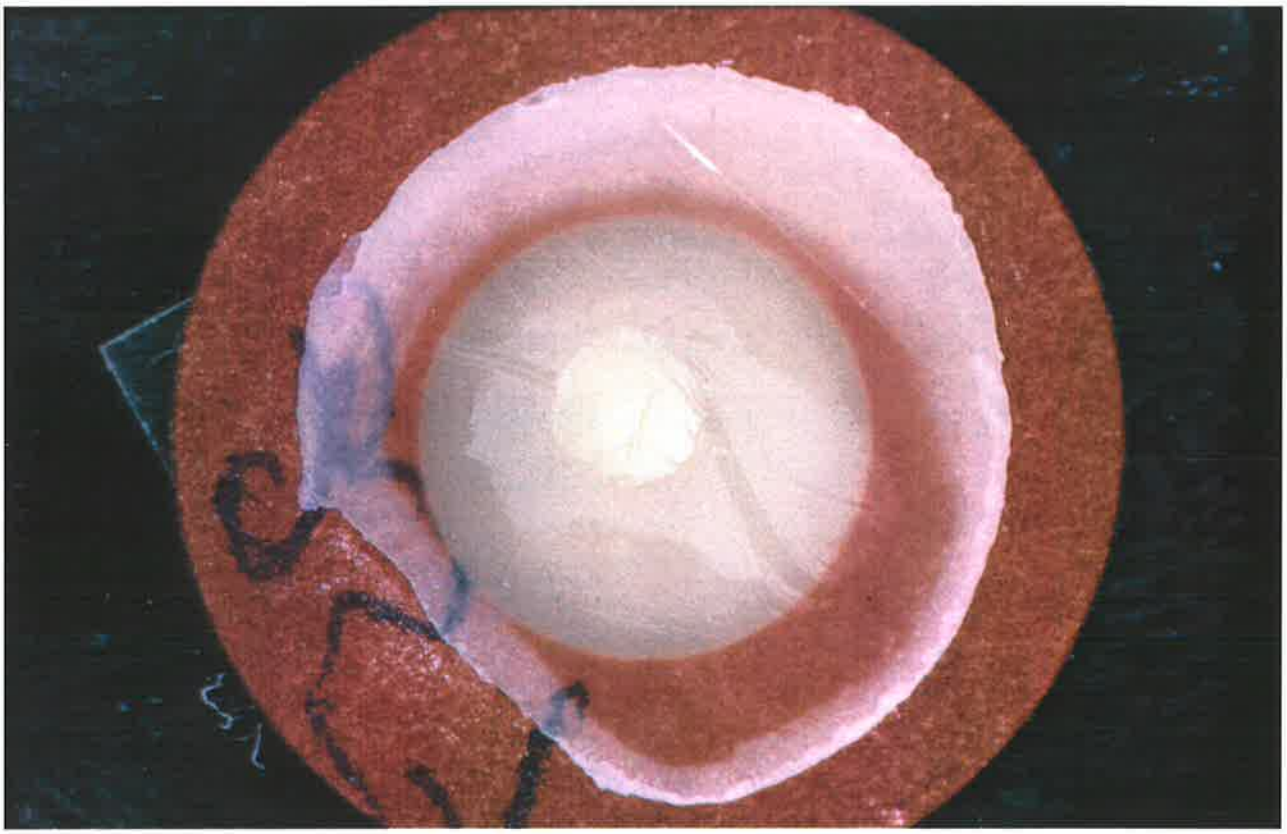


Figure 4.2.d

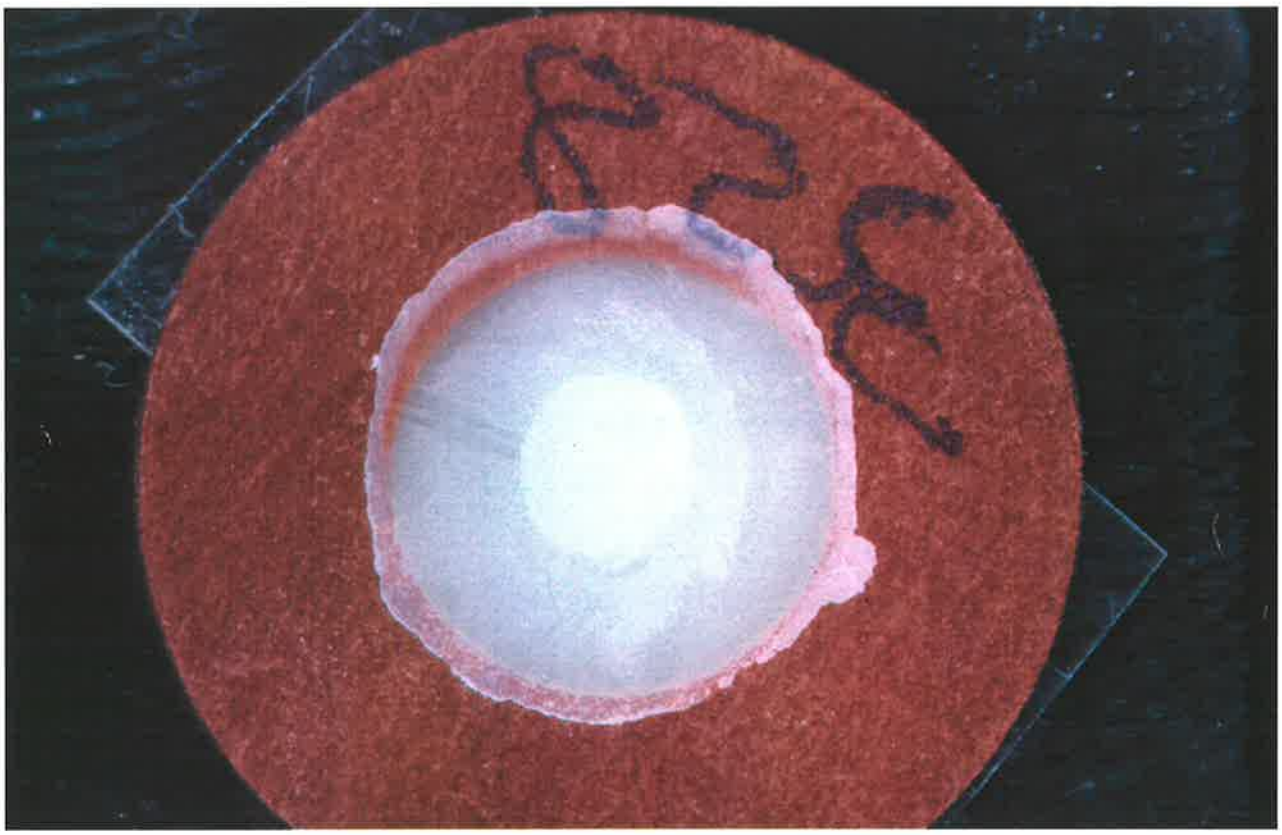
Colour Change

Herculite Syringeable photographed against a black backround, showing the change from opaque white to a more translucent grey-white.

The white opaque centre is uncured resin.

The translucent grey-white outer resin ring surrounded by the red fibre washer is the cured resin.

The difference in colour is the result of curing the resin for 40 seconds.



4.3 RESULTS

The results of the colour change experiment suggested that most posterior resins become more translucent (darker colouring) on a dark backround. This may be due to the increase in translucency during setting of the 1mm thick specimens, a feature demonstrated by the changes in opacity observed in chapter five. These sections were photographed against a black backround. The Visio-Molar group of resins produced very little colour change over the range of shades. All the Occlusin specimens show a marked degree of colour change, the standard shade demonstrating the least change. The P-30 group of resins show a lower degree of colour change and are in the region between the Visio-molar group and the Occlusin group. Similarly the Herculite group, (Yellow ,Universal, Light and Grey) also show an increased change towards a darker colour. The results may be viewed in the graph4.3

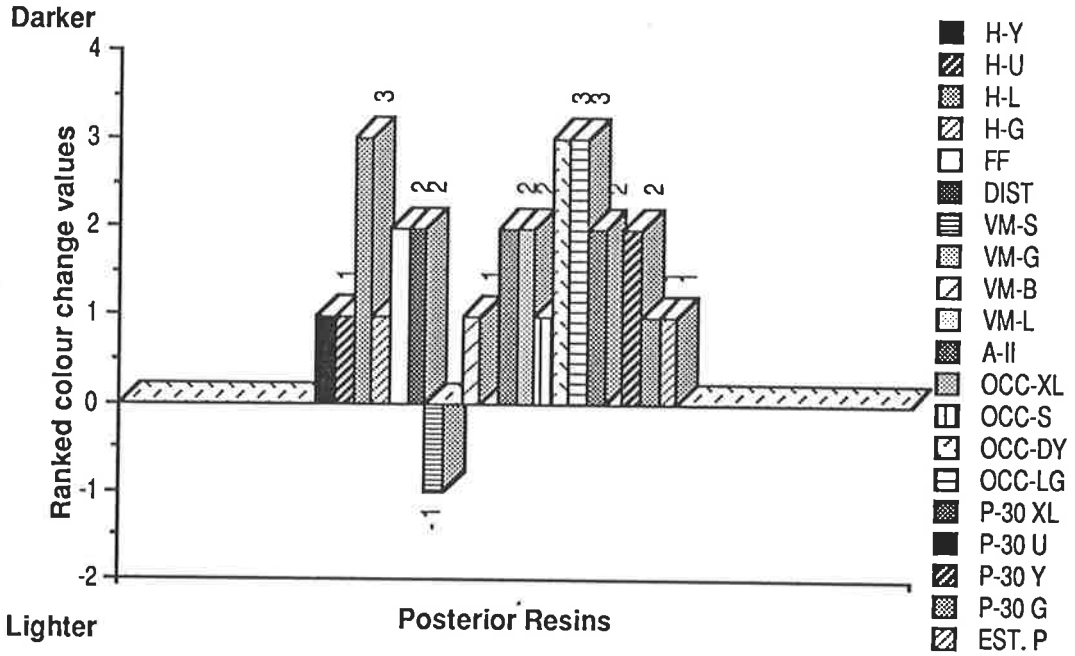
GRAPH 4.3

Results of colour change.

It should be noted that VM-G, VM-L and P - 30 U show no colour change.

No standard deviation or range is shown as these are results of individual specimens.

GRAPH 4.3


Darker
Lighter
Ranked colour change values
4
3
2
1
0
-1
-2
Posterior Resins
H-Y
H-U
H-L
H-G
FF
DIST
VM-S
VM-G
VM-B
VM-L
A-II
OCC-XL
OCC-S
OCC-DY
OCC-LG
P-30 XL
P-30 U
P-30 Y
P-30 G
EST. P

4.4 DISCUSSION

From the results of this simple test it can be seen that posterior resins do show a tendency to a darker colouring (having become more translucent) when viewed against a black backround on curing. The view of teeth in the oral cavity is under similar conditions, the teeth having a darker or light absorbing backround behind them. An interesting addition to this experiment might be to add 20 second and 60 second exposures to the existing 40 second exposure. A further addition may be to make the sections 2 mm thick, as this appears to correspond well with the depth at which a uniform depth of cure occurs, shown on the scratch test.

4.5 CONCLUSIONS.

From the results it may be concluded that most posterior composites on curing develop a degree of translucency. This occurs where materials of similar refractive indices are chemically bonded together to produce a more unified compound, with less reflective interfaces. Uniform colour change matching uniform depth of cure values indicate that it is best to keep increments within this level, i.e. approximately 2mm for a 40 second exposure for most resins, to ensure a predictable shade match.

CHAPTER 5. OPACITY AND REFLECTANCE

5.1 INTRODUCTION

A group of eight posterior resins were studied to determine possible opacity changes occurring during curing. The objective was to note the initial and post-curing effects relating to the opacity of the resin, and if there was a trend for increased exposure by the curing light at the time of insertion to alter the opacity. Variations between shades of the same resin were also tested. A further variation was to test the surface reflectance of the resin specimens to determine the difference in diffuse reflection by varying the exposure times.

It is often noted clinically that the changes in shade of the restoration during curing causes a mismatch in colour with the surrounding tooth. An indication of the degree of colour change would be an assistance clinically. Perhaps this can be related to the composition of the material.

Graphs and statistics are used for descriptive purposes only to demonstratw possible trends. Sample sizes are in general too small to provide means and enough other statistical data for reliable statistical tests.

5.2 MATERIALS AND METHODS

The resins investigated in this section are listed along with their manufacturers in Table 5.2.1. A detailed listing of resin restorative materials investigated during this project appears in Appendix B.

The opacity measurements are for changes in translucency due to curing light exposure time and the effect that time has on translucency variation during post cure. The reflectance values were taken subsequent to this.

The resins were placed in the centre of fiber washers, (internal diameter approximately 7 mm, thichness 1 mm, see figure 4.2.a). Care was used to place the resins with minimum porosity or voids. The resin was slowly squeezed into place by compressing the initial sample lump between two flat glass slabs, separated from the resin by clear plastic matrix strips. The glass slabs were removed and the sample exposured for either 20, 40 or 60 seconds by a Translux CL[17] curing light. One specimen for each resin or resin shade was left uncured to act as a control. The resins were immediately tested on a densitometer[11] and then placed in light proof storage for 24 hours, tested again, and re-stored for a further 24 hours after which a third measurement was taken. This gave readings at zero, twenty-four and forty-eight hours.The specimens were subject to the laboratory lights and the test light of the densitometer when readings were taken. These periods were up to 20 seconds at which point they were returned to light proof storage. The densitometer zero setting was checked immediately before and after each reading to ensure that voltage fluctuations within the building did not alter the results.

Reflectance values were taken using an exposure photometer[12]. This device was used at an angle of approximately 45^{o} and measured the reflectance of the available laboratory fluorecent lighting off the surface of the resin sample. Two measurments were made:

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[11] Densitometer; Photovolt Densitometer, Model 502M , New York City, U.S.A.

[12] Exposure Photometer : S.E.I. Exposure photometer Serial number EB - 9824, Made in England.

1. The first where the specimen was placed on a glazed white ceramic tile, i.e. to represent a laminate restoration, a Class V cavity or a posterior restoration on enamel

2. The second with the specimen on a matt black surface, i.e. to represent a Class III cavity.

This enabled a comparison of how reflectance values may be dependent on the presence or absence of underlying tooth structure. The reflectance might also be affected by the presence of dentine as the underlying structure instead of enamel.

TABLE 5.2.1

Resins investigated for opacity and reflectance variations as a result of different exposures to the same curing light

TABLE 5.2.1

MATERIAL	MANUFACTURER
HERCULITE SYRINGEABLE	KERR MFG
FULFIL	L.D.CAULK
DISTALITE	JOHNSON & JOHNSON
VISIOMOLAR	ESPE
ESTILUX POSTERIOR	KULZER
P-30	3M
ADAPTIC II	JOHNSON & JOHNSON
OCCLUSIN	ICI

5.3 RESULTS

The general trend was for all resins to display a reduction in opacity on curing, with the major difference between cured and uncured being at 0 hours. Although a minor trend for further reduction occurred after 24 hours and a further reduction after 48 hours, the sample size was too small to show any significant results although trends for individual resins were apparent, see appendix E for graphs of individual resins tested in this series. However, the values for all resins at 0, 24 and 48 hours were grouped and the means calculated. This was also done for the uncured, 20 second exposure, 40 second exposure and 60 second exposure intervals, graph 5.3.1.a. Sub-groups for the yellow, grey, universal and light shades were also done. These results are displayed in graphs 5.3.2.a - n and appear in appendix E.

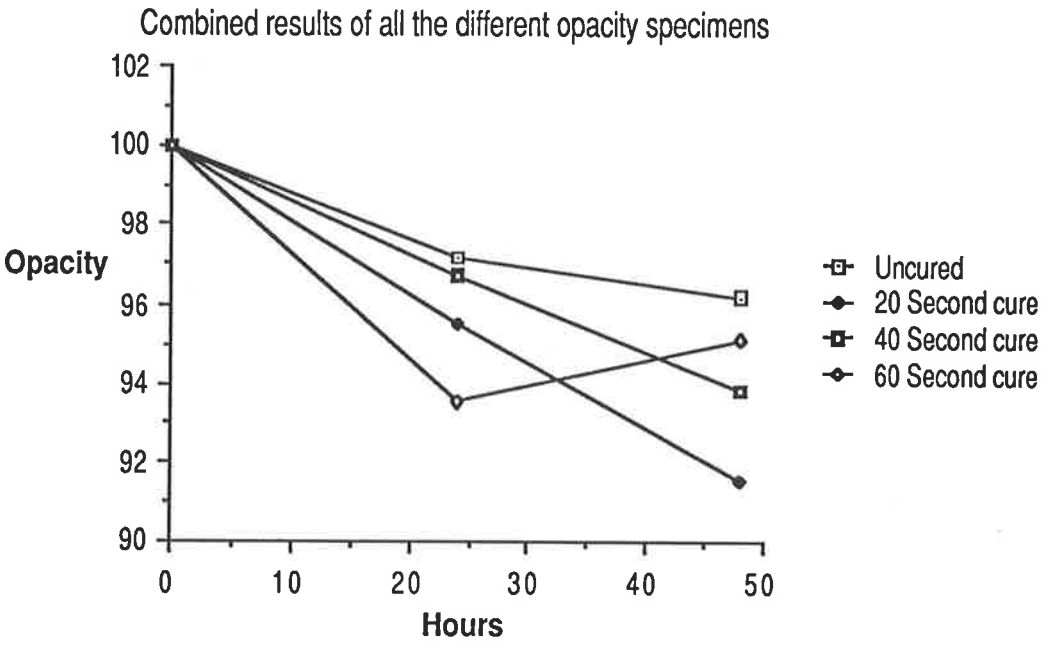
Although the uncured control specimens were subjected to the laboratory backround light and that of the densitometer, relatively small changes in opacity were observed compared with those specimens that had been exposed to the curing light.

Graph 5.3.1.a.

Opacity results for all resins at 0, 24 and 48 hours. Values represent the mean for the combined results.

The values were converted to percentages, with the controls being given the value 100, so that all values would be on the same scale and all measurements could then be read as percentages.

Graph 5.3.1.a

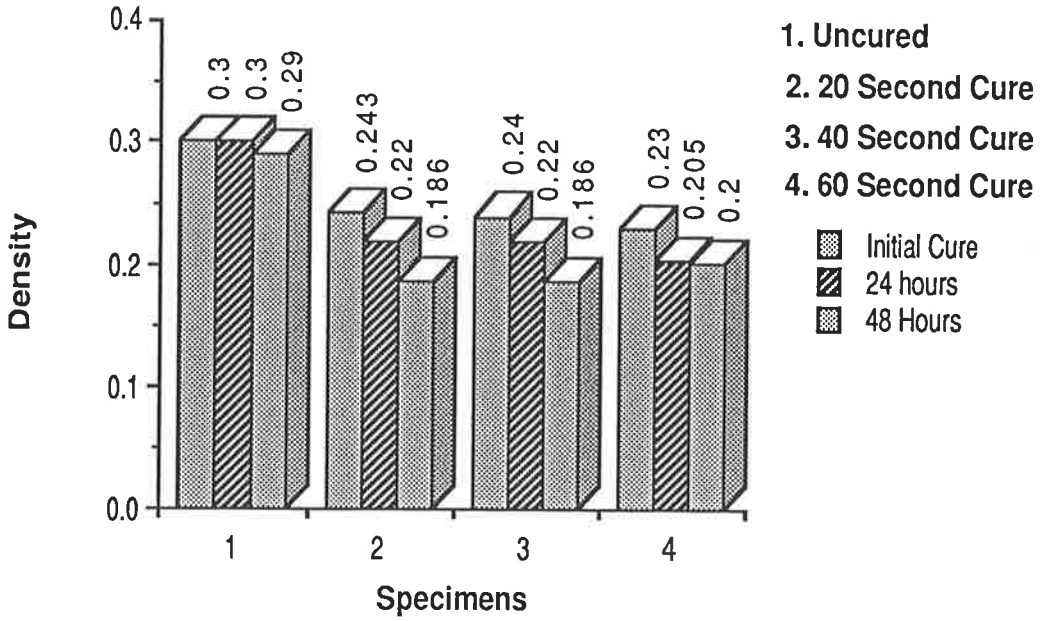

Combined results of all the different opacity specimens
Opacity
102
100
98
96
94
92
90
0
10
20
30
40
50
Hours
Uncured
20 Second cure
40 Second cure
60 Second cure

Graph 5.3.1.b

Opacity results showing the changes that occur between uncured specimens and those given 20 second exposure, 40 second exposure and 60 second exposures respectively at the initial exposure. The material used is Herculite Syringeable, Universal shade.

A range of three specimens was used for each of the specimen groups

Graph 5.3.1.b


Density
0.4
0.3
0.2
0.1
0.0
0.3
0.3
0.29
0.243
0.22
0.186
0.24
0.22
0.186
0.23
0.205
0.2
1
2
3
4
Specimens
1. Uncured
2. 20 Second Cure
3. 40 Second Cure
4. 60 Second Cure
Initial Cure
24 hours
48 Hours

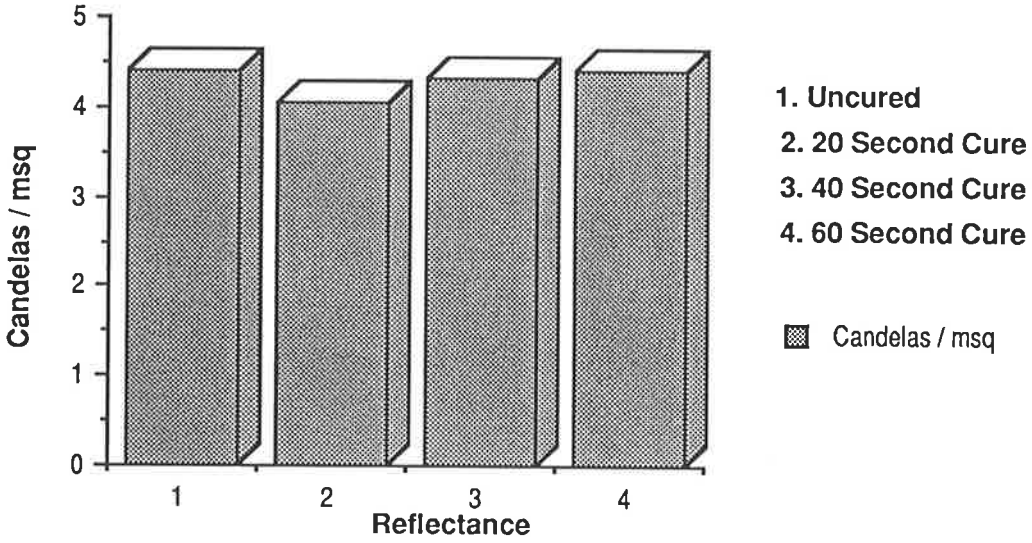
The results for the reflectance measurements, measured in candelas/ square metre, are recorded in the tables listed in appendix F. The major findings are shown in the combined result graph 5.3.3.a. When analysing the results, the value of the uncured specimen, measured against the white backround was used as the control or base line value for each shade. The control was given a value of 100%. Differences from this value were calculated as percentages to enable easy comparison with other specimens. The control was then charted on the graph with a value of zero and increased reflectance had positive values and decreased reflectance had negative values. The trend is for the values measured against the black backround to be less than those on the white backround.

Graph 5.3.3.a

Reflectance results for all resins.

This graph shows the combined mean values for all the different resin specimens used in this experiment.

Graph 5.3.3.a


5
4
3
2
1
0
Candelas / msq
1
2
3
4
Reflectance
1. Uncured
2. 20 Second Cure
3. 40 Second Cure
4. 60 Second Cure
Candelas / msq

The results for the individual resins are described below. All numeric values are as percentages. The results are also shown in graphs 5.3.3.b, c, d & e.

1. Herculite Syringeable

In general the Herculite Syringeable shades showed a wide range in values between the white backround and the black backround. The greatest difference was the yellow shade which had a difference of 31 percent following a 60 second exposure, indicating that it develop a high degree of translucency when optimally cured.

2. Fulfil.

The reflectance values from this resin were very consistent, despite the length of exposure. The level of reflectance against the black backround was quite low and indicated a high level of translucency. Fulfil is a small particle filled restorative.

3. Distalite.

The reflectance values were also quite similar. The main feature is that the values between white and black backrounds are not as widespread as those for Fulfil. This is a microfilled restorative.

4. Visio-Molar.

Reflectance values for Visio-Molar produced a consistent pattern with the exception of the standard shade. The grey, brown and light specimens demonstrated a drop in reflectance values against both white and black backrounds, the grey shade producing the greatest change against white and the light and grey shades producing the greatest change against the black backround.

The exception is the standard shade, which demonstrated a consistent increase in reflectance on both backrounds. Range on white, 0 to +11.5% , on black, 10-11%. The only major change was the control which was given 0 as the base measure on the white backround and then scored 10 on the black backround.

5. Adaptic II.

All cured specimens, and the uncured specimen on the black backround, experienced a loss in reflectance. The result was consistent with all exposure times.

6. Occlusin.

Reflectance values for Occlusin show a pattern unique to this experimental resin group, (graph 5.3.3.f). Despite the length of exposure to the curing light, all shades demonstrated an increased reflectance when observed against a glossy white backround. (Range, 0 to +18%). Against a black backround, most values were negative and in general, the stronger the reflectance against a white backround, the better the reflectance against the black backround. (Range, minus 15.6% to plus 4.5%).

7. P - 30.

This group of resins tended to show an average 11.1 percent reduction in reflectance from the uncured control on a white backround, to the cured specimens on a black backround. The range is from -21 to +9. The same cured specimens measured on the white backround demonstrate an average 0.75 increase in reflectance. The range is from -9 to +12.5 percent.

8. Estilux Posterior.

This resin had a small increase in reflectance values on a white backround. On the black backround the result was a uniform reduction of approximately 18 percent in reflectance.

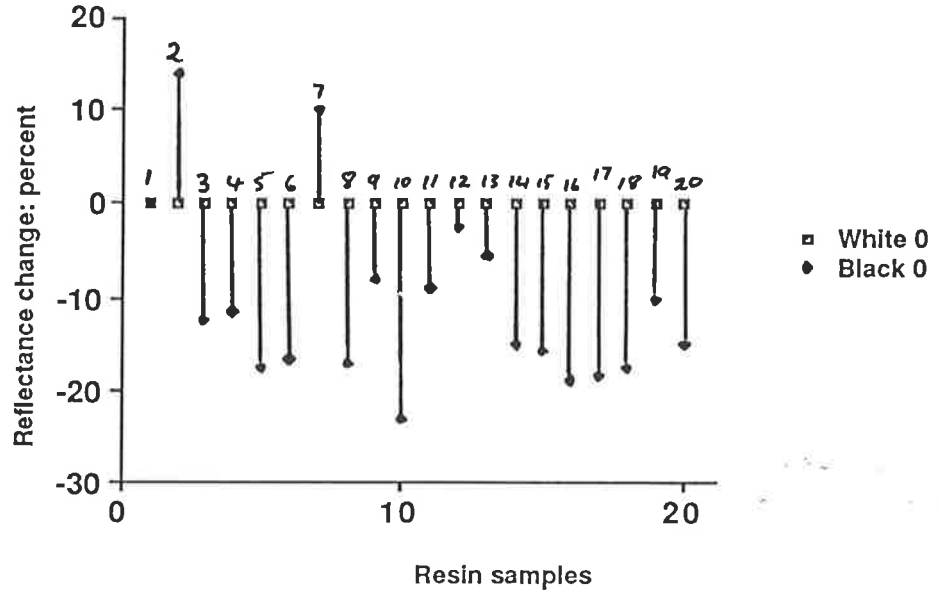
Graph 5.3.3. b

Graph for the reflectance values of the uncured specimens listed in table 4.2. The circle represents the value for the uncured specimen recorded against a white backround and the black symbol represents the value recorded against a matt black backround.

Graph 5.3.3. c

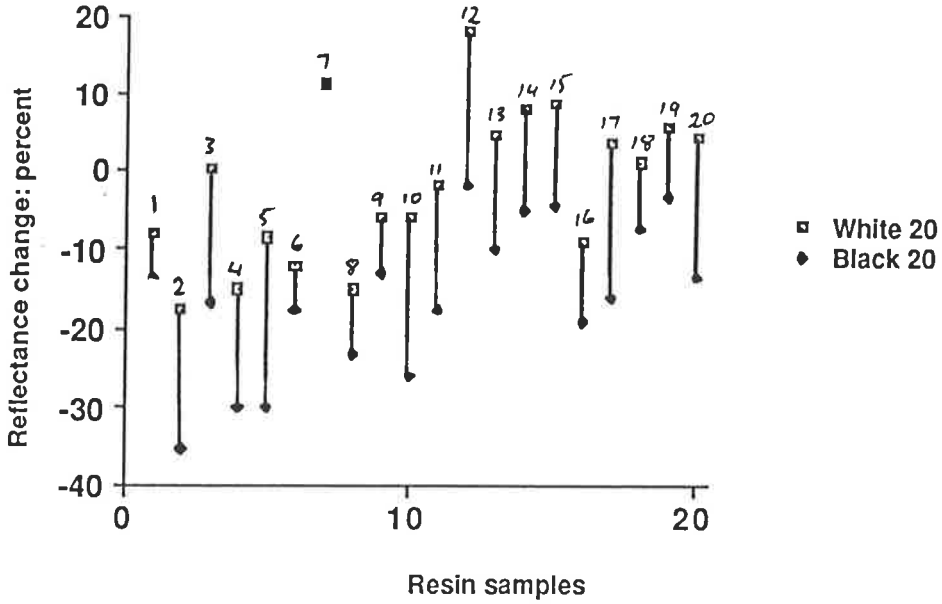
Graph for the reflectance values of the specimens cured for 20 seconds, listed in table 4.2. The open square represents the value for the specimen recorded against a white backround and the black symbol represents the value recorded against a matt black backround.

Graph 5.3.3. b



1. H-Y
2. H-U
3. H-L
4. H-G
5. FF
6. DIST
7. VM-S
8. VM-G
9. VM-B
10. VM-L
11. A-II
12. OCC-XL
13. OCC-S
14. OCC-DY
15. OCC-LG
16. P-30 L
17. P-30 U
18. P-30 Y
19. P-30 G
20. EST. P

Graph 5.3.3. c



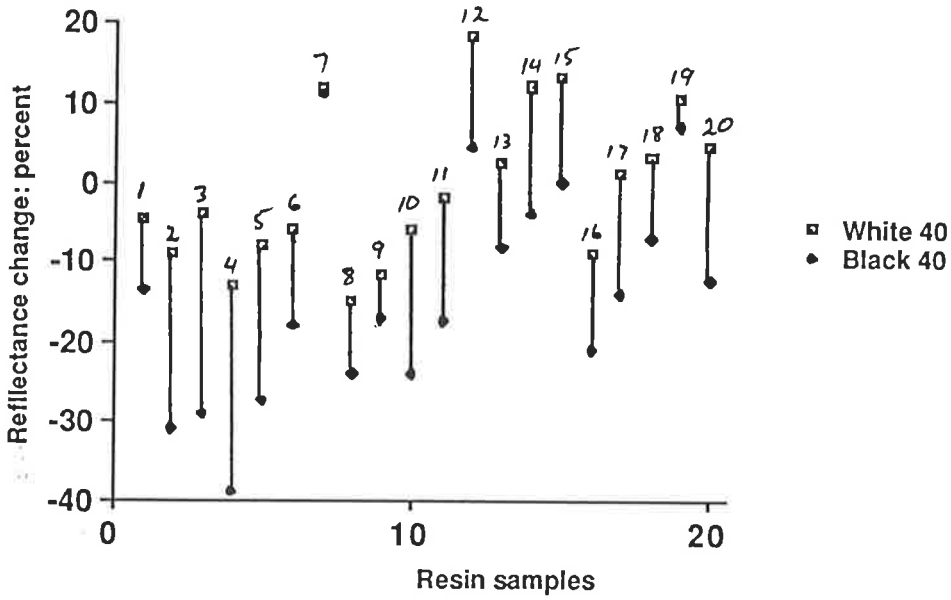
Graph 5.3.3. d

Graph for the reflectance values of the specimens cured for 40 seconds, listed in table 4.2. The open square represents the value for the uncured specimen recorded against a white backround and the black symbol represents the value recorded against a matt black backround.

Graph 5.3.3. e

Graph for the reflectance values of the specimens cured for 60 seconds, listed in table 4.2. The open square represents the value for the uncured specimen recorded against a white backround and the black symbol represents the value recorded against a matt black backround.

Graph 5.3.3. d



1. H-Y
2. H-U
3. H-L
4. H-G

5. FF

6. DIST

7. VM-S
8. VM-G
9. VM-B
10. VM-L

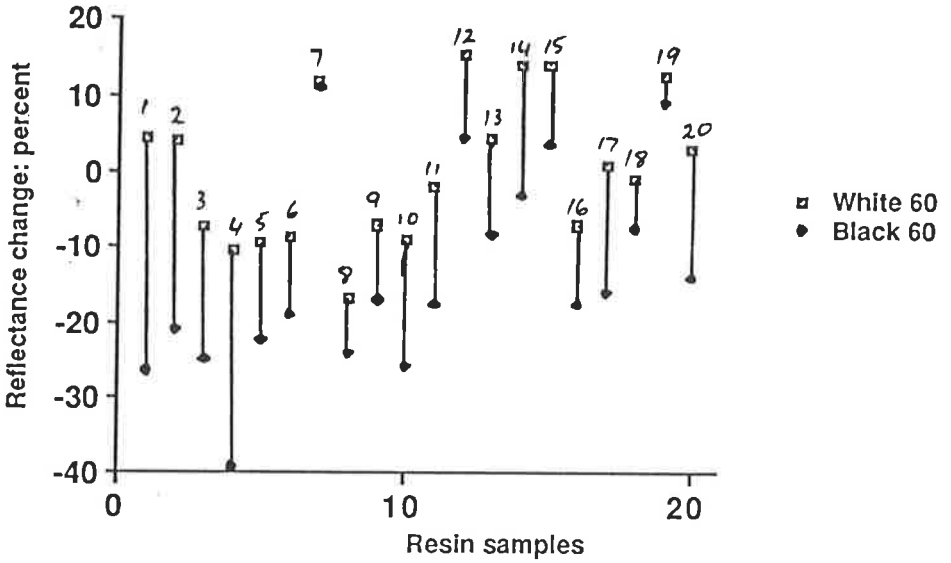
11. A-H

12. OCC-XL
13. OCC-S
14. OCC-DY
15. OCC-LG

16. P-30 L
17. P-30 U
18. P-30 Y
19. P-30 G

20. EST. P

Graph 5.3.3. e

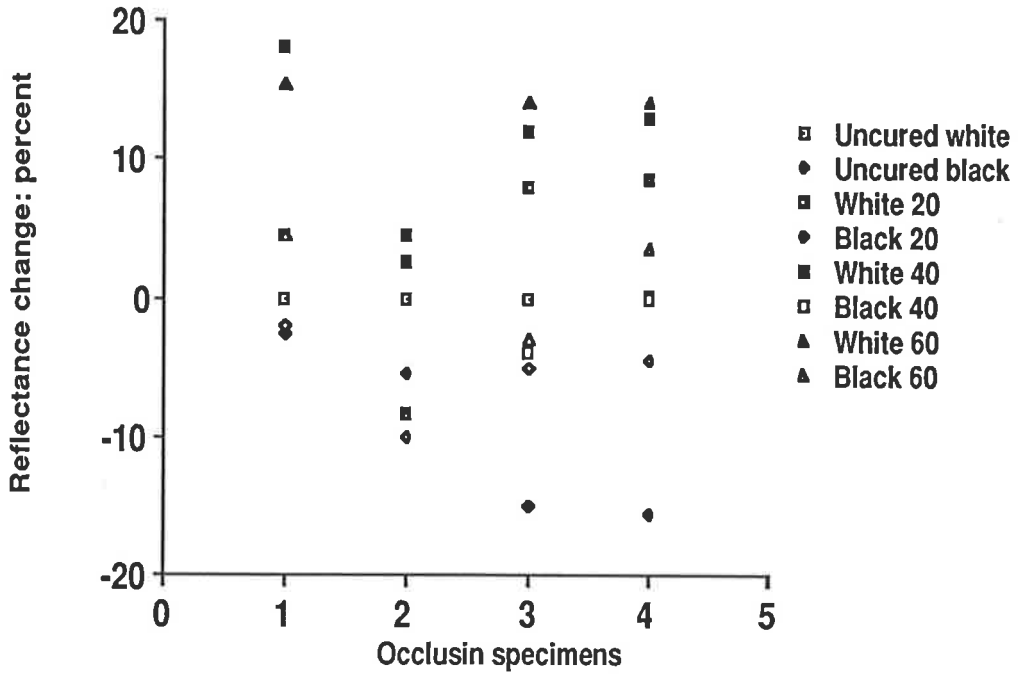


Graph 5.3.3.f

Graph for the reflectance values of the Occlusin specimens, listed in table 4.2.

1. Occlusin extra light
2. Occlusin standard
3. Occlusin dark yellow
4. Occlusin light grey

Graph 5.3.3.f


Reflectance change: percent
20
10
0
-10
-20
0
1
2
3
4
5
Occlusin specimens
Uncured white
Uncured black
White 20
Black 20
White 40
Black 40
White 60
Black 60

5.4 DISCUSSION

The thicknesses of all specimens were measured to determine whether there was a significant difference to invalidate some of the results of this experiment. No significant difference was found at the 99% confidence level, (appendix J).

A subsection of thickness measurements, representing those of the Visio-Molar group was statistically analysed separately and at the 95% confidence level was outside the rest of the group. This resin was harder to compress into the washer due to its stiff nature. The Visio-Molar composite is an extremely low slumping resin and an extremely stiff resin to extrude from the tube.

The results from the table above indicate a general trend for posterior composite resins to change opacity continuously for a least 48 hours after the 20 and 40 second exposure times. The 60 second exposure groups show a tendency to stabilize after 24 hours which would indicate a more successful conversion for increments exposed for that time. The 20 second exposure group is by far the least stable.

Characteristics of individual resins have different values, however they all seemed to follow the same pattern. Individual resins are discussed below.

1. Herculite syringeable.

This is a small particle restorative, with an average particle size of 0.6 micrometers. The wide variability between shades warrants further investigation, however this group of resins may be influenced more by the surrounding tooth structure than some of the others in this group. The predictability of final optical characteristics could be a little difficult.

2. Fulfil.

This resin has a medium to large colour change, becoming quite dark when viewed against a black backround. When this result is aligned with the reflectance, it would then be reasonable to assume that the translucency aquired during curing will remain so for a reasonable period of time, and therefore the resin should not be used in situations where this translucency will be detrimental to the aesthetics.

3. Distalite.

Despite the fact that this resin is a microfil, the results are similar to large particle resins. The resin will develop a reasonable degree of translucency, with lowered reflectance where the backround is light absorbing.

4. Visio-Molar.

The opacity results for Visio-Molar indicate that standard and grey shades show a larger drop in opacity than light and brown shades, and could therefore be considered to be more translucent. However the reflectance results place the standard shade in a group on its own, with increased reflectance while the others show decreased reflectance. The answer possibly lies in the fact that the densitometer shines a light through the resin which is highly translucent, and the reflectance values were measured using light which was incident to the top surface, and that particular surface was much more reflective than the others by virtue of the fact that the shade was different.

This means that translucency, measured by light passing straight through the sample is relatively consistent for all shades, but that the reflectance value for the standard shade is much more critical of the incident angle and therefore gives a different performance expectation clinically.

5. Adaptic II.

This restorative demonstrated a loss of reflectance which was consistent regardless of cure time. The shift in reflectance is not as severe as some resins and at this stage would have to be considered as not a great problem.

6. Occlusin.

The reflectance values for Occlusin were quite characteristic for this resin. The values against the white backround increased with curing.

7. P - 30.

The results for P-30 demonstrated some variation between shades, again the sample size was too small for this to be statistically significant, but there was an immediate trend for this material not to show uniformity of performance between the different shades. The only trend that may be evident is that as the exposure time increased and the shades became darker, i.e. Extra-Light, Universal, Yellow and then Grey, the reflectance increased against the white backround. The performance for the black backround followed a similar pattern, always tending to increase with the darker shade and the longer exposure time.

8. Estilux Posterior.

This material tended to behave in a similar manner to most of the others, with no great difference between exposure and reflectance. See graphs 5.3.3.b, c, d & e. A degree of loss of reflectance is evident on the black backround.

From this information some resins have shown a large capacity to transmit light and variations in placement will affect the aesthetic properties. Some opaquer resins when placed over highly refective enamel will stand out when there is a slight colour mismatch, while other translucent resins will be very dark when they are place in areas where the underlying structure is not very reflective at all.

As a general comment, there does not appear to be a distinct correlation between changes in opacity and reflectance and colour change, although a much higher sample size may produce a recognisable trend. The other major influence which may begin to demonstrate a difference between the exposure times was the thickness of the specimen. A 1 mm specimen should have a very even conversion for the full thickness with these exposure times, particularly when the evidence in chapter 6 of this report suggests that conversion rates start to fall away at depths greater than 2mm.

5.5 CONCLUSION

In general, the posterior composites tested all demonstrated an increased translucency due to a reduced opacity following curing. The longer curing times produced a lower and more stable degree of opacity. Post-operative curing continues with significant changes in the first 24 hours and less significant changes in the second 24 hours. The more stable resins such as Visio-Molar show relatively little change at 24 and 48 hours from the initial measurement. Although thickness differences in the specimens was not statistically significant, it may be that opacity changes are sensitive enough that more uniform thicknesses are required.

Reflectance values also tended to show a consistent pattern with values generally lowered after curing, and the degree more pronounced on a non-reflective surface. This would tend to indicate that the sub-surface over which the restorative is placed could be very important, particularly with regard to aesthetics. The classic example for this would be to replace an old amalgam which has deeply stained a tooth with a highly translucent posterior composite and still retain a dark looking tooth.

The reflectance values for this experiment were recorded under laboratory conditions and could not be construed to indicate clinical behaviour directly. All specimen surfaces were cured against clear mylar strips and were not polished, a situation not likely to occur in vivo.

The trends shown in this brief experiment are now the subject of a more detailed project.

CHAPTER 6. DEPTH OF CURE

6.1 INTRODUCTION

Although the depth of cure for a given direct filling resin material can be determined by several methods, historically there has never been a universally recognised method to determine this value. The report by Tirtha et al., (1982) uses top and bottom Barcol hardness comparisons to determine depth of cure, but only tests specimens of set thicknesses, i.e. the specimens ranged from 1.5 mm. to 3.5 mm in 0.5 mm increments, so a continuum of cure quality was not established. The Australian method, (see Appendix D), provides a quick method to determine depth of cure, however it has a major shortcoming which will be described during this chapter. If several hardness tests are performed down the axial wall of the test specimen, it becomes obvious that the conversion rate during polymerisation is not uniform with a marked reduction in hardness often appearing long before the end point according to the Australian Standard is reached.

The article by Dewald et al., (1987), describes the use of degree of conversion, (determined by Infrared Spectroscopy), as the most accurate method for determining depth of cure, and adds that the only other system they tested which correlated well with degree of conversion, was the Knoop hardness test. Other methods, for example Newman et al., (1983) describe depth of cure as being measured by observing thin sections of polymerised resin under transmission light microscopy and determining the value to be where a "noticeable change in translucency" occurred. This system could be somewhat variable, depending on the observer and the type and colour of the resin. Results from section 4.2 indicate that some resins show little colour change on curing, so one might think that observer errors may be increased.

The range of influences which cause variations in results between different comparisons include the following:

1. Type of specimen mould, (metal or clear plastic).
2. Type of curing light, including age of the bulb.
3. Condition and diameter of the light delivery system.
4. Test method.

Furthermore the clinical implications rely on how close the combination of the wedges, clear matrix and light, can be made to the resin increment to be cured. Combined with the variablity for control of increments, (size and layering), and ability to approximate the light in the right position for the best beam alignment, the depth of cure in vitro may be hard to repeat in vivo.

As noted in the Australian Standard (AS 1278-1982), the external energy source to be used for a particular resin test is that which is recommended by the manufacturer for that resin. This provides difficulties for the practitioner when he elects to change to a new resin system; does he need to buy the matching light?

The first step in this evaluation was to produce three cured resin specimens according to AS 1278-1982. The data appear in Appendix D.

6.2.1 INVESTIGATION OF A SUITABLE DEPTH OF CURE STANDARD

6.2.1.1 MATERIALS AND METHODS.

Specimens of Herculite Syringeable[13] posterior composite were produced by the Australian standards method for depth of cure, (AS 1278-1982 Appendix C). The specimens were measured by micrometer after uncured resin was gently scraped away, seen in figure 6.2.1.b. The results are shown in table 6.2.1.a. The specimens were then mounted in one half of the split mould which was in turn mounted on the movable stage of a mini-loader hardness tester[14] with a key made of self-cure special tray material, [15]Ivolen SR. A conical diamond, was then drawn along the axis of the specimen, producing a scratch. The details about the particular diamond used are contained in appendix J. The load applied was 15 grams $\pm$ 50 mg, which is the weight of the indenting unit alone. The end point of the scratch, termed "catastrophic failure", corresponded to the level where the uncured resin which remained after curing, had been scraped away.

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[13]Herculite Syringeable: Kerr, Romulus, Michigan, 48174 U.S.A
[14] Miniload Hardness Tester; Ernst Leitz, GMBH, West Germany.
[15]Ivolen SR; Ivoclar Aust., Melbourne Vic.

This method was also used to test specimens produced in the same mould that had been cured while various separators were in place between the two halves of the mould, as seen in figure 6.2.1.c. The width of the scratch produced by the conical diamond was then measured. This is done by bringing one edge of the scratch in contact with a line of the plotting scale in the viewfinder of the Miniload hardness tester, and the measuring scale is read. The other edge of the scratch is then brought in contact with the same or another graduating line and the measuring scale is read again, with the difference between the two measurements being the width of the scratch. These were then observed under both light and scanning electron microscopy. The nature of the increase in width of the scratch was recorded by scanning electron photomicrographs[16].

[16]ETEC Scanning Electron Microscope ; Etec Corporation, 2284 Old Middlefield Way, Mountain View, California 94040, U.S.A.

Table 6.2.1.a

Results of Depth of Cure experiment to verify the repeatability of AS 1278-1982 to measure Depth of Cure in Dental composite restorative resins

Table 6.2.1.a

Material: Herculite Syringeable, Universal shade.

Batch Number: P8506 5 3144 1

Sample size : 10 **Range** : 4.7 mm - 4.98 mm

Measurements.		
	#1	4.72 mm
	#2	4.98 mm
	#3	4.74 mm
	#4	4.70 mm
	#5	4.72 mm
	#6	4.82 mm
	#7	4.84 mm
	#8	4.72 mm
	#9	4.74 mm
	#10	4.92 mm

Mean : 4.79 mm

Standard deviation : 0.1

Figure 6.2.1.b

Resin specimen being measured according to AS 1278-1982. The uncured resin has been gently scraped away leaving only composite which has shown some degree of cure.

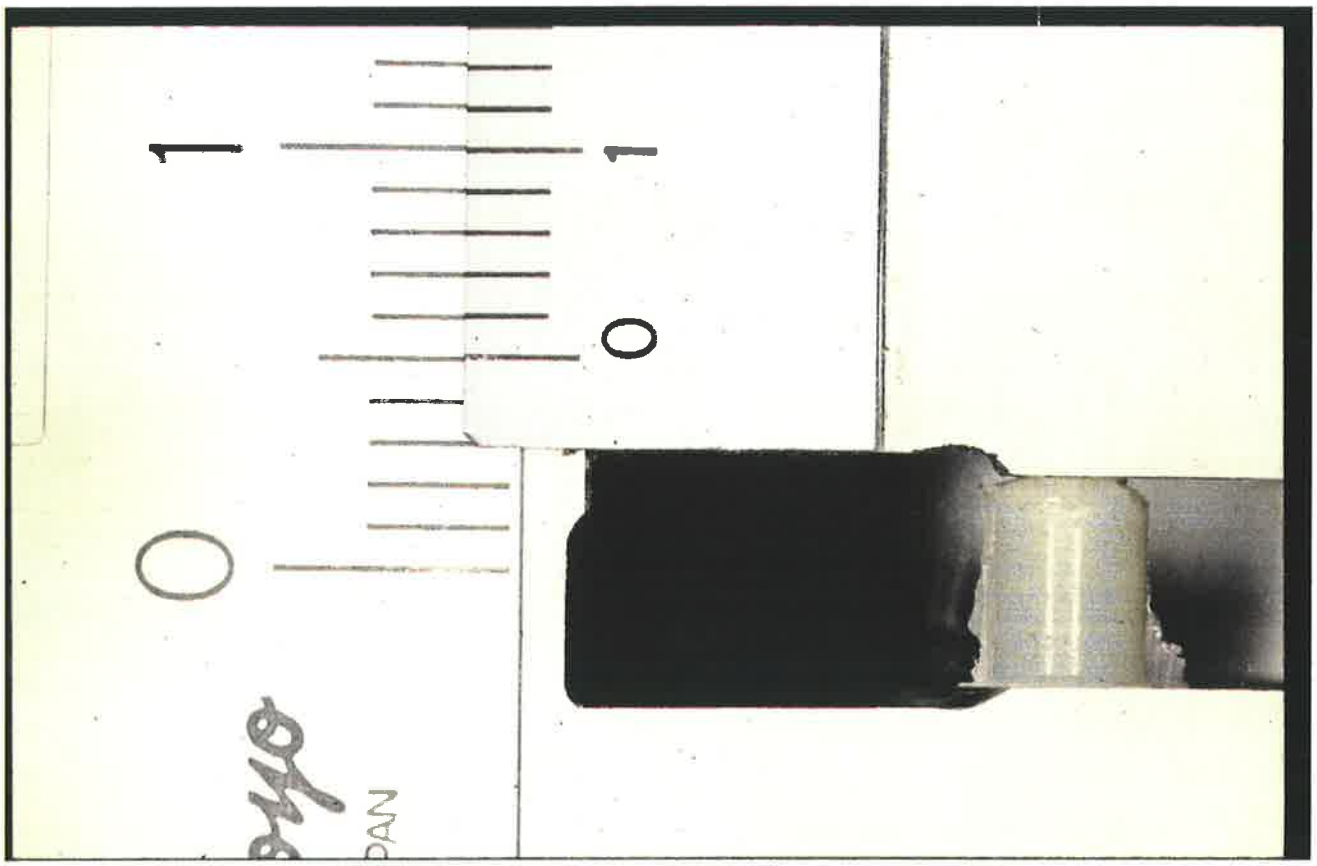
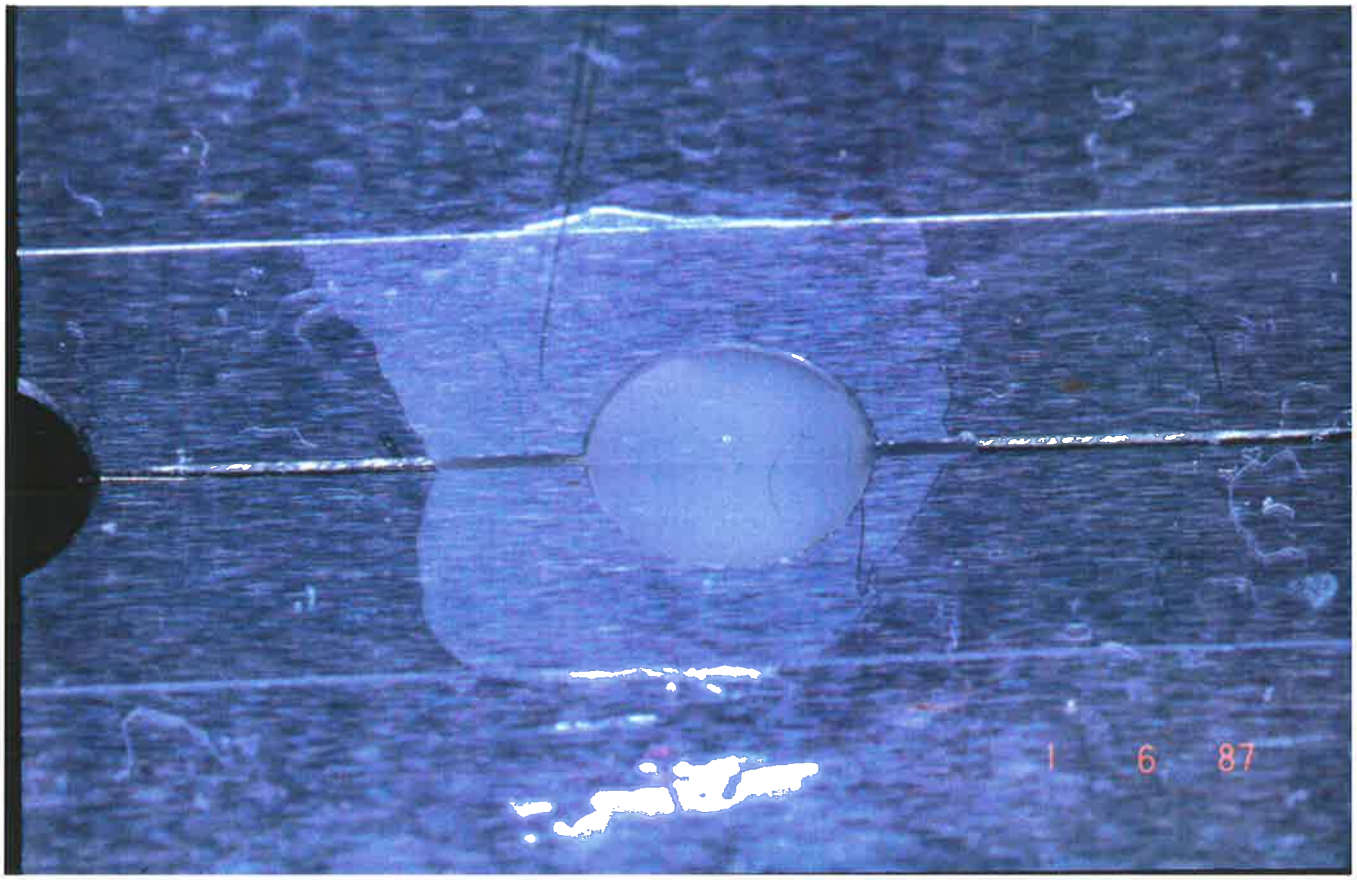

1
0
1
0
JAPAN

Figure 6.2.1.c

Stainless steel mould of 4mm diameter with a resin specimen in situ. The specimen is covered by a matrix strip which served as a separator when a glass slab was pushed down on the top surface to make it flat. The glass slab was removed and then the specimen was cured for 40 seconds. Where necessary, separators were also placed between the two halves of the mould, to study the effects of matrix bands on the depth of cure.


1 6 87

6.2.1.2. RESULTS.

The results for the control group, cured and measured according to AS 1278-1982 appear in graph 6.2.1.a. The most significant result is an indication that the cured resin begins to show significant failure in the matrix well before the AS 1278-1982 standard is reached. In all cases the scratch was observed to increase in width at a point well short of the AS 1278 -1982 measurement, indicating a decrease in the strength of the resin well before the accepted depth of cure. The Scanning Electron Micrographs of the scratch depict a tearing of the matrix, after only 60% of the ASA standard value has been traversed, to leave fissures extending down through the sample, (figures 6.2.1.2.a, b & c). These fissures clearly appear to be through the resin matrix, with distinct intact filler particles being left untouched. This would indicate resin failure within the matrix due to a reduction in the conversion rate of carbon double bonds to form crosslinks between monomer molecules. Thus the depth of cure would appear to be compromised.

In addition, a split sample was produced using the system described in figure 6.3.2.1.a The flat surface was tested with both a scratch using a conical diamond, and a Knoop Hardness test with indentations 0.5 mm apart along a line that ran parallel to the long axis of the specimen and the conical diamond scratches. S.E.M. micrograph of this specimen may be seen in figure 6.2.1.2. e .

Graph 6.2.1.a

Depth of Cure using AS 1278-1982

This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. The test mould did not have a separator strip to divide the sample into two halves. These results differ from those in table 6.2.1.a because the globe in the curing light was replaced between the experiments.

Graph 6.2.1.a

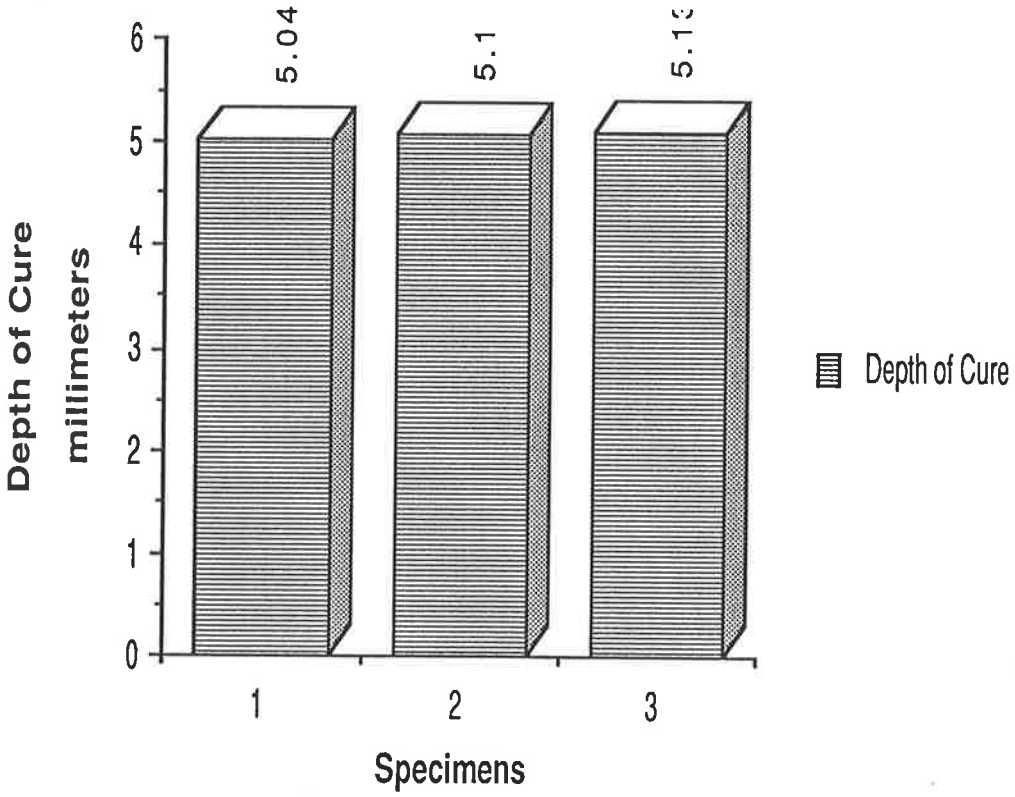
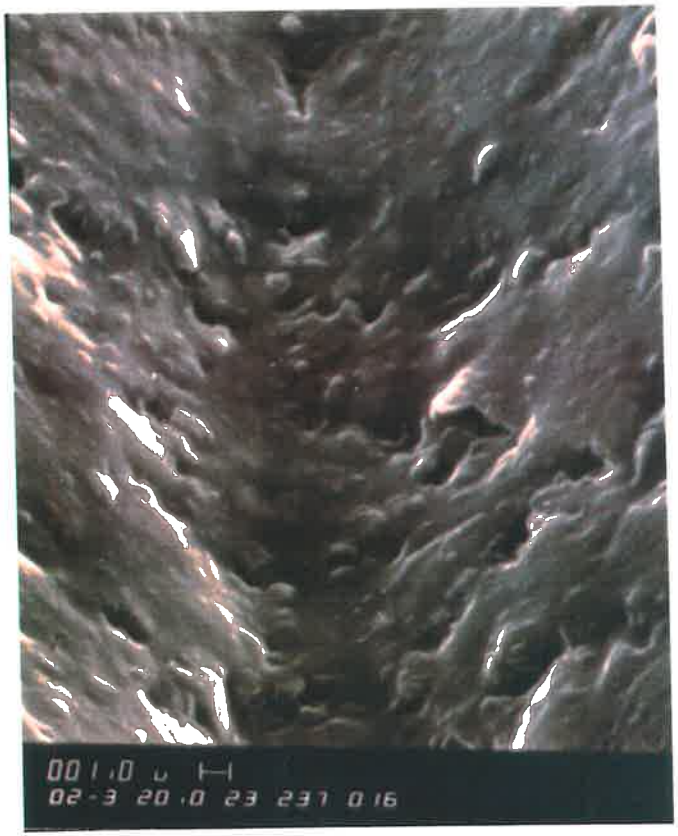

Depth of Cure
millimeters
6
5
4
3
2
1
0
5.04
5.1
5.13
1
2
3
Specimens
Depth of Cure

Figure 6.2.1.2.a.

Scanning electron micrograph of scratch from the conical diamond, where the resin matrix appears to be normal. The scratch is uniform, and there do not appear to be any tears through the matrix. The surface has a smeared or melted appearance. The scratch is approximately 23 micrometers across at this point. The top figure shows the scratch at 120 times magnification and the bottom figure shows the surface of the scratch at 3000 times magnification.


001.0 u
02-3 20.0 23 237 016

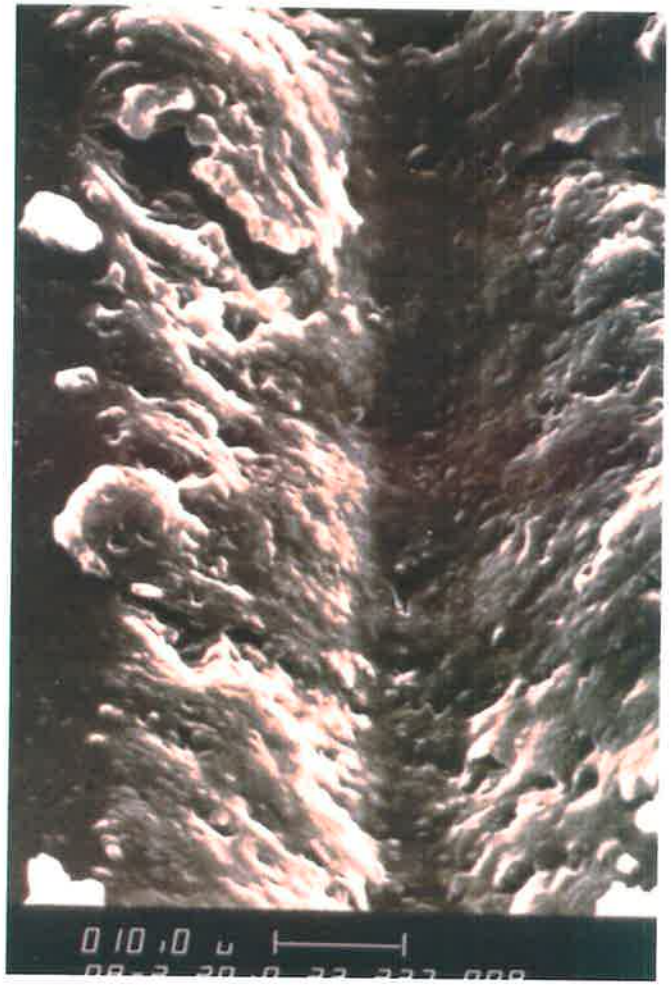

010.0 u

Figure 6.2.1.2.b.

Scanning electron micrograph of scratch from the conical diamond, where the resin matrix appears to have failed due to inadequate curing and tensile strength. This photograph was taken near the middle of the specimen where the resin matrix is starting to show signs of tearing. The tears start to appear at the sides of the scratch with the deeper part still having the same melted appearance as found in the previous example, (figure 6.2.1.2.a) Distinct filler particles can be seen lying in the surface of the cracks.

The top figure shows the scratch at 120 times magnification and the bottom figure shows the surface of the scratch at 3000 times magnification.

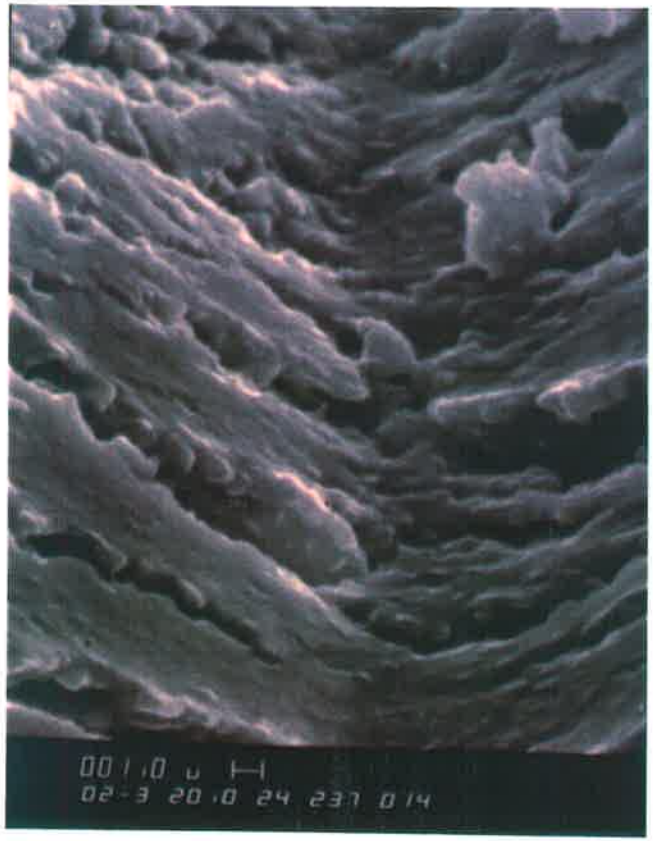
00 1.0 u
02-3 20.0 23 237 017

010.0 u
07-2 20.0 24 237 010

Figure 6.2.1.2.c.

Scanning electron micrograph of scratch from the conical diamond, where the resin matrix appears to have failed due to inadequate curing and tensile strength. This photograph was taken near the end of the specimen where the uncured resin had been gently scraped away and represents the point termed "catastrophic failure". The tears are now apparent throughout the depth of the scratch.

The top figure shows the scratch at 120 times magnification and the bottom figure shows the surface of the scratch at 3000 times magnification.



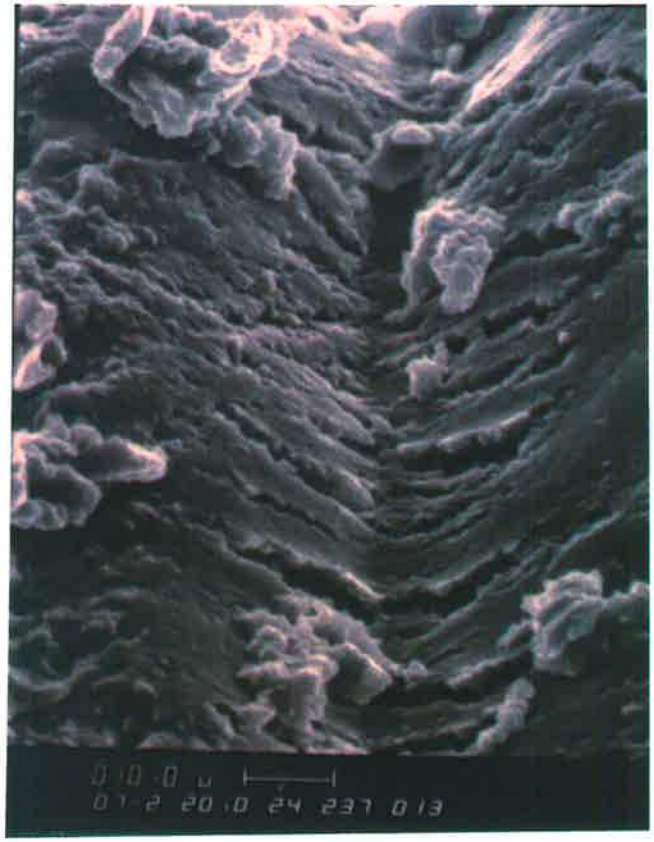
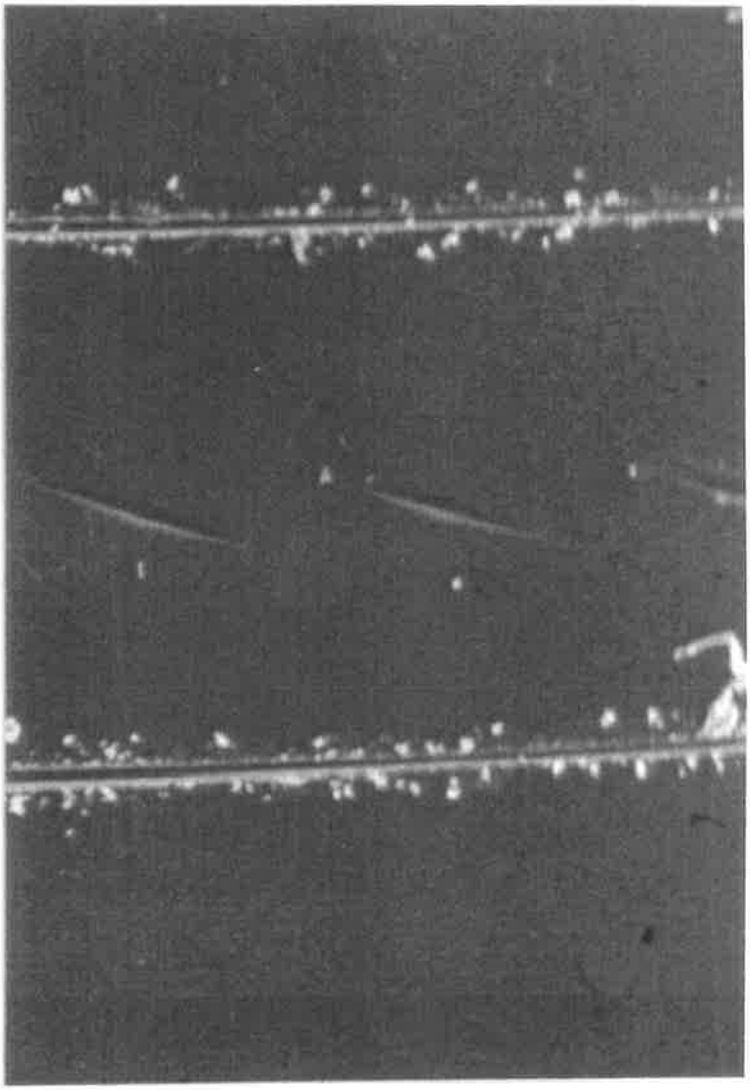


Figure 6.2.1.2.d.

Scanning electron micrograph of Knoop Hardness indentations in resin sample adjacent to scratch where the resin matrix appears to be normal.

Magnification : X 10.

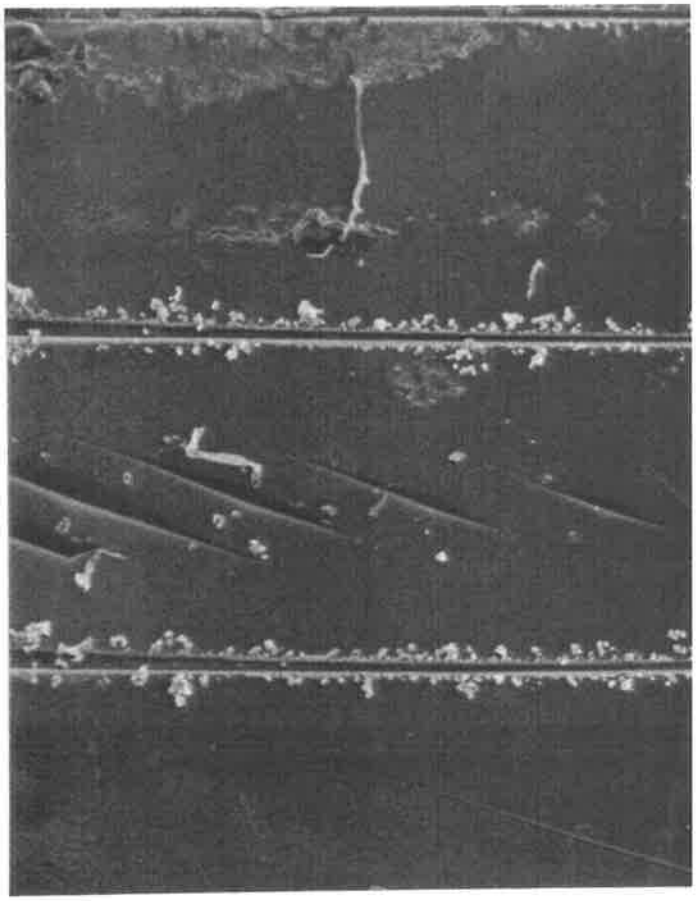


100 µ

Figure 6.2.1.2.e.

Scanning electron micrograph of Knoop Hardness indentations in resin sample adjacent to scratch where the resin matrix appears to have failed due to inadequate curing and tensile strength.

Magnification : X 10



100 µ

6.2.2. DISCUSSION AND CONCLUSIONS

The accepted Australian standard depth of cure measurement (AS 1278-1982) is readily repeatable, (graph 6.2.1.a). However it does not give a true indication for the limits of the optimal polymer structure of these materials. The specimen produced in the mould according to AS 1278-1982 directions, always has the same characteristic shape, (figure 6.2.3.a). When separators are used to split the specimen axially, the shape varies according to the separator and is directly influenced by the ability of the separator to transmit light, (figure 6.2.3.b). The relevance of this phenomenon is apparent when discussing the influence of matrix bands on the depth of cure of Class II restorations. A value equivalent to half this measurement is being used in some experiments, as it agrees with the constant Knoop values reported to this point, (Fan et al., 1987). Following this point the Knoop values indicate a progressive weakening of the resin to a point where effectively there is no cure, which is the measurement accepted by the Australian Standard as the Depth of Cure .

The use of the scratch test produces a continuous profile of a resin's performance when cured. This measurement can be repeated at later time intervals at adjacent sites on the same sample to observe the effect of post-irradiation curing, or used to compare the effect of the same light on different materials. As the scratch traverses the specimen it leaves a groove which is easily measured on a microscope fitted with a measuring device. The scratch will also be seen to flare at a point usually about half way down the specimen and this point should be taken as the end of optimal cure as it corresponds to that point seen in figure 6.2.1.2 b, where tearing of the matrix has started to occur.

This system might then provide a basis for comparing different materials, or batches within the same material to test for relative depth of cure performance. The test gives a far better insight into the true depth of cure, because a point can be detected by normal light microscopy where the scratch begins to widen. This point is easily confirmed with the help of a Scanning Electron Microscope.

It is therefore the recommendation of this report that a scratch test with a conical diamond with an inclusive angle of 90° and loaded by the indenting unit alone, be used to test the depth of cure of resin restorative materials. The depth of cure should be taken as that point at which the scratch begins to widen.

Figure 6.2.3.a

The top figure is a diagram of the shape of the cured specimen from the depth of cure mould used in AS 1278-1982.

The bottom figure is a photograph of the shape of the cured specimen from the depth of cure mould used in AS 1278-1982.

The removal of uncured resin from the bottom of the specimen always leaves the same hemispherical dome shape, with the greatest depth of cure at the centre and the least at the periphery.

CURING LIGHT

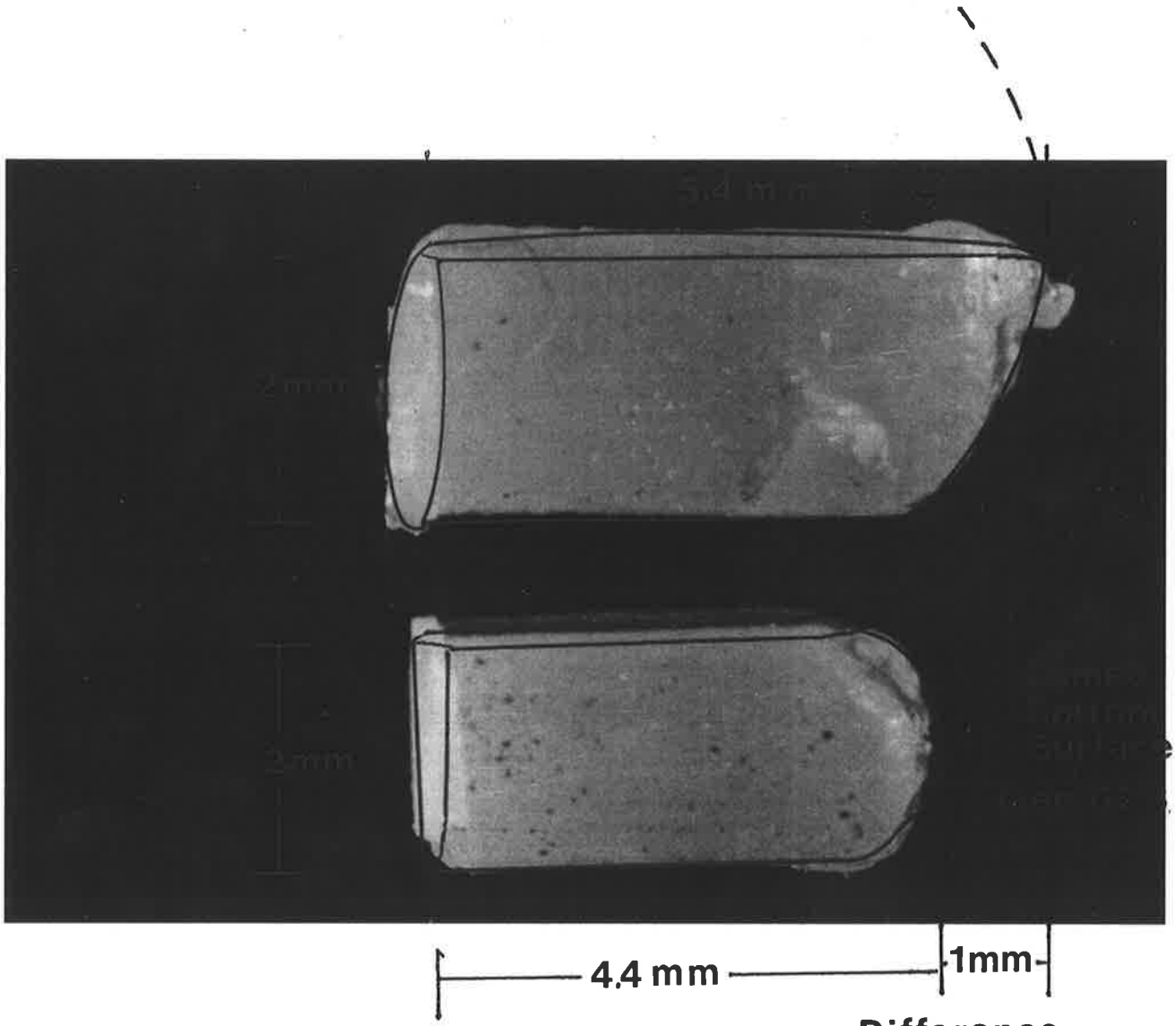
TOP (flat)

BOTTOM (curved)

Figure 6.2.3.b

This photograph shows two resin depth of cure specimens produced according to As 1278-1982, with the exception that separators were used in the middle of the mould apparatus, as demonstrated in figure 6.3.2.1.a.

The top specimen had a clear plastic separator and the bottom specimen had a stainless steel separator.



a)

6.3 DEPTH OF CURE: CLINICAL INFLUENCES.

6.3.1. INTRODUCTION.

Posterior composite resins are placed in the mouth under conditions vastly different to the laboratory. The resin is surrounded by enamel and/or a matrix and the shape and size of the surface presenting to the curing light is not regular. Also, during placement the resin is subjected to strong operatory lighting. The most important clinical influences are the direction of cure, the use of plastic matrix bands and light transmitting wedges[17], (figure 6.3.1.a & b), the size of the resin increment, the duration of the irradiation and whether the light comes directly from the primary beam or via some other transmission enhancer.

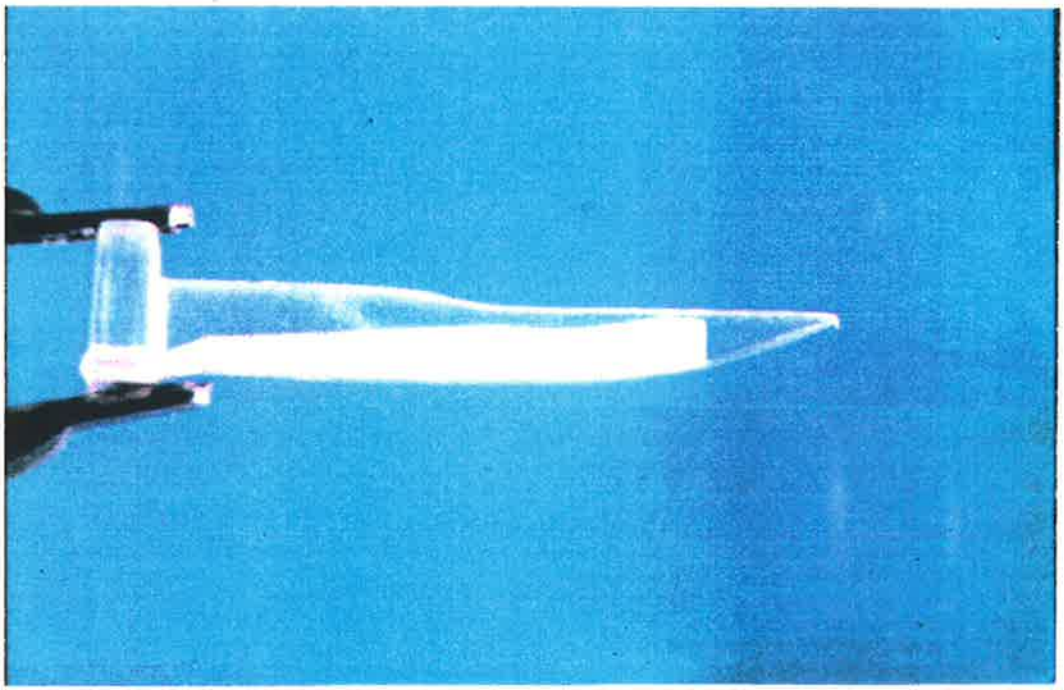
[17]Luciwedge; Hawe-Neos Dental, Switzerland.

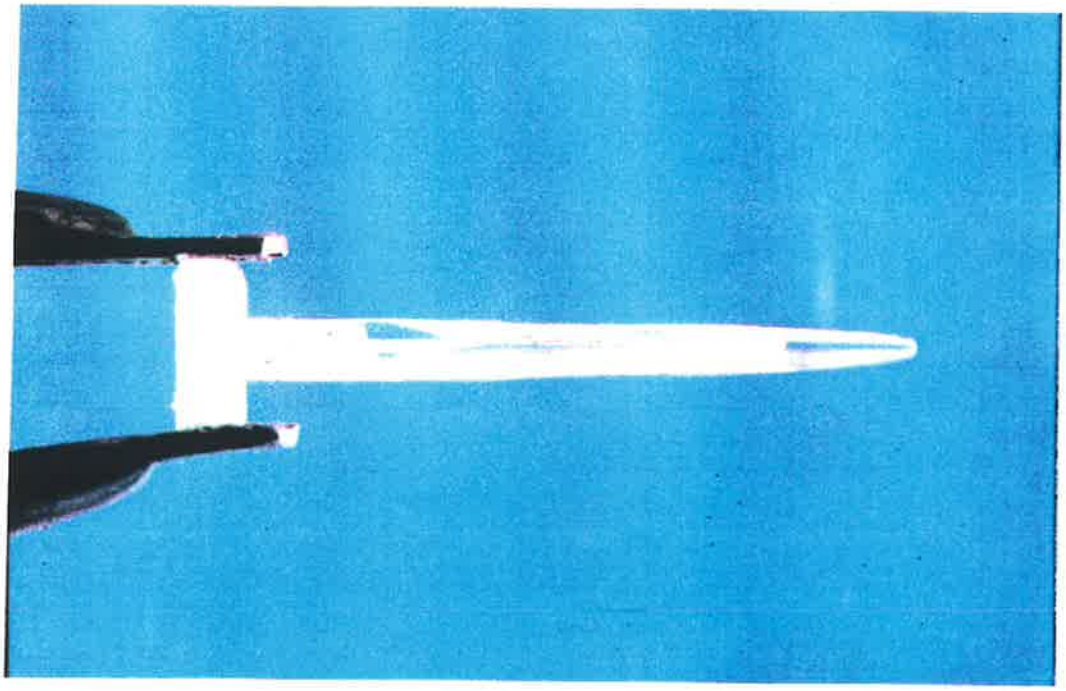
Figure 6.3.1.a

Photograph of a light transmitting Hawe-Luciwedge. (Side View)

Figure 6.3.1.b

Photograph of a light transmitting Hawe-Luciwedge. (Top View)



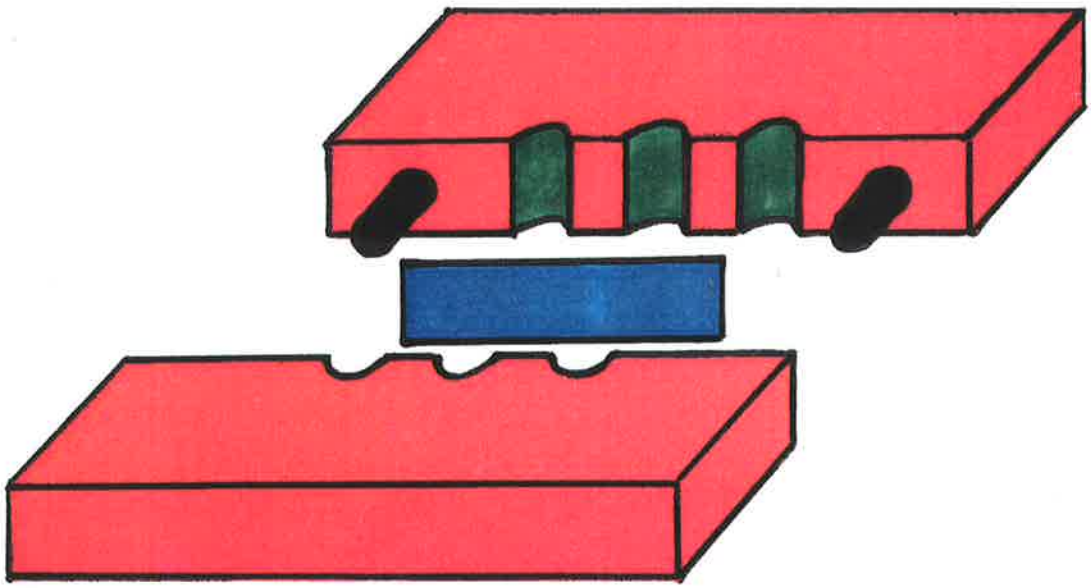


6.3.2.1 MATERIALS AND METHODS ; MATRIX BAND INFLUENCE

Herculite Syringeable composite resin placed in the same stainless steel split mould as used for the A.S. 1278-1982 test was used to produce further depth of cure specimens. The first group of specimens used a mylar plastic strip as a separator, the second group used a black plastic separator and the third group used a stainless steel matrix band as a separator, (figure 6.3.2.1.a). The test set-up to scratch the resin surface is seen in figure 6.3.2.1.b. The curing time for each sample was 40 seconds, using the Translux CL light. In addition to this, Class II cavities were placed in several premolars and restored in the same order as described in section 9.2.2.4 of this report, (figures 9.2.2.4. a - i). These in vitro restorations were made in premolars where the proximal surface to be restored were ground flat. The mylar strip was then held in apposition to this surface with a clamp and matte surfaced flat steel block, (figure 6.3.2.1.c). The specimens were then assembled in a mounting system which allowed the conical diamond to be drawn axially along the flat surface and scratch test the surface, (figure 6.3.2.1.d).

Figure 6.3.2.1.a

Diagram of apparatus used to simulate the effect of matrix strips on the quality of surface cure in the interproximal box.



Steel Mould Assembly

4mm diameter holes

Locating Dowel

Matrix Strip (separator)

Figure 6.3.2.1.b

Photograph of apparatus used to test the effect of matrix strips on the quality of surface cure in the interproximal box.

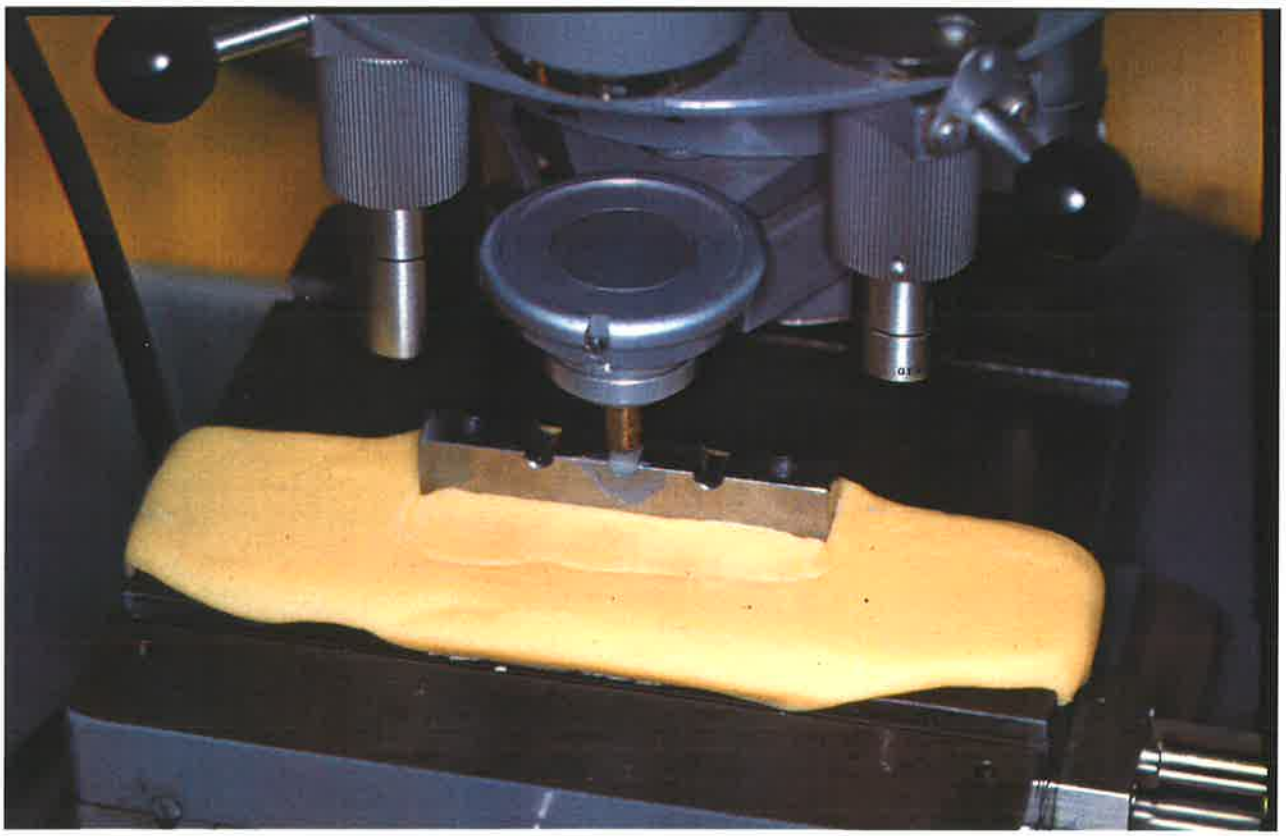


Figure 6.3.2.1.c

Diagram of apparatus used to simulate the effect of the clear mylar strips on the quality of surface cure in the interproximal box for the premolar specimen.

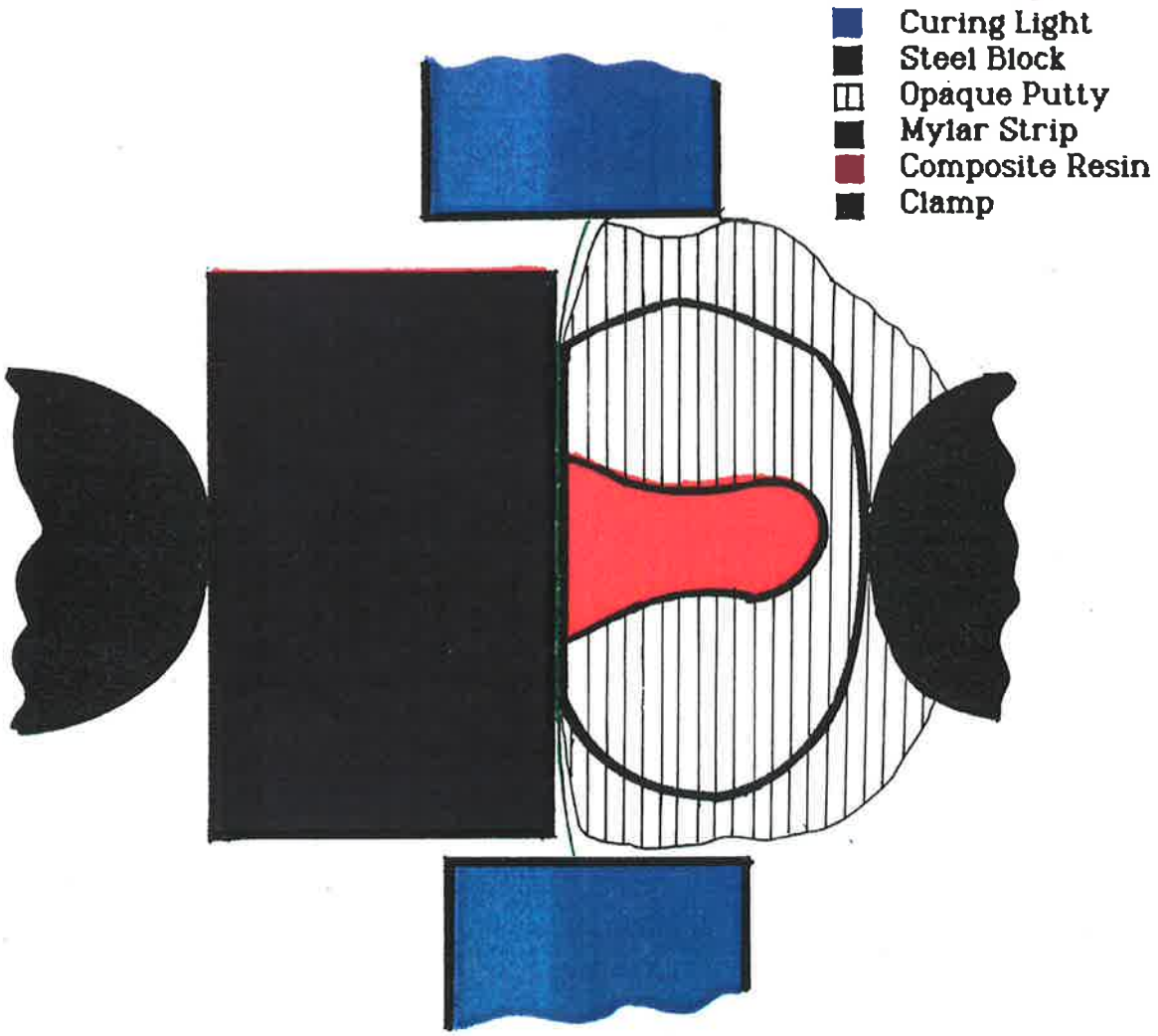
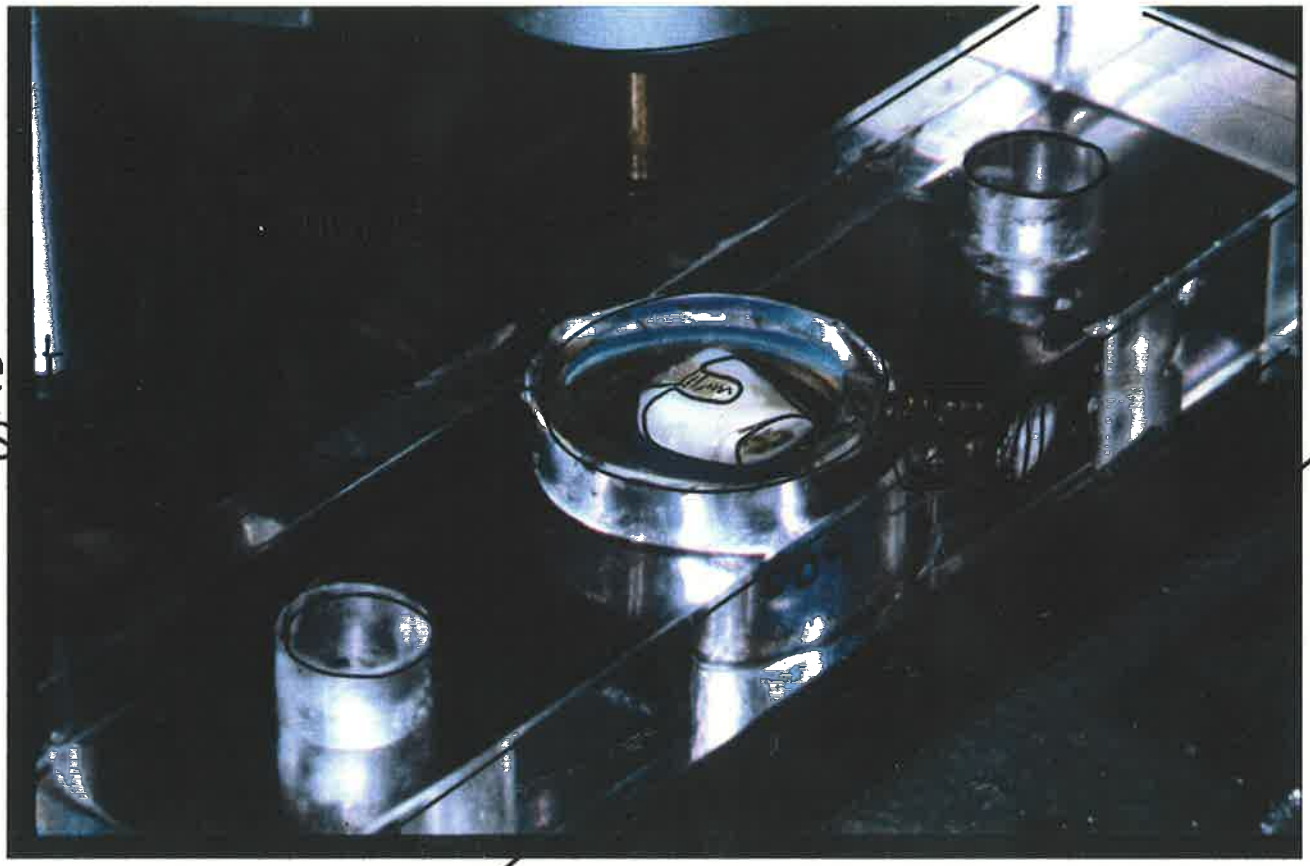

Curing Light
Steel Block
Opaque Putty
Mylar Strip
Composite Resin
Clamp

Figure 6.3.2.1.d

Photograph of apparatus used to test the effect of the clear mylar strips on the quality of surface cure in the interproximal box for the premolar specimen.



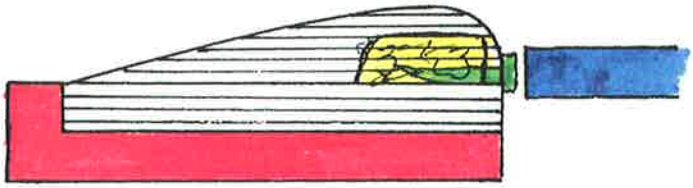
specimen
mounting
assembly

6.3.2.2 MATERIALS AND METHODS; LIGHT TRANSMITTINGWEDGES

Light transmitting wedges, (Hawe-Luciwedges), were placed through black plastic sheet. The point where the wedge punctured the plastic was further sealed with a black sealing compound. The wedge was then covered with approximately 6mm of uncured resin and this portion of the wedge was then sealed from all backround light, (figure 6.3.2.2.a and b). The sample was then cured via the wedge for 40 seconds with the same light mentioned above. Then uncured resin gently was scraped away leaving the shape seen in figure 6.3.2.2.c. Further specimens were produced using the system shown in diagram 6.3.2.2.d to produce a measurable flat surface parallel to the base of the wedge, see figure 6.3.2.2.e. The specimens were measured with a micrometer at 0.5 mm intervals along the axis of the wedge. The specimens were also scratch tested at the same intervals.

Figure 6.3.2.2.a

Diagram of the system used to measure the enhancement of depth of cure by the use of light transmitting/reflecting wedges.



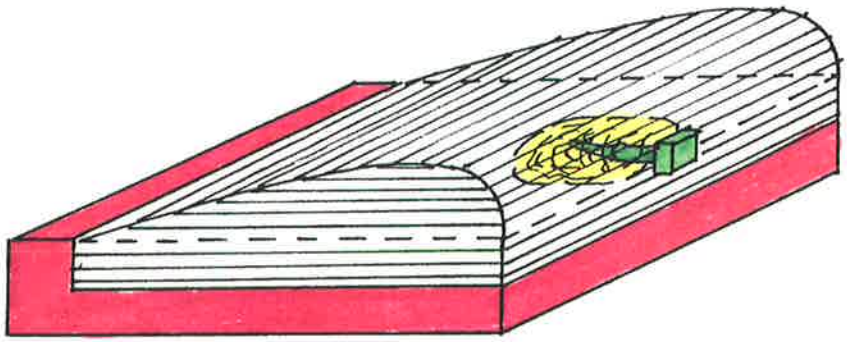


Figure 6.3.2.2.b

Photograph of the system used to measure the enhancement of depth of cure by the use of light transmitting/reflecting wedges.


27 10 86

Figure 6.3.2.2.c

Photograph of the cured resin sample following a 40 second application of the Translux CL light. Polydent Wedge[18]

[18]Polydent wedge : Polydent Matrix Systems, Switzerland.

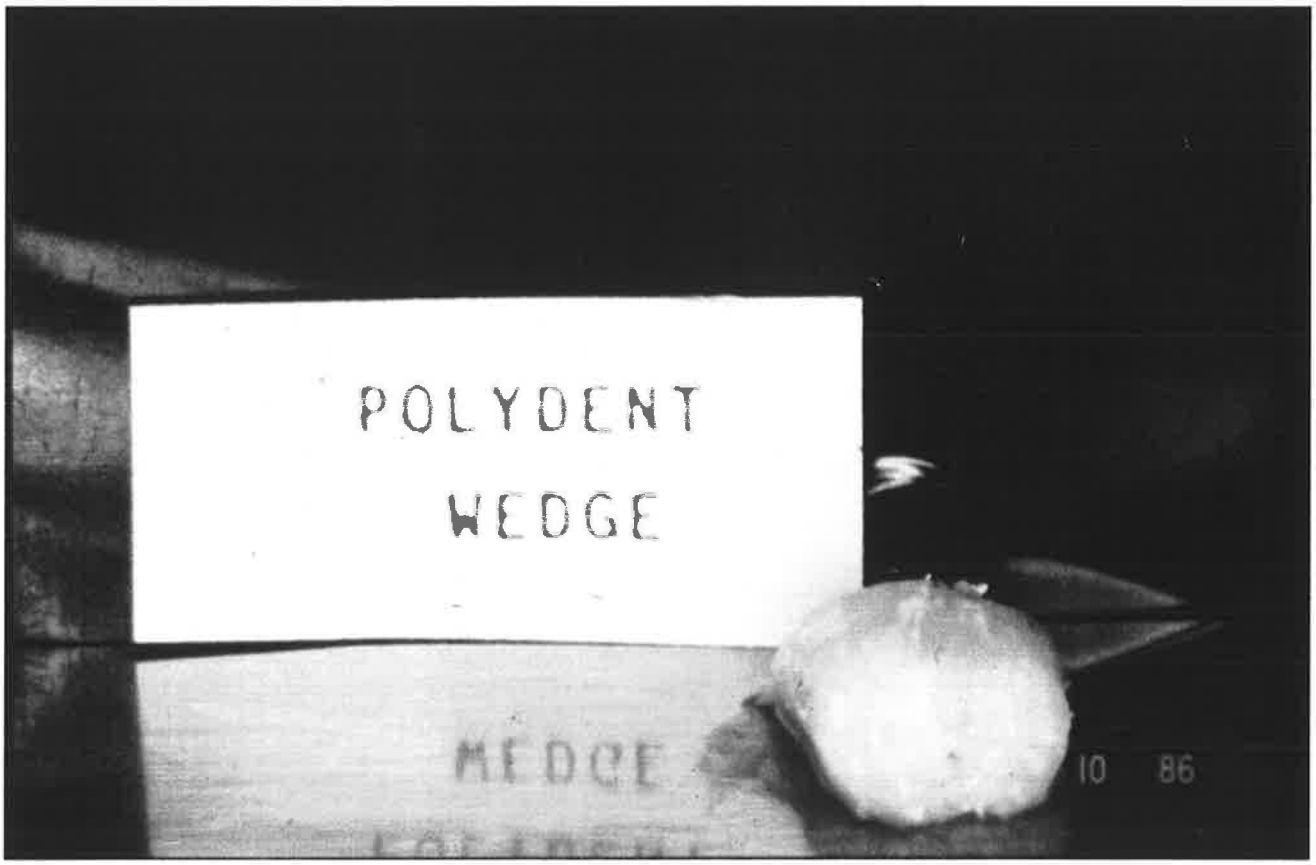
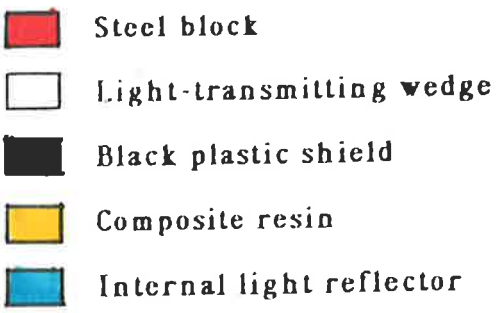

POLYDENT
WEDGE
10 86

Figure 6.3.2.2.d

Diagram of the system used to produce a test surface at the top of the wedge, parallel to the base, at points that would approximate the centre of the interproximal region.



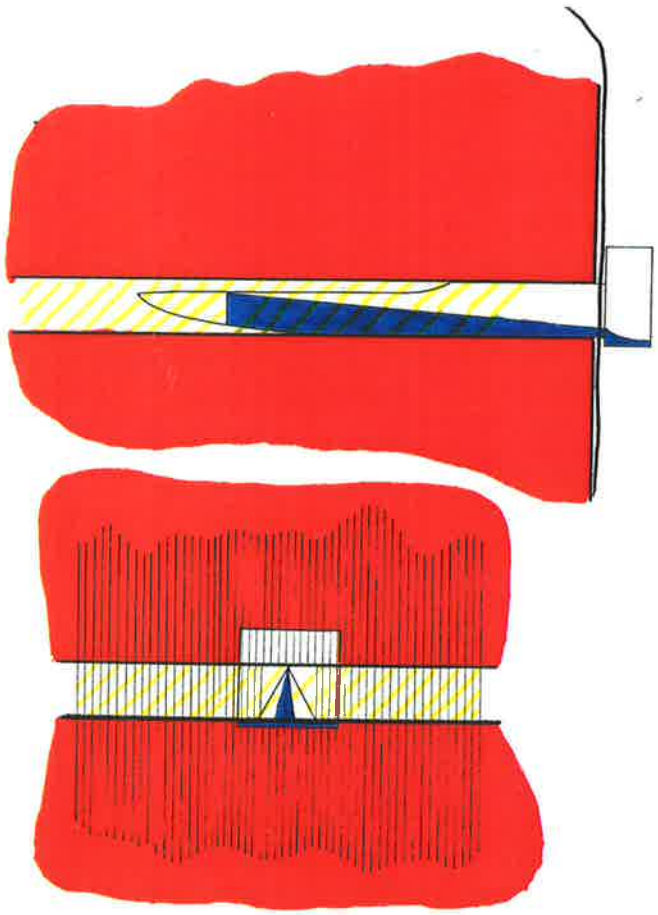
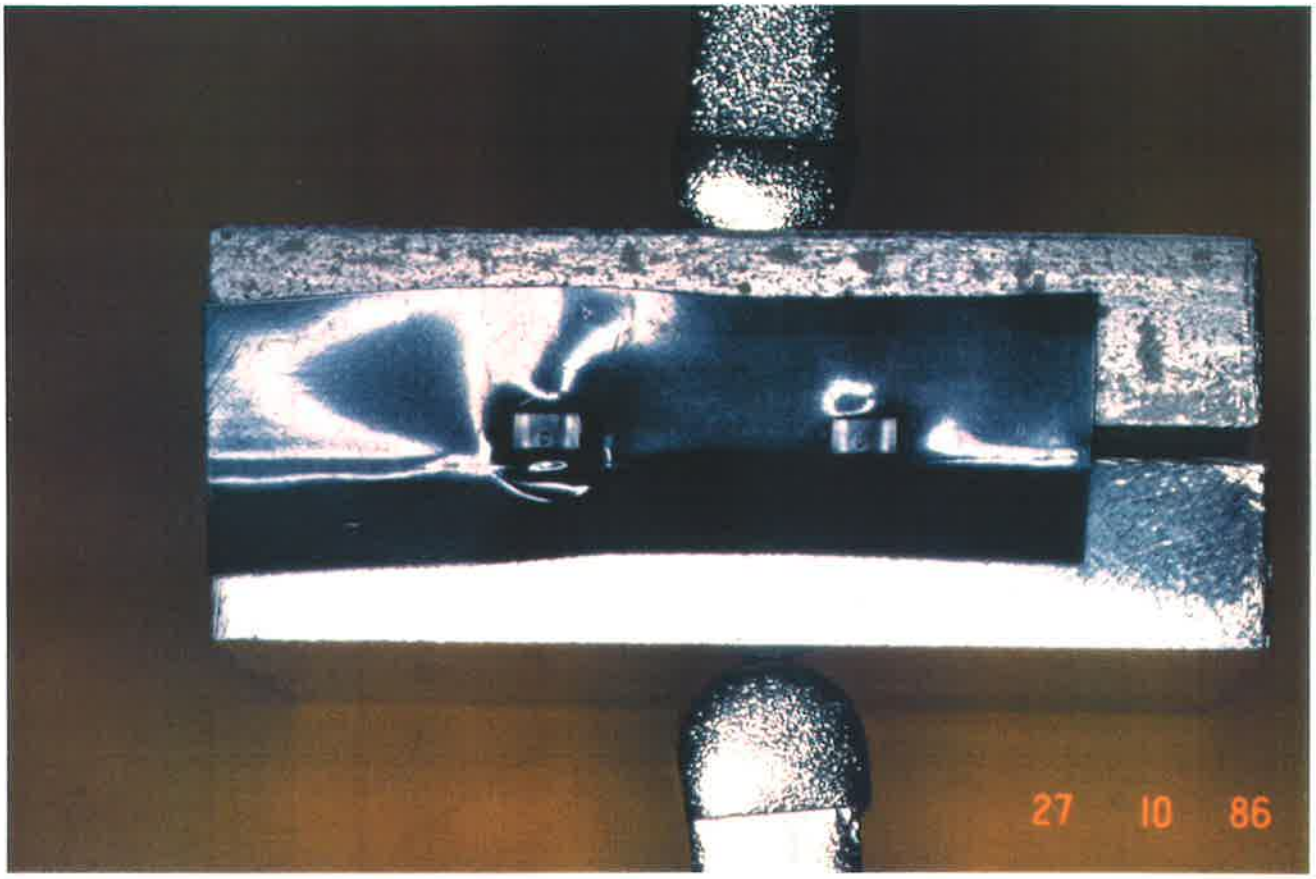


Figure 6.3.2.2.e

Photograph of the system used to produce a test surface at the top of the wedge, parallel to the base, at points that would approximate the centre of the interproximal region.


27 10 86

6.3.2.3 RESULTS: MATRIX BANDS

The metal moulds were split apart and the resulting specimens examined. The metal separators and the black plastic separators produced very similar results, as seen in figures 6.3.2.3.a & b. The clear plastic matrix had the effect of enhancing the depth of cure for the resin immediately adjacent to its surface as can be seen in figure 6.3.2.3.c. This enhancement produced a result greater than that for the Aust. Standard 1278-1982. The results are seen in graphs 6.3.2.3.d,e & f.

When all the specimens are measured with a micrometer, according to the method in AS 1278-1982, then it is very evident that the clear matrix will enhance the depth of cure, just as clear tubes give an enhanced depth of cure when compared to values achieved in metal moulds. The comparative graph 6.3.2.3.g demonstrates the difference between these materials.

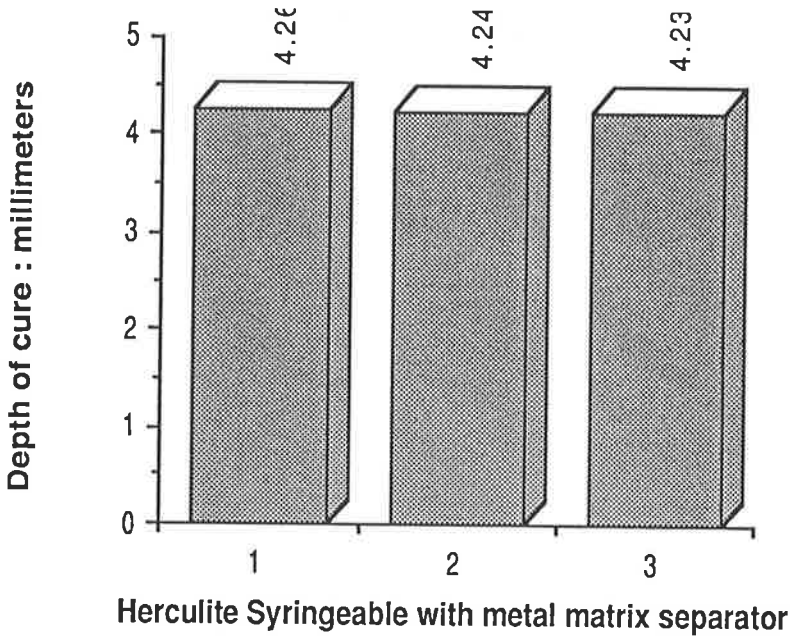
The specimens produced using premolars (see diagram 6.3.2.1.c) exhibited a uniform depth of cure over all increment surfaces. This can be seen in figures 6.3.2.3. h & j .

Graph 6.3.2.3.d

Depth of Cure using AS 1278-1982

This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. The test mould had a metal separator strip to divide the sample into two halves.

Graph 6.3.2.3.d

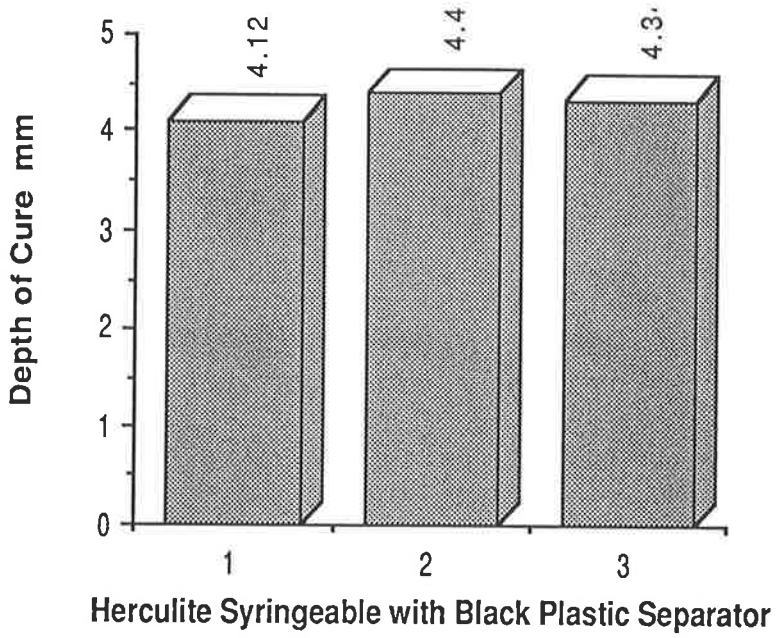

Depth of cure : millimeters
5
4
3
2
1
0
4.26
4.24
4.23
1
2
3
Herculite Syringeable with metal matrix separator

Graph 6.3.2.3.e

Depth of Cure using AS 1278-1982

This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. The test mould had a black plastic separator strip to divide the mould and specimens into two halves.

Graph 6.3.2.3.e

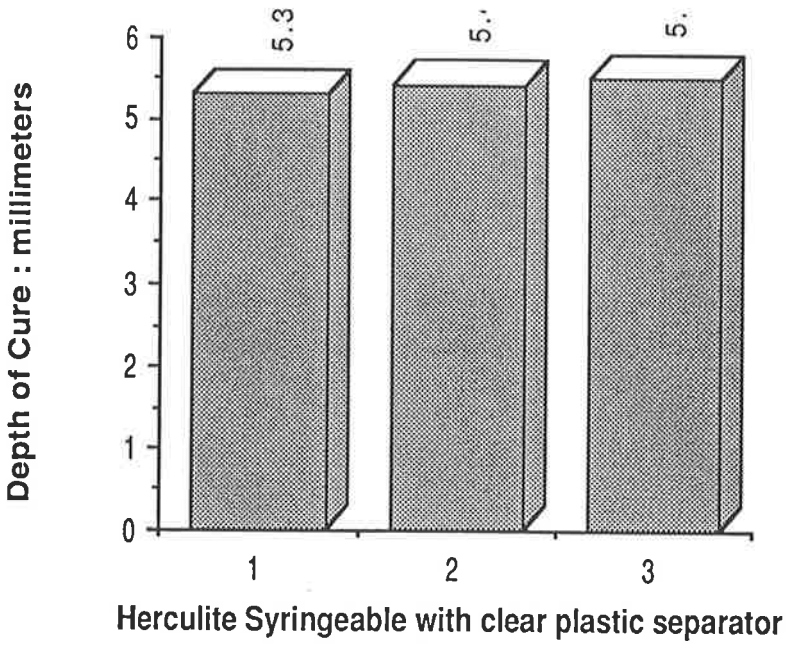

Depth of Cure mm
5
4
3
2
1
0
4.12
4.4
4.3
1
2
3
Herculite Syringeable with Black Plastic Separator

Graph 6.3.2.3.f

Depth of Cure using AS 1278-1982

This graph shows the results, measured in millimeters, when Herculite Syringeable was tested for cure depth according to AS 1278-1982. The test mould had a clear plastic separator strip to divide the sample into two halves.

Graph 6.3.2.3.f


Depth of Cure : millimeters
6
5
4
3
2
1
0
5.3
5.
5.
1
2
3
Herculite Syringeable with clear plastic separator

Graph 6.3.2.3.g

Comparison graph to demonstrate the differences in the depth of cure results between different matrices. Each bar represents the mean value for each of the previous 4 graphs.

1. **Normal** : Control depth of Cure specimens made and measured according to AS 1278-1982.

2. **Black Plastic** : Specimens as per 1. above, but with a black plastic separator in the middle.

3. **Metal Matrix** : Specimens as per 1. above, but with a metal matrix separator in the middle.

4. **Clear Matrix** : Specimens as per 1. above, but with a clear plastic separator in the middle.

Graph 6.3.2.3.g

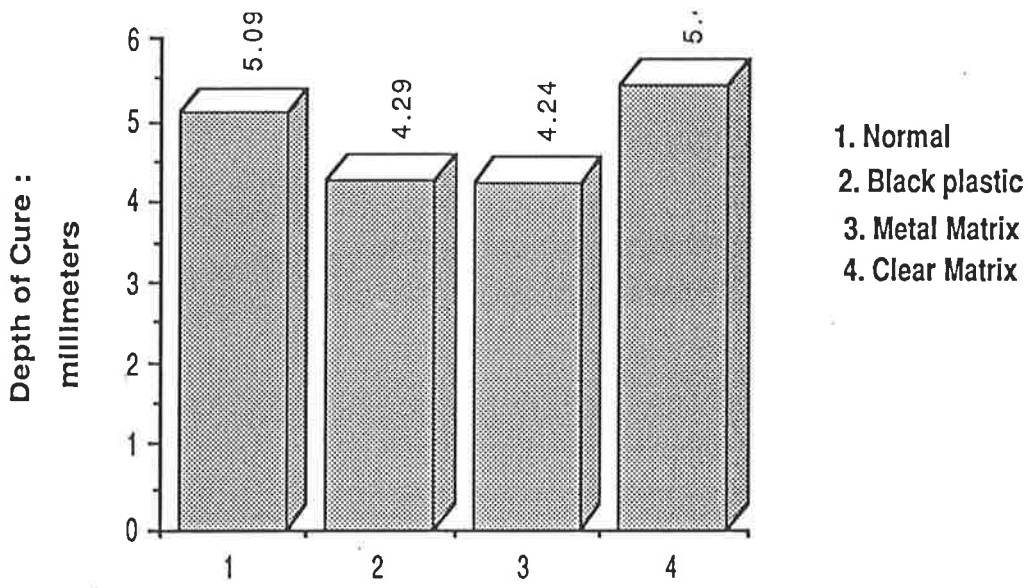

Depth of Cure :
millimeters
6
5
4
3
2
1
0
5.09
4.29
4.24
1
2
3
4
1. Normal
2. Black plastic
3. Metal Matrix
4. Clear Matrix

Figure 6.3.2.3. h.

Photograph of the in vitro interproximal surface of a specimen produced by the method shown in diagram 6.3.2.1.c and then scratch tested as shown in figure 6.3.2.1.d

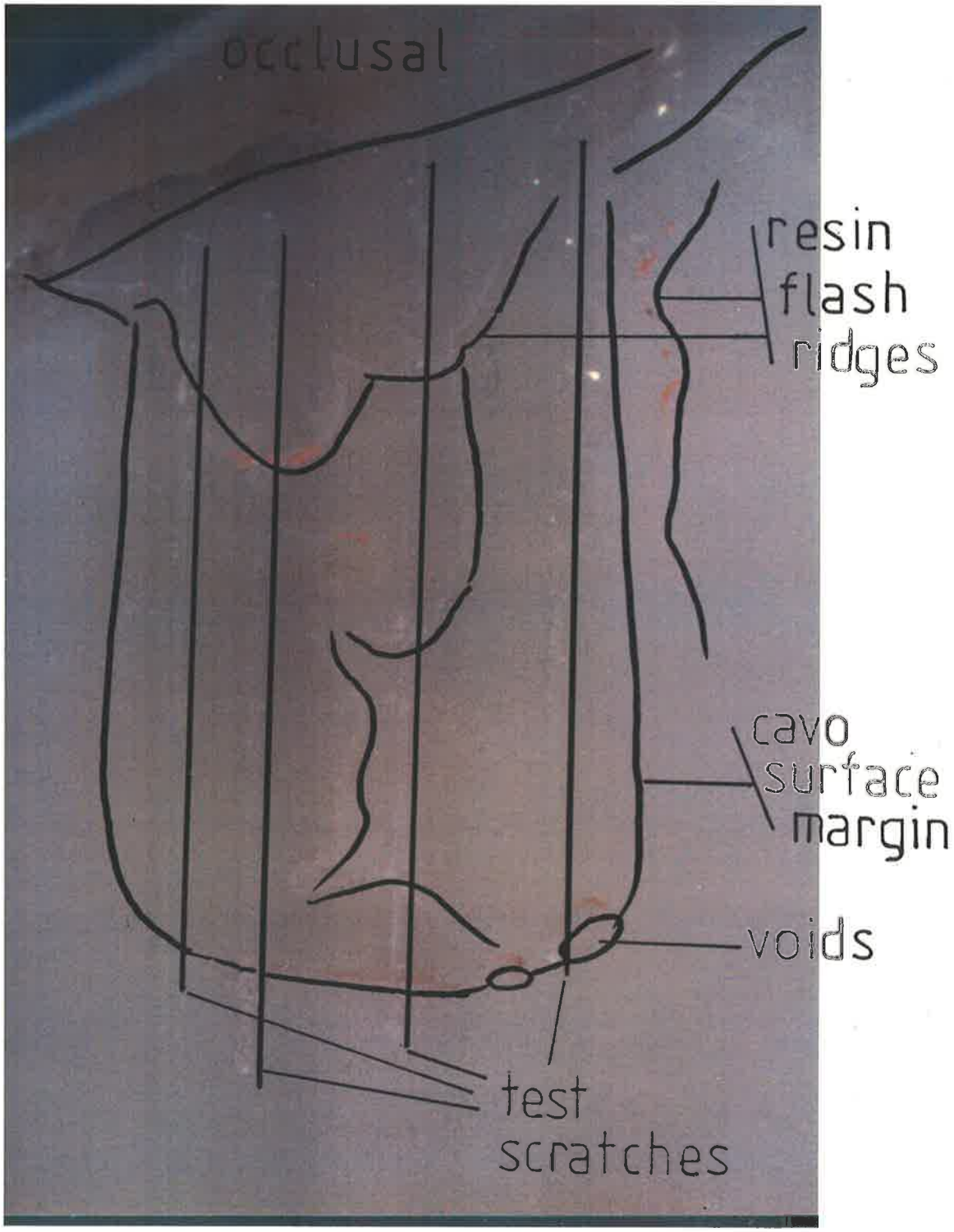
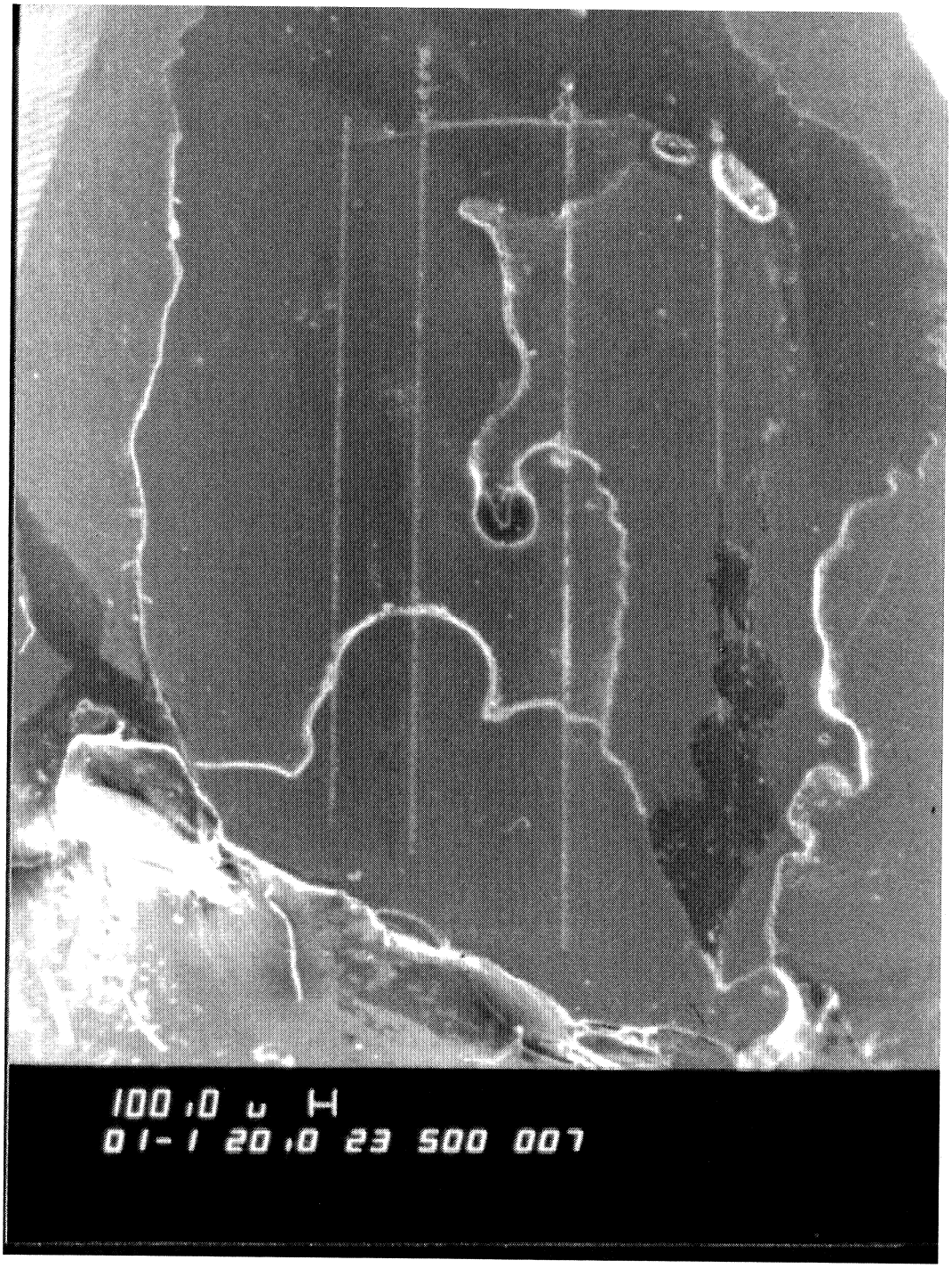

occlusal
resin
flash
ridges
cavo
surface
margin
voids
test
scratches
gingival

Figure 6.3.2.3. i.

S.E.M. Photomicrograph of the flat in vitro interproximal surface of a specimen produced by the method shown in diagram 6.3.2.1.c and then scratch tested as shown in figure 6.3.2.1.d


100,0 u H
01-1 20,0 23 500 007

6.3.2.4 RESULTS: LIGHT TRANSMITTING WEDGES

Following removal of the uncured resin, it is evident that the Luciwedge could have a significant effect on increasing the cure at the gingival margin for a Class II posterior composite due to the large amount of polymerisation at that point. Measurements were made at 0.5 mm intervals perpendicular to the axis of the wedge, as shown in diagram 6.3.2.4.b. The values are plotted in graph 6.3.2.4.a In general the resin closest to the light developes the greatest depth of cure, decreasing to form a triangular pattern towards the tip of the wedge where it has the least depth of cure. Using the scratch test it is easily seen that the quality of the cure shows the same degeneration when the specimens are tested by this method. The scratch begins to flare mid way down the sample, in this case the scratch has begun to flare half way across the wedge sample as can be seen in figure 6.3.2.4.c. The point from the surface of the wedge to the beginning of the flare of the scratch gives us an indication that the wedge itself can provide extra curing efficiency for the resin in the gingival floor region. As suggested earlier in section 6.2.3, this is the point which should be regarded as the depth of cure.

Graph 6.3.2.4.a

Graph representing the depth of cure measurements from the transmitting light wedge. The wedge forms the middle surface of the specimen, therefore the measurements are taken from one side to the other and halved, giving a left and a right side.

Graph 6.3.2.4.a

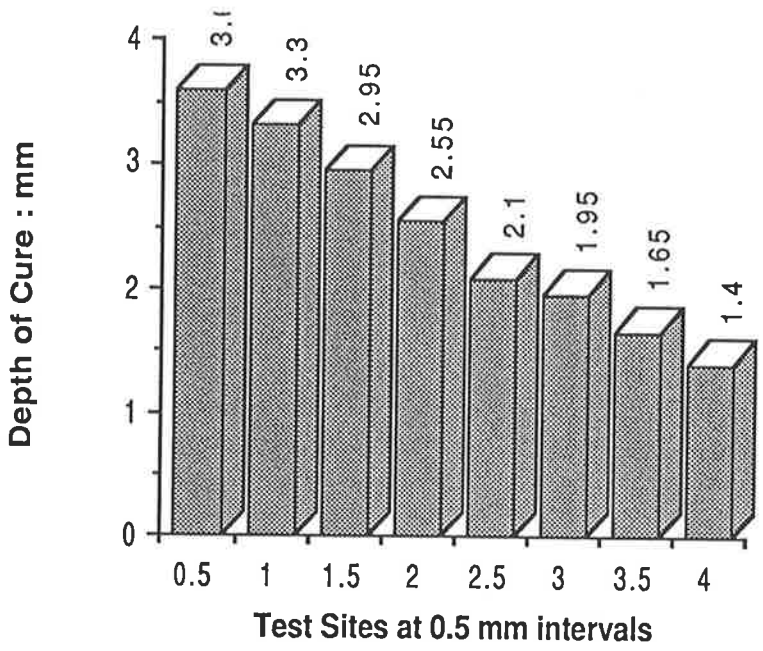

Depth of Cure : mm
4
3
2
1
0
3.3
2.95
2.55
2.1
1.95
1.65
1.4
0.5
1
1.5
2
2.5
3
3.5
4
Test Sites at 0.5 mm intervals

Figure 6.3.2.4.b

Diagram of the flat specimen of resin cured but light transmitted through the wedge only. The depth of cure was measured using the same method as in AS 1278-1982, where the uncured resin was simply scaped off and the distance calculated using a micrometer. In this case the midline of the wedge was used as the reference or zero point. In addition the specimen was scratch tested and the yellow lines with flared ends represent the result found. This correlates linearly with the scratch tests conducted in the split steel moulds.

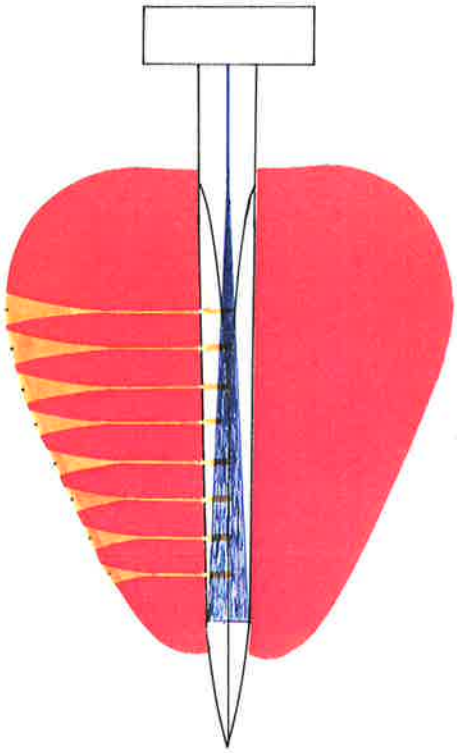
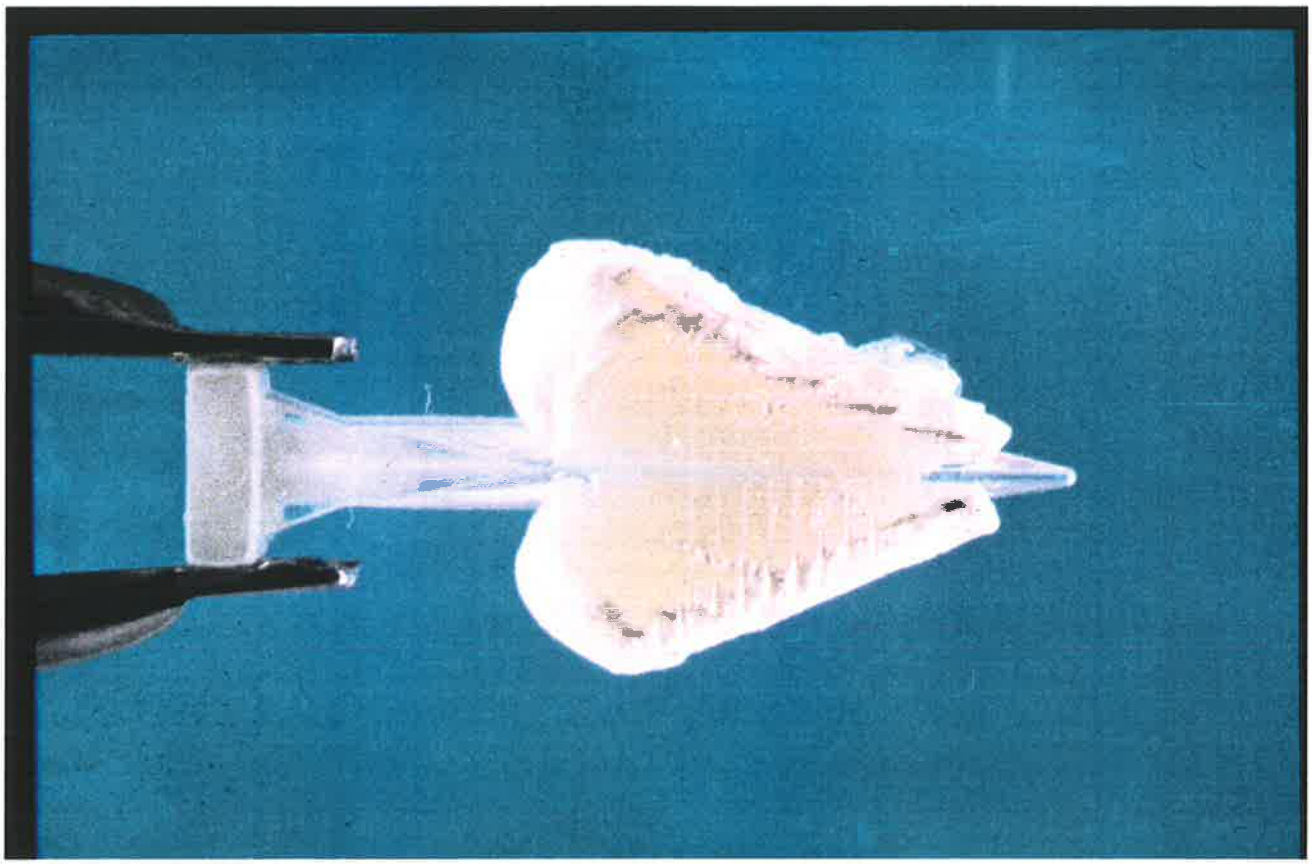


Figure 6.3.2.4.c

Photograph of the surface of a specimen of Herculite Syringeable cured against a steel block with 40 seconds irradiation onto the light transmitting wedge, i.e. where the only light allowed to cure the specimen was transmitted through the wedge.. The surface has been measured by micrometer and also scratch tested to give an indication of the effectiveness at the apex of the wedge, a point most likely to be near the gingival margin.



6.4 DISCUSSION:

Both the clear plastic matrix and the light transmitting wedge have shown significant increases in depth of cure in the difficult often shadowed proximal box region. As polymerisation contraction tends to develop by pulling uncured resin toward the light source, by using this method of light transmitting wedges, the contraction can be directed towards all cavo-surface margins, leaving the surface bond between the prepared tooth surface and the resin under the minimum tension. This will also help to reduce intercuspal stress due to polymerisation contraction. Microleakage and damage to the glass-iomoner dentinal bond on the floor of the proximal box can also be minimised. Final occlusal increments are too small to provide a distruptive force to the already established strong enamel bonds and bulk stable filling material of the earlier increments.

From the work of Fan et al., (1987) it would appear that the best time to measure Depth of Cure is at least 24 hours after irradiance. This information is in agreement with the results from chapter 5 where the level of opacity change after 24 hours was relatively little, provided that the irradiance time was a least 40 seconds.

6.5 CONCLUSIONS

The depth of cure value given for restorative resins is often misleading and should be replaced by a system such as the "Scratch Test". This test demonstrates the failure to achieve bond links by polymerisaton within the resin matrix at levels corresponding to 50 -60 % of the depth calculated according to AS 1278-1982.

The use of clear plastic matrices and light transmitting wedges should be used in Class II cavities to maximise the opportunity for stable inter-molecular resin matrix bonds near the cavo-surface margins, particularly in the proximal box.

CHAPTER 7. POROSITY

7.1 INTRODUCTION

The quality of placement of posterior composite resins has significant effects on the success of the restoration. The aim of this section is to note the types of porosities that are incorporated in the restoration. The study includes the influence of:

1. Vacuum packaging of the materials.
2. Incremental placement of resins.
3. Pins.
4. Line angles.
5. Effects of intrument placement.
6. Matrices.

7.2 MATERIALS AND METHODS.

7.2.1 VACUUM PACKAGING OF THE MATERIALS.

The posterior resins investigated in this section appear in table 7.2.1.a. below. These resins are vacuum packed and are often marketed as being free of porosity. This was tested by placing a small sample of material between two glass slides and pressing them together to produce a very wide and thin specimen. The increment was only about 3 cubic millimeters in volume and care was taken not to lift or slide the top glass slide once pressing out had started. The final thickness was guaged by placing a piece of 0.001" stainless steel matrix band either side of the specimen. The distance between the spacers was apprximately 10 mm.

To ensure that the glass slides did not bend under load, the pressure was applied using flat steel blocks, slightly larger than the glass slide. The steel blocks also prevented any backround light from causing premature polymerisation, which may have hindered a maximum achievable spread (diagram 7.2.1.b and figure 7.2.1.c). Following a period of approximately 3 minutes during which the spreading resin was allowed to stabilise, the specimens were cured for a period of 40 seconds using a VLC generator. This was to ensure that the sample was not damaged by any further handling.

However, the thickness of the top glass slide interfered with the focusing ability of the 40X phase contrast objective on a microscope[19] used to observe the sample. The specimens were then reproduced using standard glass cover slips, which enabled observation of the specimens using phase contrast objectives of both 10 and 40 times magnification.

Coupled with the 6 times photographic eyepiece final magnifications of 60 and 240 times were produced and photographed[20]. Porosity was assessed by visual presence.

---

[19]Wild M 20 Microscope; Wild - Leitz Co. Switzerland.

[20]Kodak Tungsten 160 film; Kodak (Australasia) Pty. Ltd., Melbourne Australia.

TABLE 7.2.1.a

RESINS TESTED FOR POROSITY INCLUSIONS DURING MANUFACTURE

HERCULITE SYRINGEABLE	KERR MFG
HERCULITE CONDENSIBLE	KERR MFG
HERCULITE XR DENTIN	KERR MFG
HERCULITE XR ENAMEL	KERR MFG
FULFIL	L.D.CAULK
SINTERFIL	GETZ
VISIOMOLAR	ESPE
ESTILUX POSTERIOR	KULZER
DISTALITE	JOHNSON & JOHNSON
P-30	3M
HELIOMOLAR	VIVADENT
ADAPTIC II	JOHNSON & JOHNSON
OCCLUSIN	ICI
LC 1000	SDI

A COMPLETE LIST WITH ADDRESSES APPEARS IN APPENDIX B

Figure 7.2.1.b

The compressed and exploded views of the apparatus used to produce thin sections of composite resin for the study of porosity inclusions incurred during manufacture.

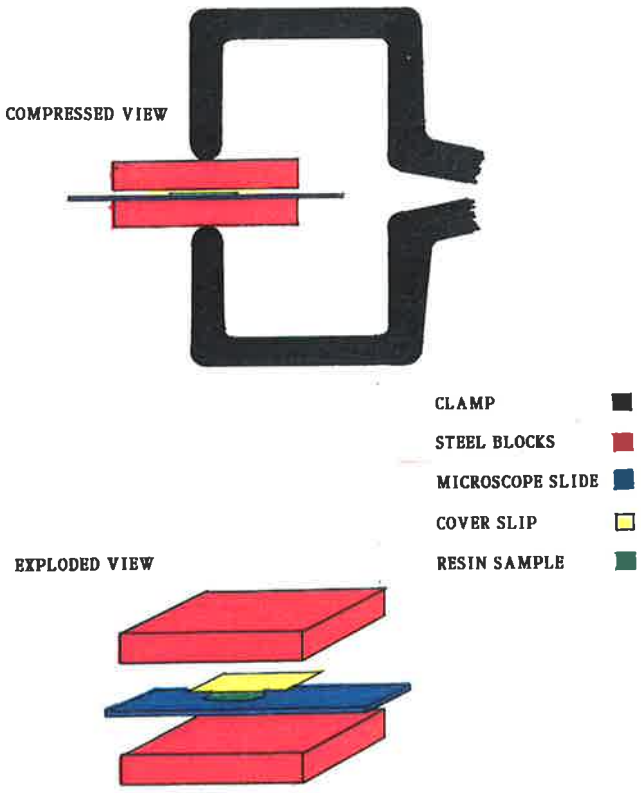
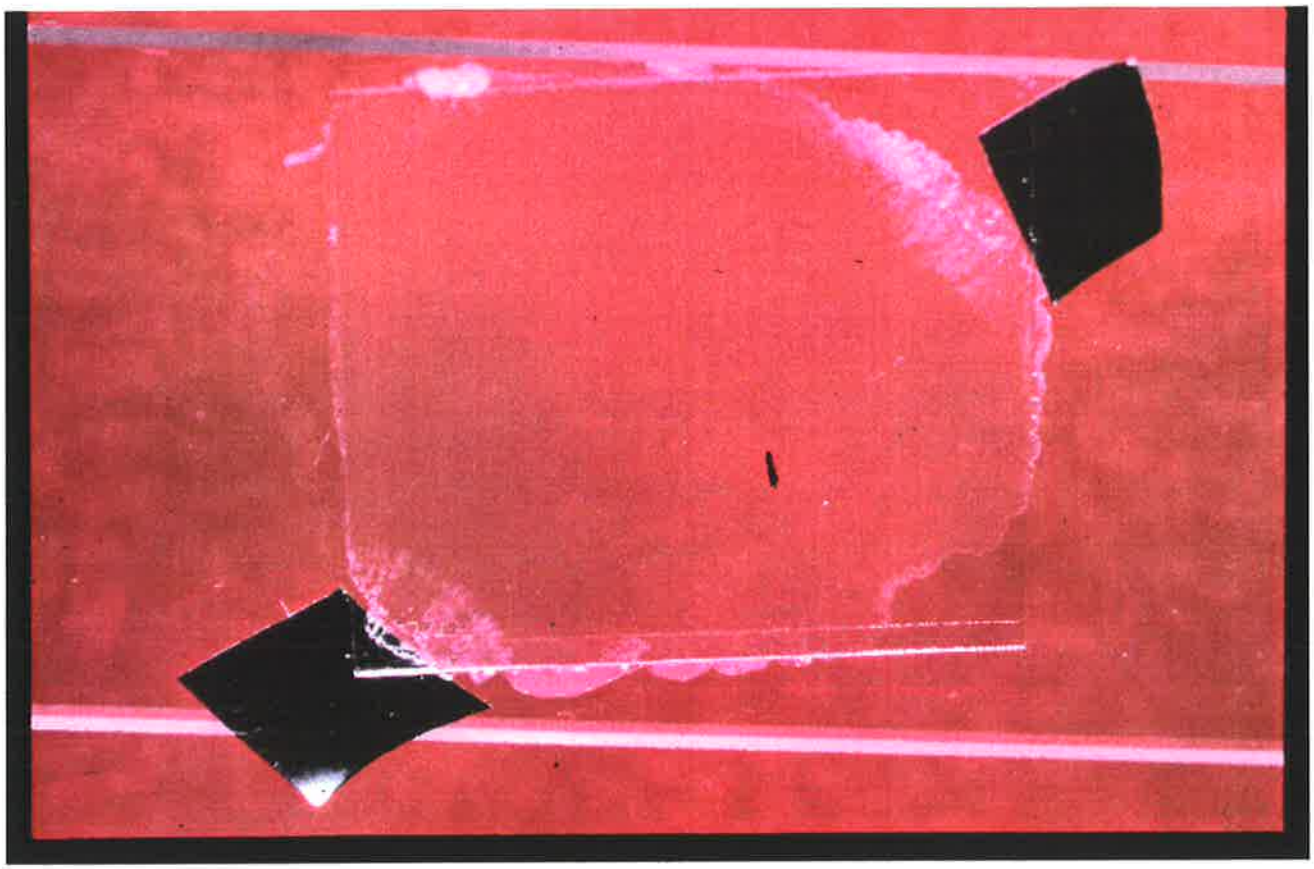

COMPRESSED VIEW
CLAMP
STEEL BLOCKS
MICROSCOPE SLIDE
COVER SLIP
RESIN SAMPLE
EXPLODED VIEW

Figure 7.2.1.c

Photograph of the very thin section produced to observe the presence of porosities in vacuum packed posterior resin restoratives.



7.2.2 INCREMENTAL PLACEMENT OF RESINS.

The placement of resin increments with direct syringing and hand instruments is described in Chapter 9. The material used was Herculite Syringeable which was syringed directly into the proximal box of a conservative class II cavity preparation cut in an extracted premolar, according to that method. The placement involved three increments, the first two oblique/vertical and the final occlusal, each with its own 40 second cure. Final packing and manipulation prior to curing was performed with a small plastic instrument.

The teeth were then ground on flat wet carborundum abrasive paper to produce a thin section in the B-L axial plane. These were then examined and the increment lines photographed, an example of which is seen in figure 7.3.4.b

7.2.3 PINS.

The third consideration was the placement of two Bondent[21] pins in the proximal box of the cavity, to provide extra resistance to the volumetric contraction of the resin which often produces a contraction gap at the gingival margin.

The pins were placed according to the manufacturer's instructions. Resin increments were placed around them, making sure that the pin was covered and cured in the same manner as described in section 7.2.2. The sample was then hand ground on wet carborundum paper to cut the proximal box back in a bucco-lingual plane parallel to the long axis of the tooth. This continued until the pins were readily observed, see diagrams 7.2.3.a, b, c and d, in association with figure 7.2.3.e.

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[21] Bondent pins; Whaledent International, 236 Fifth Ave., N.Y., N.Y. 10001 U.S.A.

Figure 7.2.3.a

Occlusal view of specimen before grinding back.

Figure 7.2.3.b

Occlusal view of specimen after grinding back, with red representing the remains of the pins.

Figure 7.2.3.c

Buccal view of specimen after grinding back, with red representing the remains of the pins.

Figure 7.2.3.d

Mesial view of specimen after grinding back, with red representing the remains of the pins.

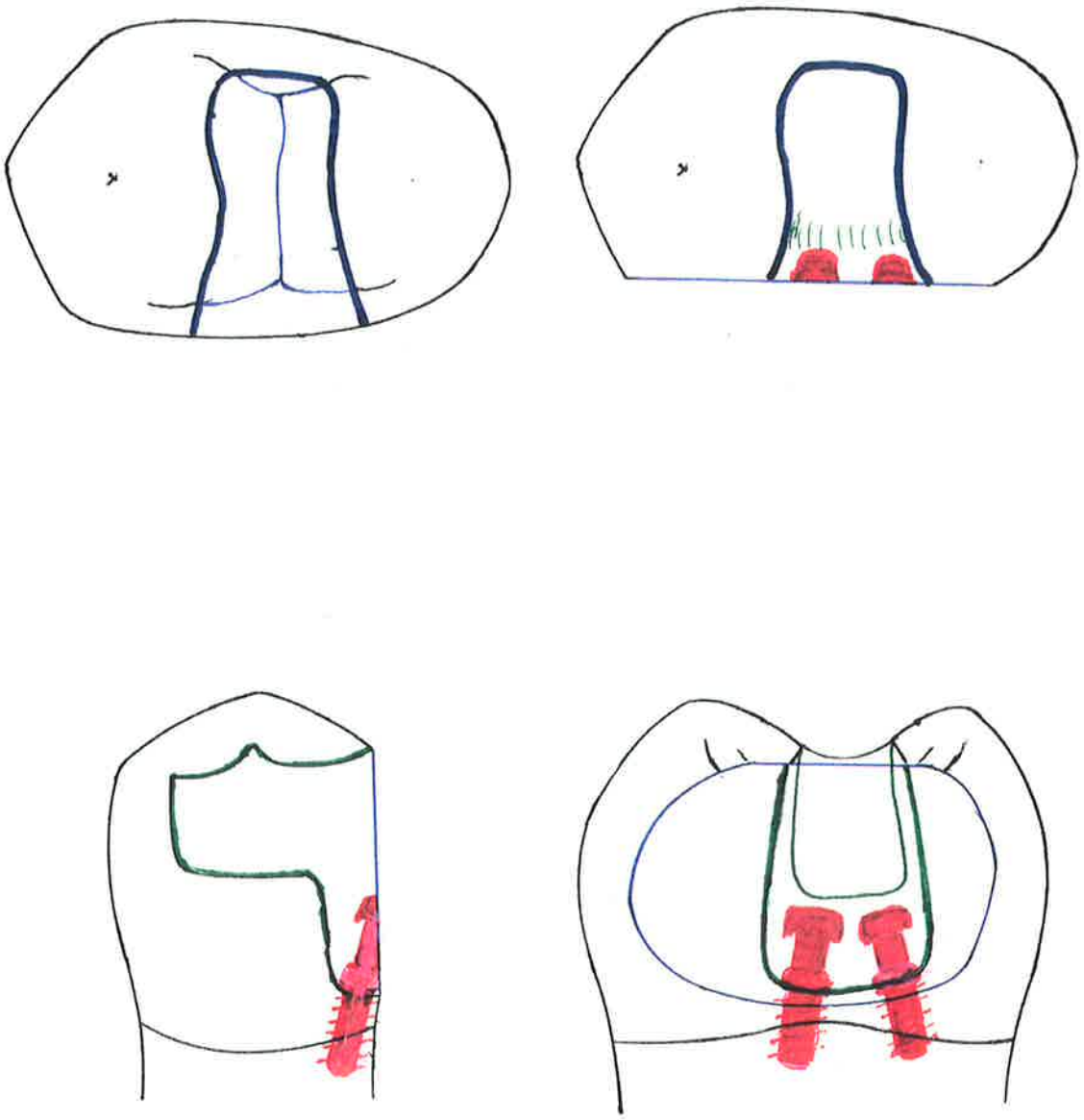
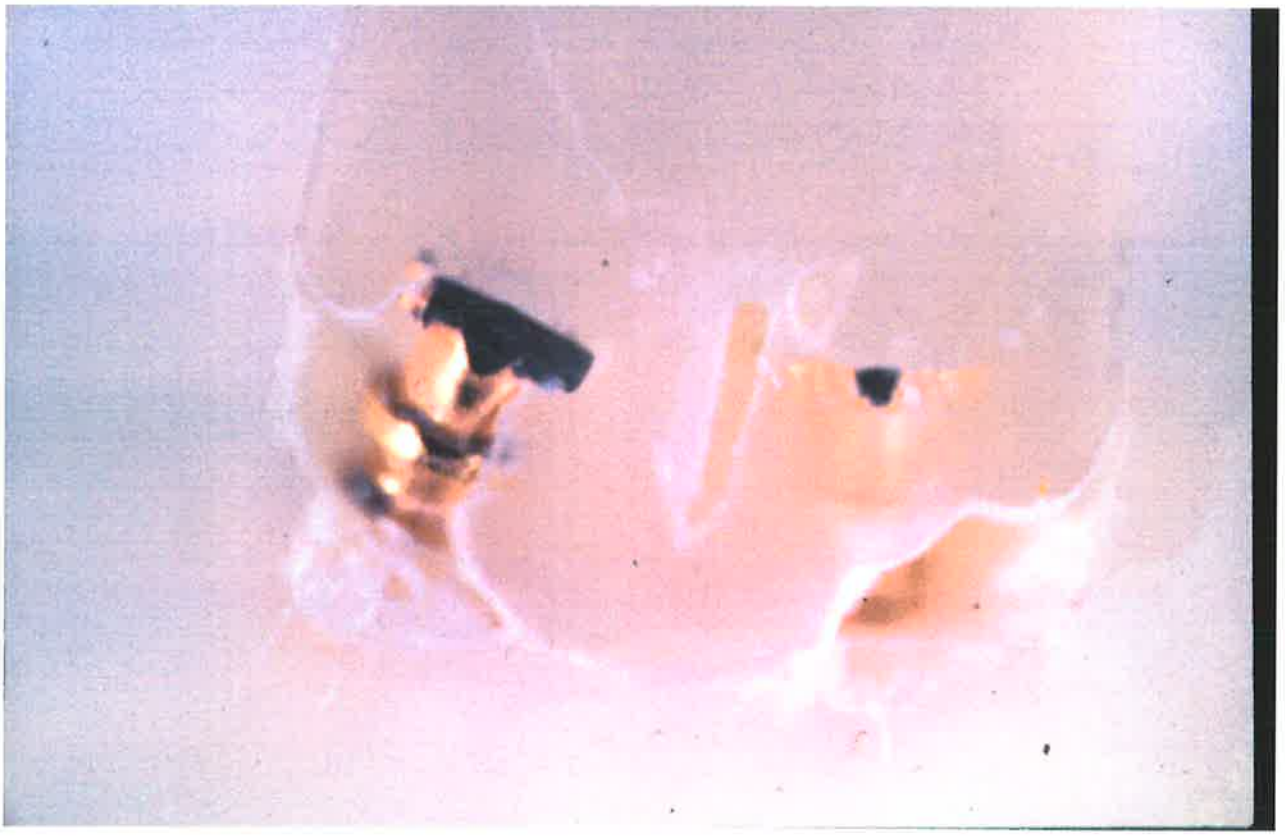


Figure 7.2.3.e

Photograph of the exposed pins and voids after the specimen was hand ground on a flat grinding surface with carborundum paper to a final grit of 1200.

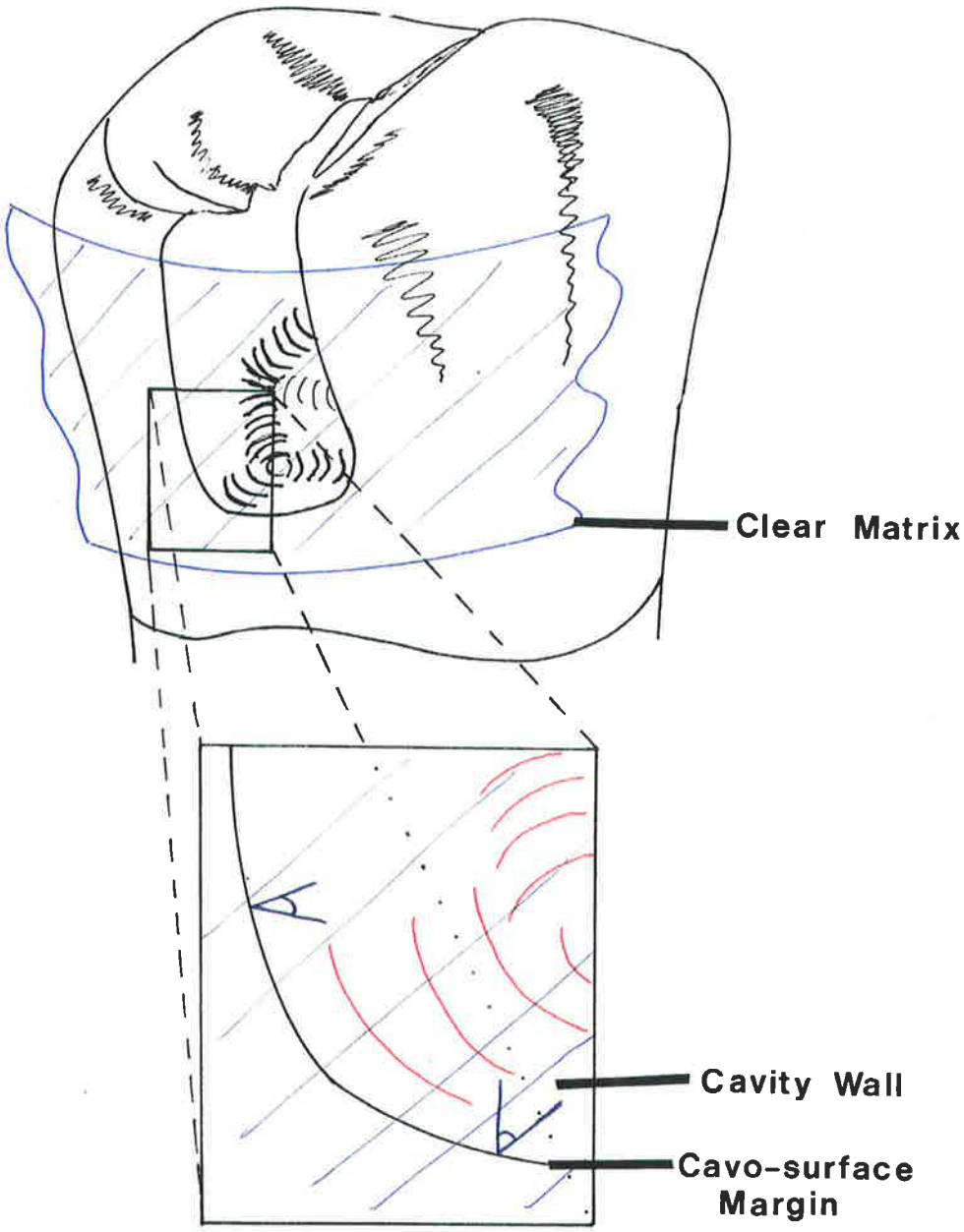


7.2.4 LINE ANGLES

The presence of porosity in the line angles was observed using the same method as described in section7.2.2. but with the omission of the pins. The temporary line angle formed between the matrix band and the gingival floor and axial walls, as seen in figure 7.2.4.a, was also included for observation as this is potentially very important for microleakage.

Figure 7.2.4.a

Diagram of the temporary line angle formed between the cavo-surface margin and the matrix band. The clear matrix is outlined in blue with a few blue streaks, the rounded internal line angle are shown in red, the tooth is outlined in black and the two angle representations are to high-light the temporary line angle.


Clear Matrix
Cavity Wall
Cavo-surface Margin

7.2.5 EFFECTS OF INSTRUMENT PLACEMENT.

Instruments used to place resins have three major effects in their method of use which influences the degree of porosity in the resin increment, particularly at the surface. A group of seven resins was investigated, (table 7.2.5.a).

TABLE 7.2.5.a

RESINS OBSERVED BY S.E.M. FOR POROSITY FOLLOWING INSTRUMENTATION

HERCULITE SYRINGEABLE	KERR MFG
OCCLUSIN	ICI
HELIOMOLAR	VIVADENT
SINTERFIL	GETZ
HERCULITE CONDENSIBLE	KERR MFG
DISTALITE	JOHNSON & JOHNSON
VISIOMOLAR	ESPE

The three effects were the effect of pushing down on the resin with a Teflon coated plugger with a flat end diameter of 1 mm, secondly, the result produced by lifting an instrument away from the resin, and finally, the effect of cutting an increment of resin from the delivery tube with a small plastic instrument.

The influence of instruments on porosity was investigated with the aid of the Scanning Electron Microscope.

A second group of resins was tested and observed under polarised dark field microscopy and macro photography. The list of resins appears below in table 7.2.5.b

TABLE 7.2.5.b

RESINS OBSERVED BY POLARIZED DARK FIELD MICROSCOPY AND MACROPHOTOGRAPHY

FOR POROSITY FOLLOWING INSTRUMENTATION

TABLE 7.2.5.b

HERCULITE SYRINGEABLE	KERR MFG
HERCULITE CONDENSIBLE	KERR MFG
HERCULITE XR DENTIN	KERR MFG
HERCULITE XR ENAMEL	KERR MFG
FULFIL	L.D.CAULK
SINTERFIL	GETZ
VISIOMOLAR	ESPE
P-30	3M
ESTILUX POSTERIOR	KULZER
ADAPTIC II	JOHNSON & JOHNSON
DISTALITE	JOHNSON & JOHNSON
OCCLUSIN	ICI
HELIOMOLAR	VIVADENT
LC 1000	SDI

A COMPLETE LIST INCLUDING ADDRESSES APPEARS IN APPENDIX B

All these resins were tested for response to:

1. Being patted down by an instrument. See figure 7.2.5.c.
2. Being cut by an instrument i.e. a plastic instrument. See figure 7.2.5.d.
3. Having a stilletto instrument pushed into them. See figure 7.2.5.e.

Figure 7.2.5.c.

Diagram of the method for patting down resin with a flat ended plugger, diameter 1mm. The plugger was pushed down and then lifted off repeatedly to give a surface that looked stamped. The specimen was then cured for 40 seconds, photographed and prepared for the scanning electron microscope.

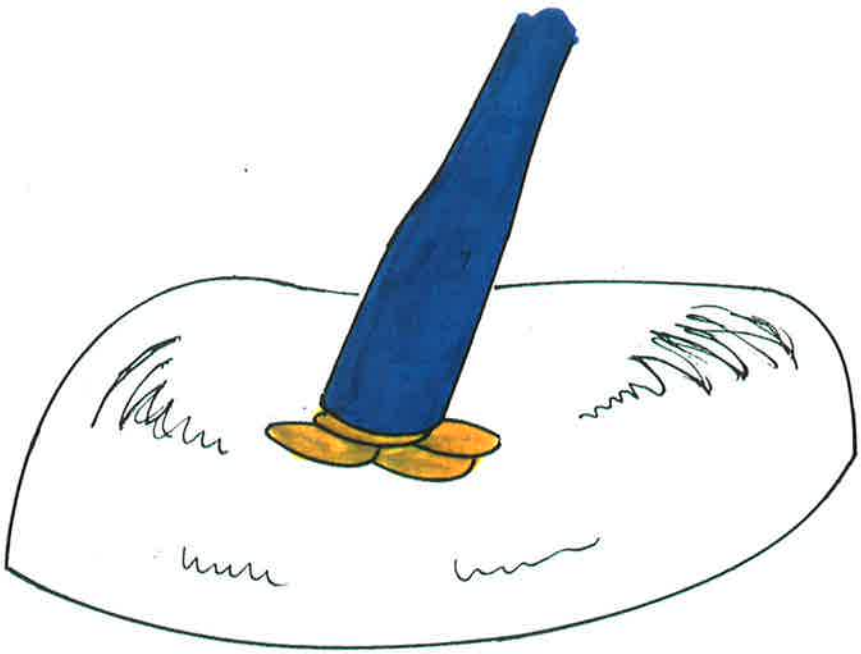


Figure 7.2.5.d.

Diagram of the method for cutting the resin increment from the delivery tube with a plastic instrument. The edge of the plastic was pushed through the stream of resin using a knife like action. The specimen was then cured for 40 seconds and photographed.

Figure 7.2.5.d.

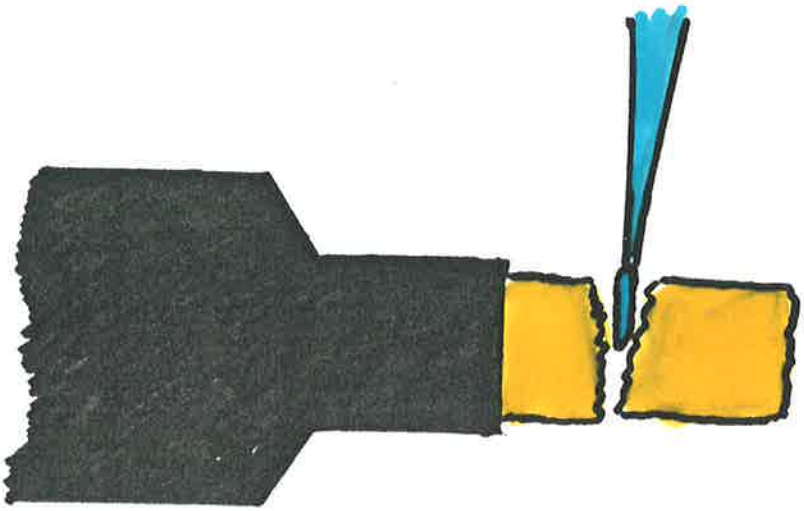
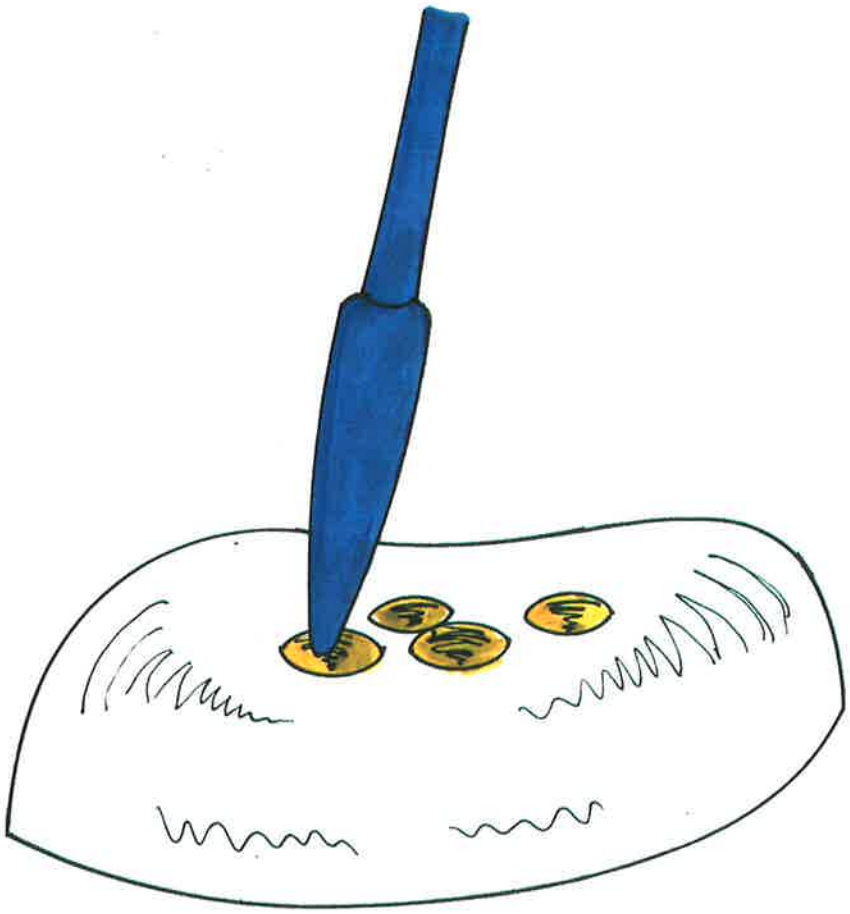


Figure 7.2.5.e.

Diagram of the method for pushing a stilletto type of instrument into the resin to manipulate the material into the cavity. The specimen was then cured for 40 seconds and photographed.



7.2.6 MATRICES.

Resin specimens were produced in the same flat discs as used for the opacity test. The specimens were then observed by transmission light microscopy for the presence of porosity. These porosities were best observed using a phase contrast objective.

Other specimens were produced in Class II cavities in freshly extracted third molars. The teeth were then embedded in embedding resin[22]. These were then sectioned at right angles to the interproximal surface in the mesio-distal plane. The presence of porosity at the resin surface observed with dark field microscopy and photographed at 240 times magnification.

[22]Biopot Embedding resin: Bond Plastics Pty., Ltd., 45 Phillips Street, Thebarton, South Australia 5031.

7.3 RESULTS.

7.3.1 VACUUM PACKAGING OF MATERIALS.

All resin specimens tested exhibited sub-micron porosity on packing when tested by this method. However, it was noted that a large void could occur in the resin tube during loading, but this seemed only to have the effect of producing separate increments, i.e. the flow of resin was merely broken and a concentration of larger bubbles appeared . Sub-micron porosity only appeared in the body of resin either side of the break. See figures 7.3.1.a&b for examples .

7.3.2 INCREMENTAL PLACEMENT OF RESINS.

The Class II B-L sections through the proximal box, exhibited fine grey lines which corresponded with the increment lines. On further examination with polarized phase contrast microscopy these proved to contain porosities, (figure 7.3.4.b). When the results of instrument manipulation are observed, these results are more easily understood.

7.3.3 PINS.

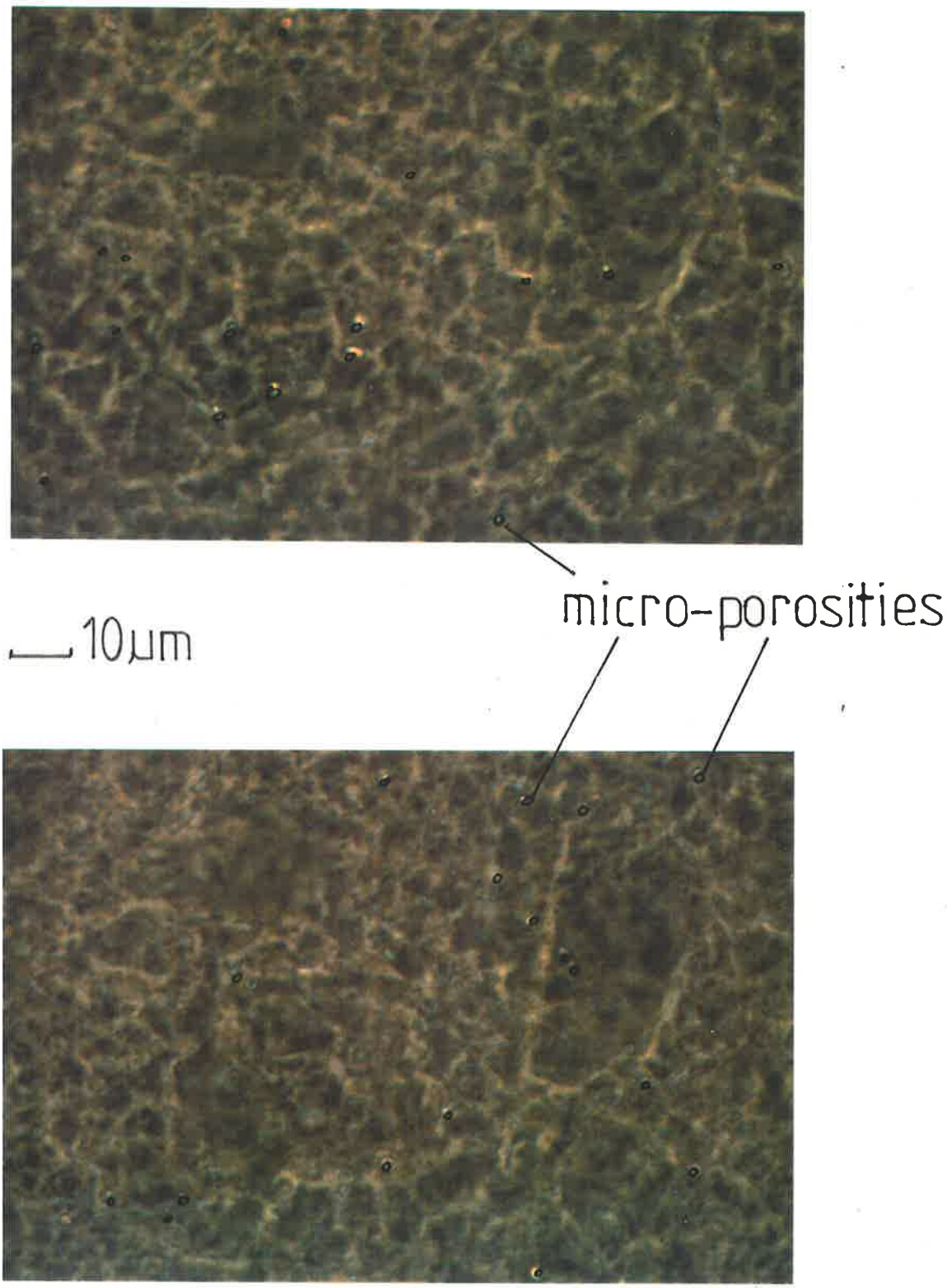
The presence of pins often proved a difficulty for the adaptation of the densely filled resins. Large porosities or voids were found to occur where the resin had to negotiate sharp corners etc. on the pins, (figure 7.2.3.e).

Figure 7.3.1.a, top.

Sub-micron porosity in a vacuum packed resin. The porosities were photographed using phase contrast microscopy at a magnification of 420 times.

Figure 7.3.1.b, bottom.

Sub-micron porosity in a vacuum packed resin. This is the same view as the photograph above, except that the plane of focus was shifted approximately 1 µm down into the specimen. The magnification is the same.


micro-porosities
10µm

7.3.4 LINE ANGLES.

The most significant void to occur in this situation was at the relatively sharp artificial line angle produced by the matrix and the gingival floor. This sharp line angle occurs in a difficult region where easy manipulation of the resin is not always possible. See fig. 7.3.4.a. Rounded line angles within the body of the cavity did not tend to produce porosity and voids. Figure 7.3.4.b shows microporosity at the intersection of the axial walls of the proximal box and the matrix strip.

Figure 7.3.4.a

Porosity at the artificial line angle produced at the intersection of the gingival floor and the matrix strip. Magnification : X80.

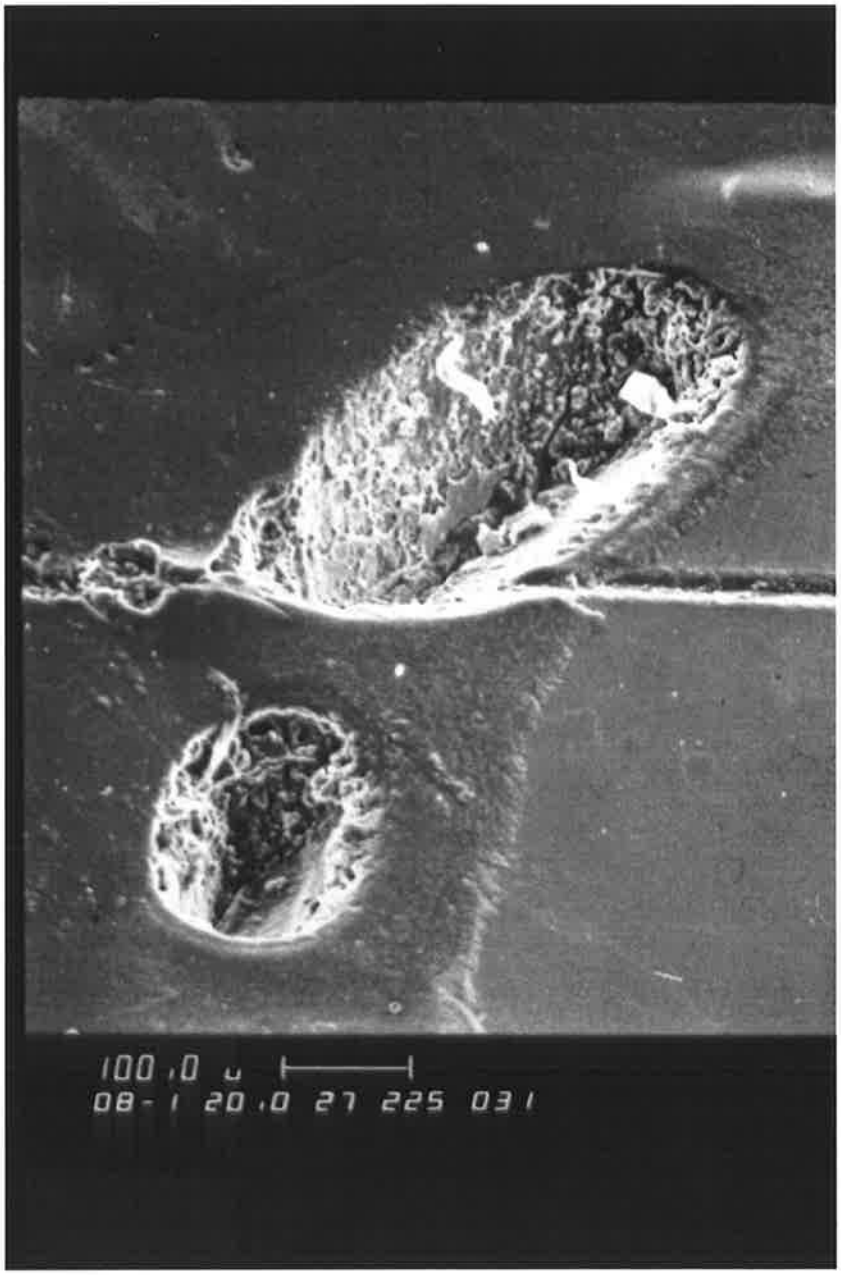
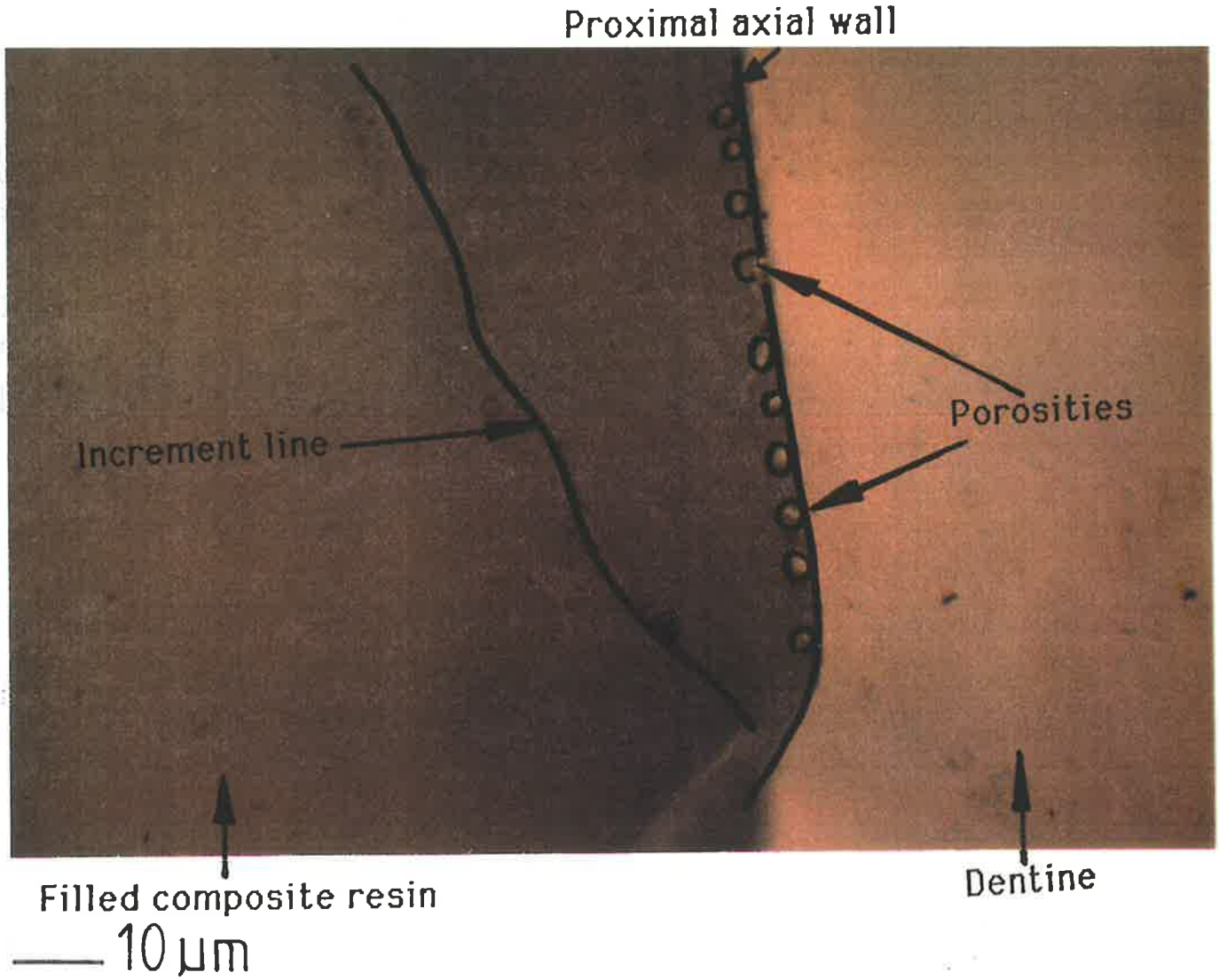

100.0 u
08-1 20.0 27 225 031

Figure 7.3.4.b

Microporosity seen at the intersection of the axial walls of the proximal box and the matrix strip and along the incremental line. Magnification : X40.


Proximal axial wall
Increment line
Porosities
Filled composite resin
Dentine
10 µm

7.3.5 EFFECTS OF INSTRUMENT PLACEMENT.

7.3.5.1 PUSHING DOWN ON THE RESIN

All resins produced some change to surface topography when manipulated in this manner. The sticky resins, which tended to be those with lower filler content, showed the greatest changes, with rebound dragging the resin mass up in a conical fashion from the original blob, (figure 7.3.5.1.a). Other resins that did not rebound, were simply left with ridges from the packer edges, (figure 7.3.5.1.b). At the microscopic level, the sticky resins appeared to leave longer tags than the highly filled resins, (figures 7.3.5.1.c & d). Pushing into the resin with a stiletto shaped instrument produced the worst voids, particularly in the more highly filled resins, (figures 7.3.5.1.e & f).

7.3.5.2 LIFTING AN INSTRUMENT OFF THE RESIN

When the instrument is removed from the surface, resin tags are dragged up with it. These tags then either collapse and entrap air, or remain only to become permanent as the resin is set. When the next increment is placed over these tags, air spaces are permanently incorporated in the resin.

S.E.M. photographs of different resins manipulated in this way with the same instrument demonstrate vastly different results. Those resins which demonstrate the least amont of tackiness present the least amount of tags and air spaces, (figures 7.3.5.2.a-d).

7.3.5.3 CUTTING THE RESIN WITH A PLASTIC

The cut surface tends to give a wavy appearance in most cases, the exceptions being those systems directly injected into the cavity. When these surfaces are examined under both light and scanning electron microscopy, the waves tend to give a curled over appearance with air spaces underneath, (diagram 7.3.5.3.a and figures 7.3.5.3.b & c).

Figure 7.3.5.1.a

Conical shaped sample of a sticky resin after the instrument had been pushed down and then lifted off. This is the same brand of material that appears in figure 7.3.5.1.c where it shows a high degree of slumping and easy glossing. Magnification : X20.

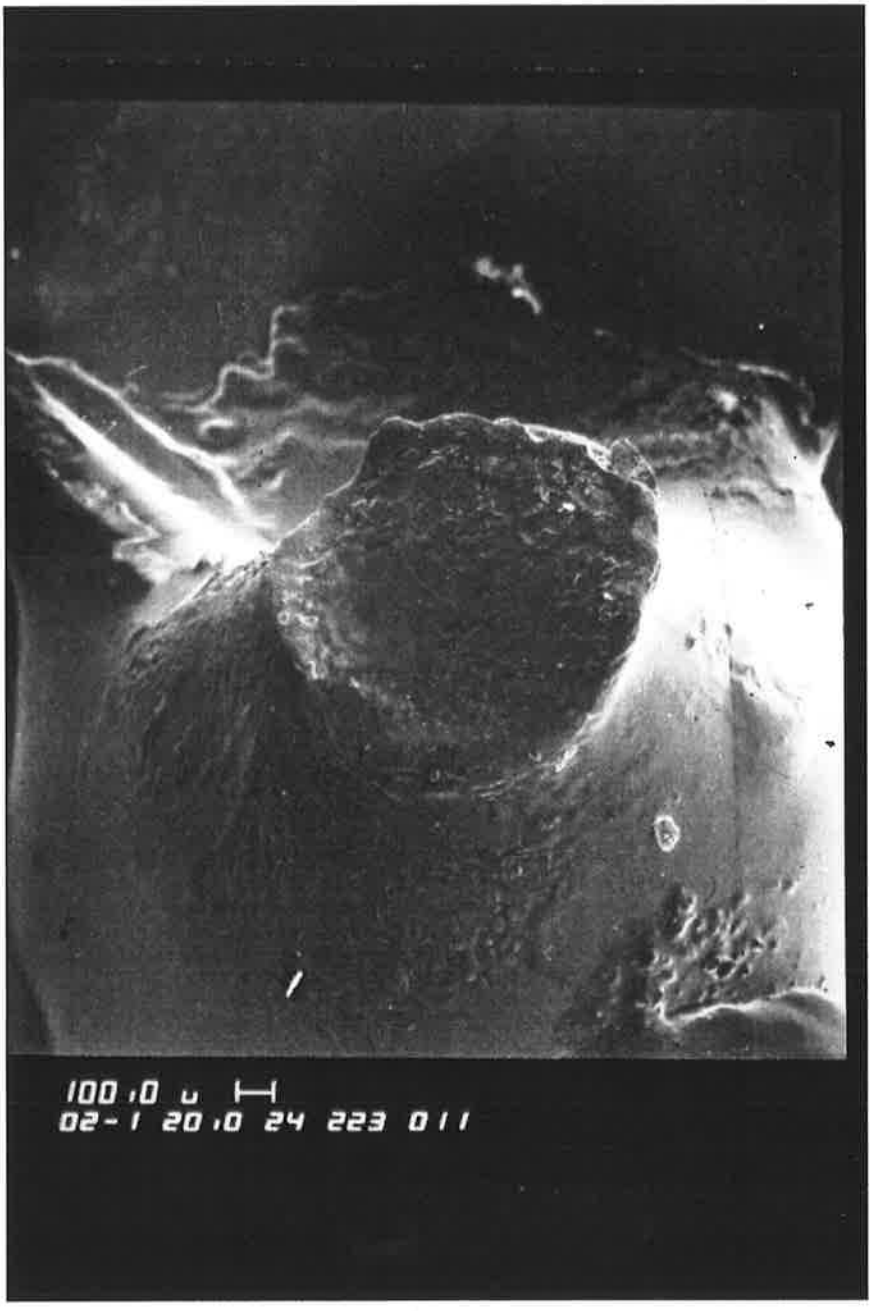

100.0 u H
02-1 20.0 24 223 011

Figure 7.3.5.1.b

Ridges left after pressing down on a highly filled resin.

Top: Magnification : X20.

Bottom: Magnification : X200.


500 E22 02 0'02 1-20
100.0 n

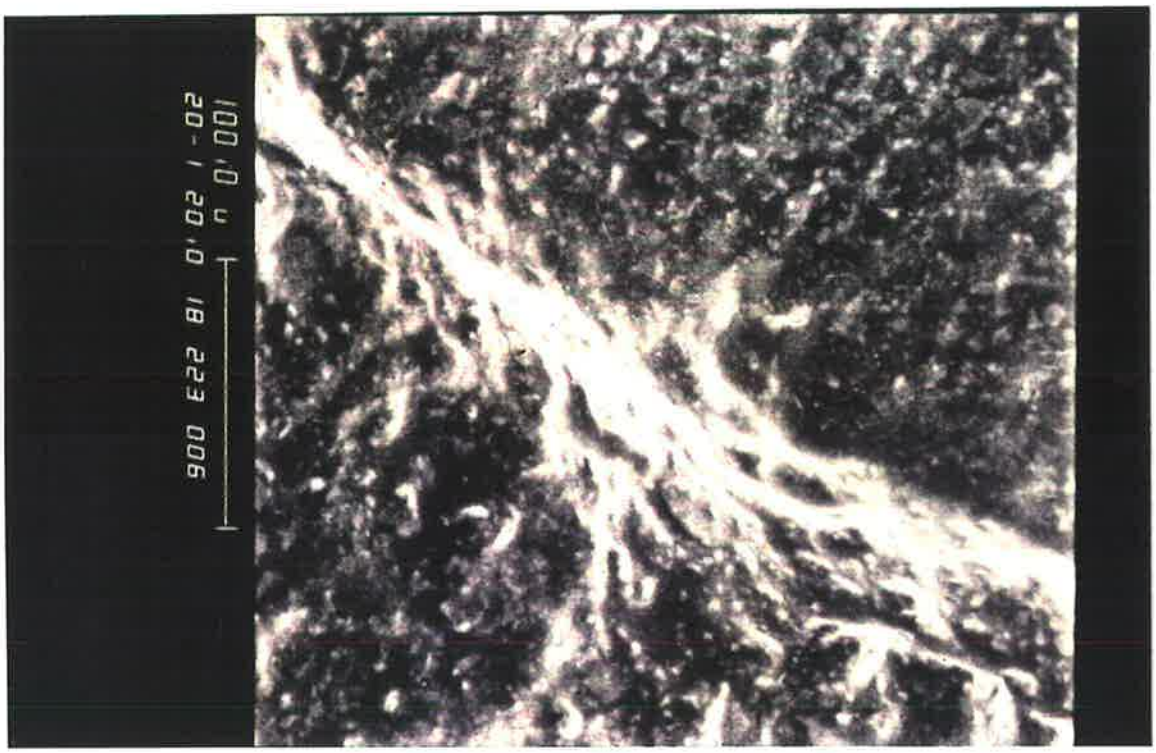

900 E22 81 0'02 1-02
100.0 n

Figure 7.3.5.1.c

Microscopic view of long resin tags in a less highly filled posterior resin following condensation by a flat instrument. Magnification : X200.

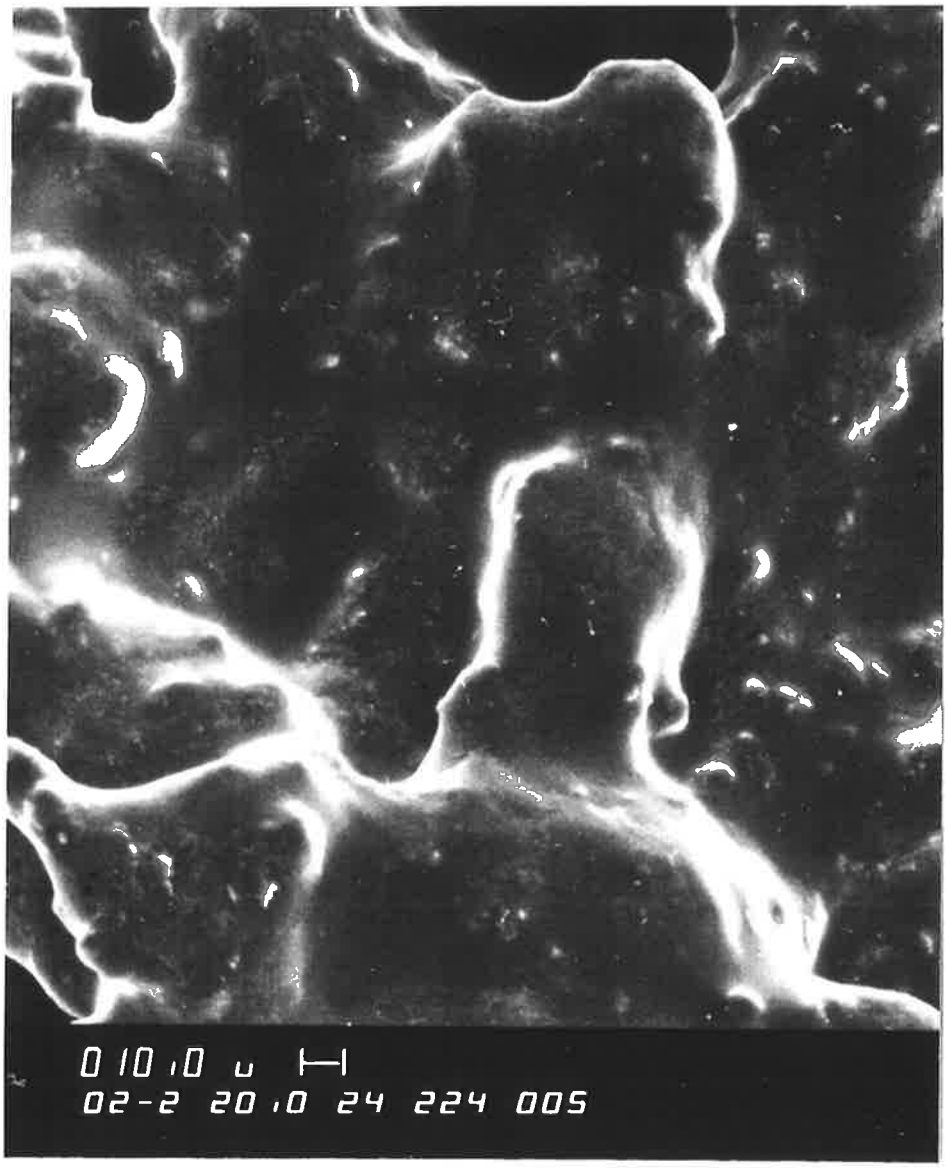

010.0 u H
02-2 20.0 24 224 005

Figure 7.3.5.1.d

Microscopic view of short resin tags in a highly filled resin after condensation by the same flat instrument. Filler particles can also be more easily distinguished in these highly filled resins. Magnification : X200.

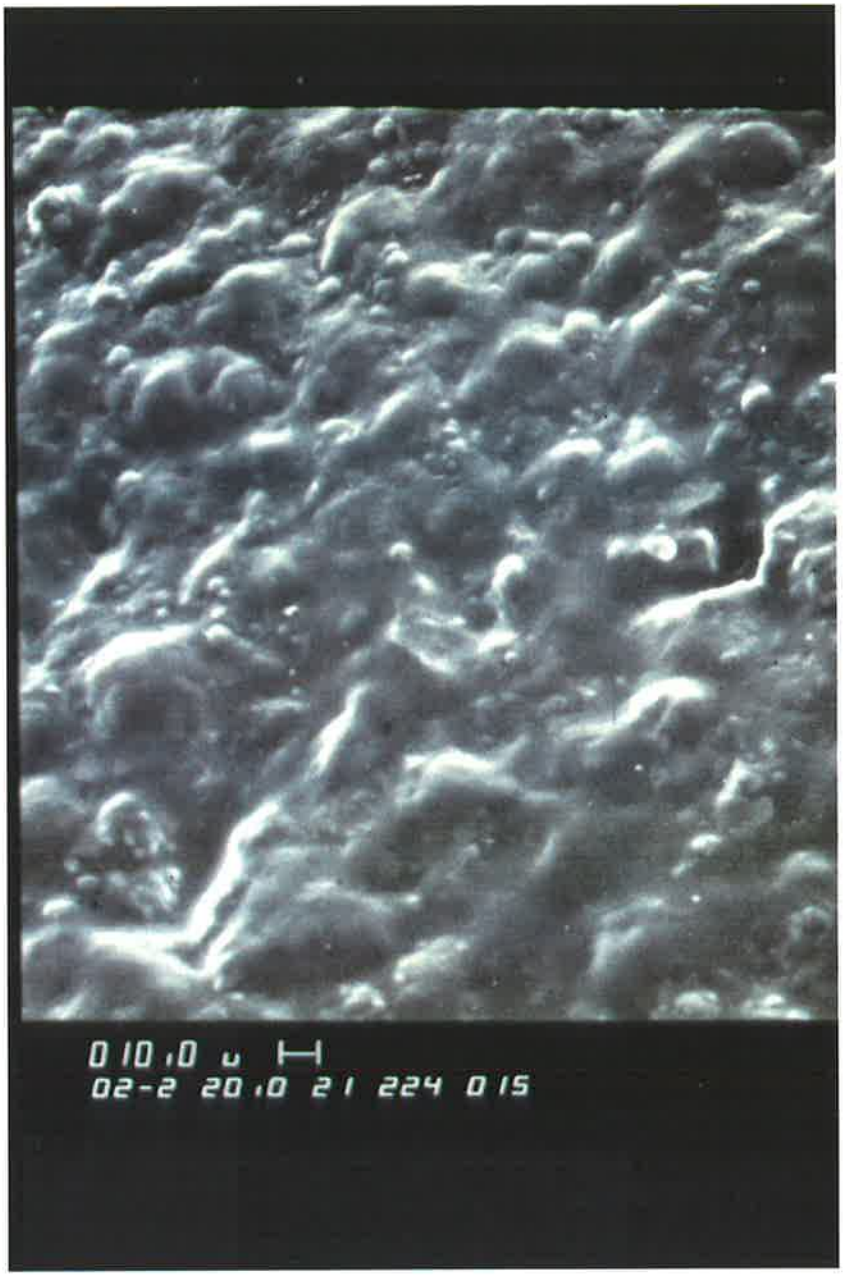

010.0 u H
02-2 20.0 21 224 015

Figure 7.3.5.1.e

Stiletto marks in a less highly filled resin. The marks are barely distinguishable, because this resin tends to gloss over or slump very quickly before it can be cured. The material was cured for 40 seconds, with as little delay as possible between manipulation with the stiletto instrument and applying the curing light.

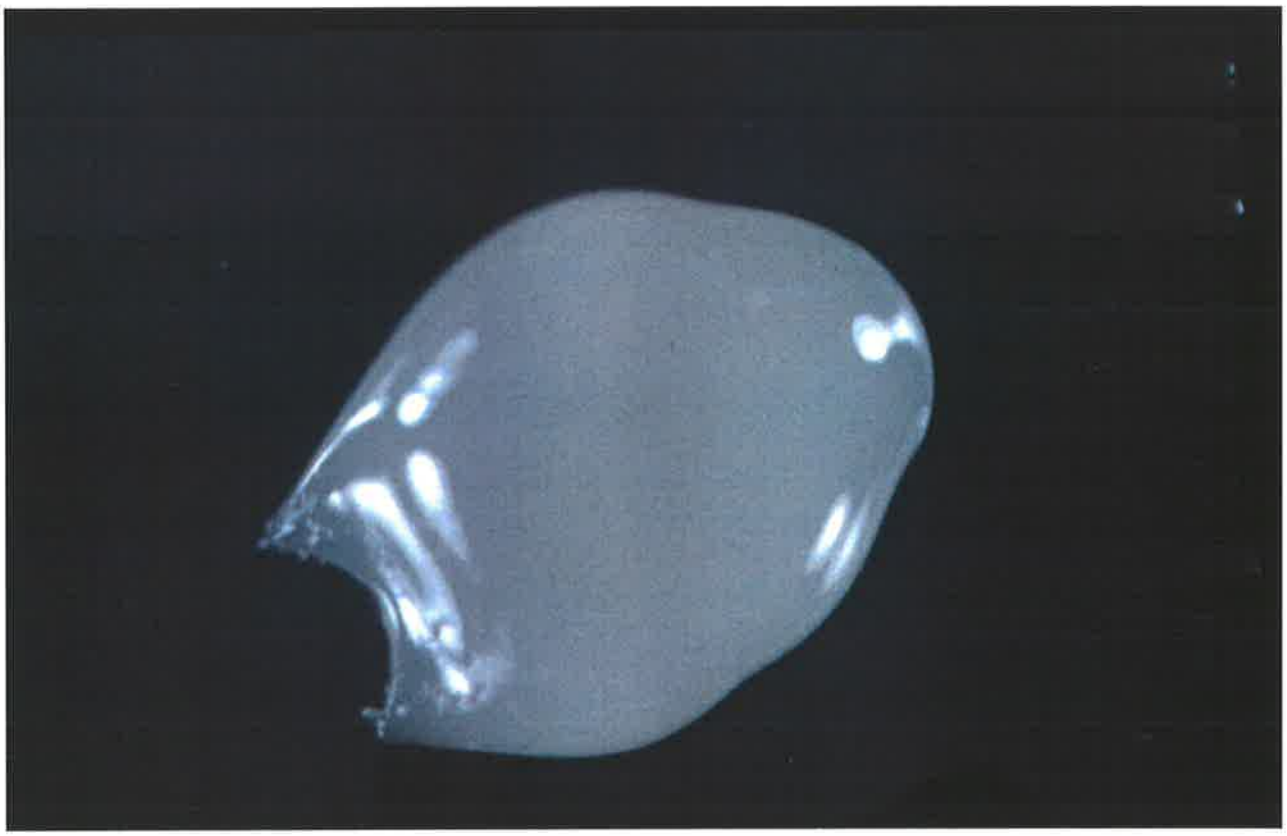


Figure 7.3.5.1.f

Stiletto marks in a highly filled resin from the packing instrument. This material does not gloss over due to its stiffness and resistance to slumping. Again this material was also cured for 40 seconds after manipulation prior to being photographed.

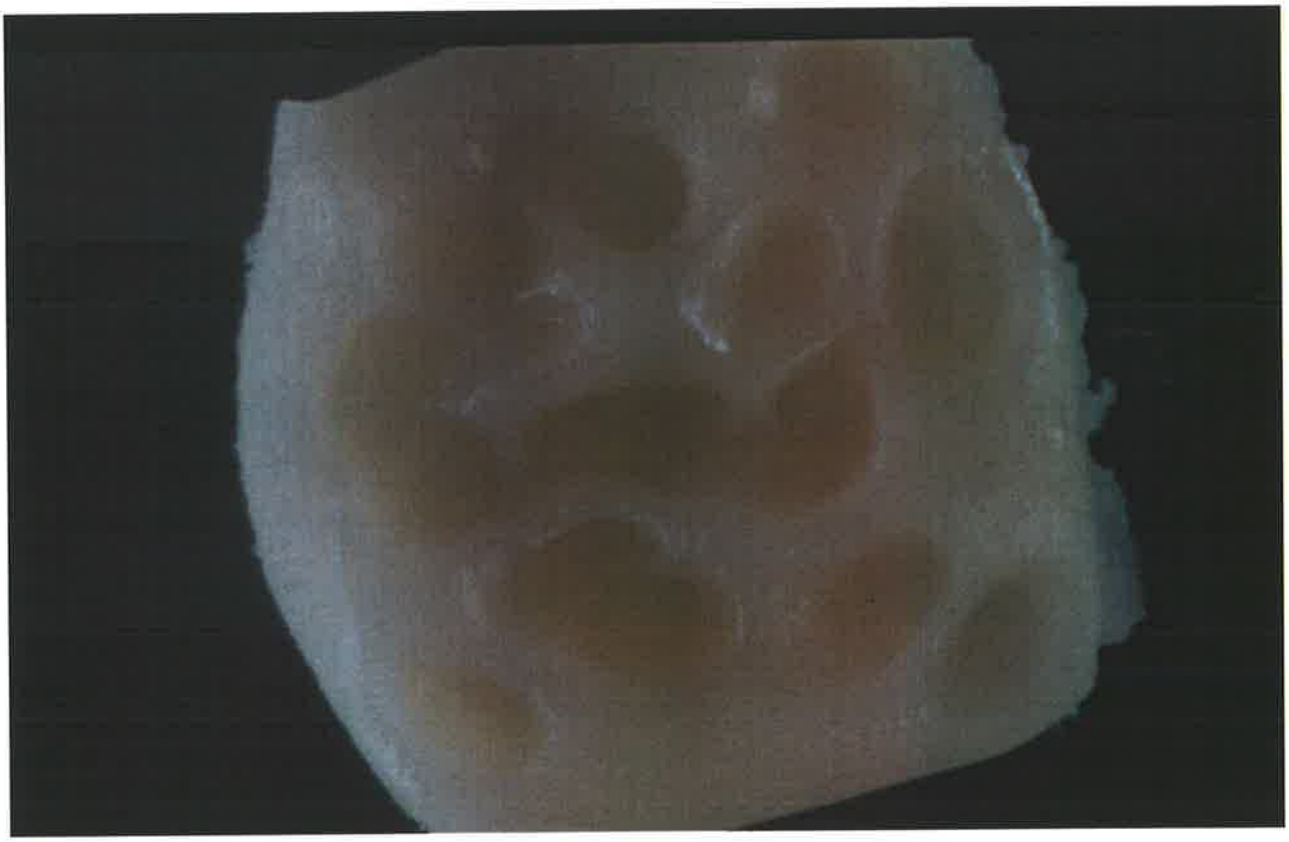


Figure 7.3.5.2.a

S.E.M. micrograph of a very sticky resin surface following removal of an instrument. (Magnification : X 70).

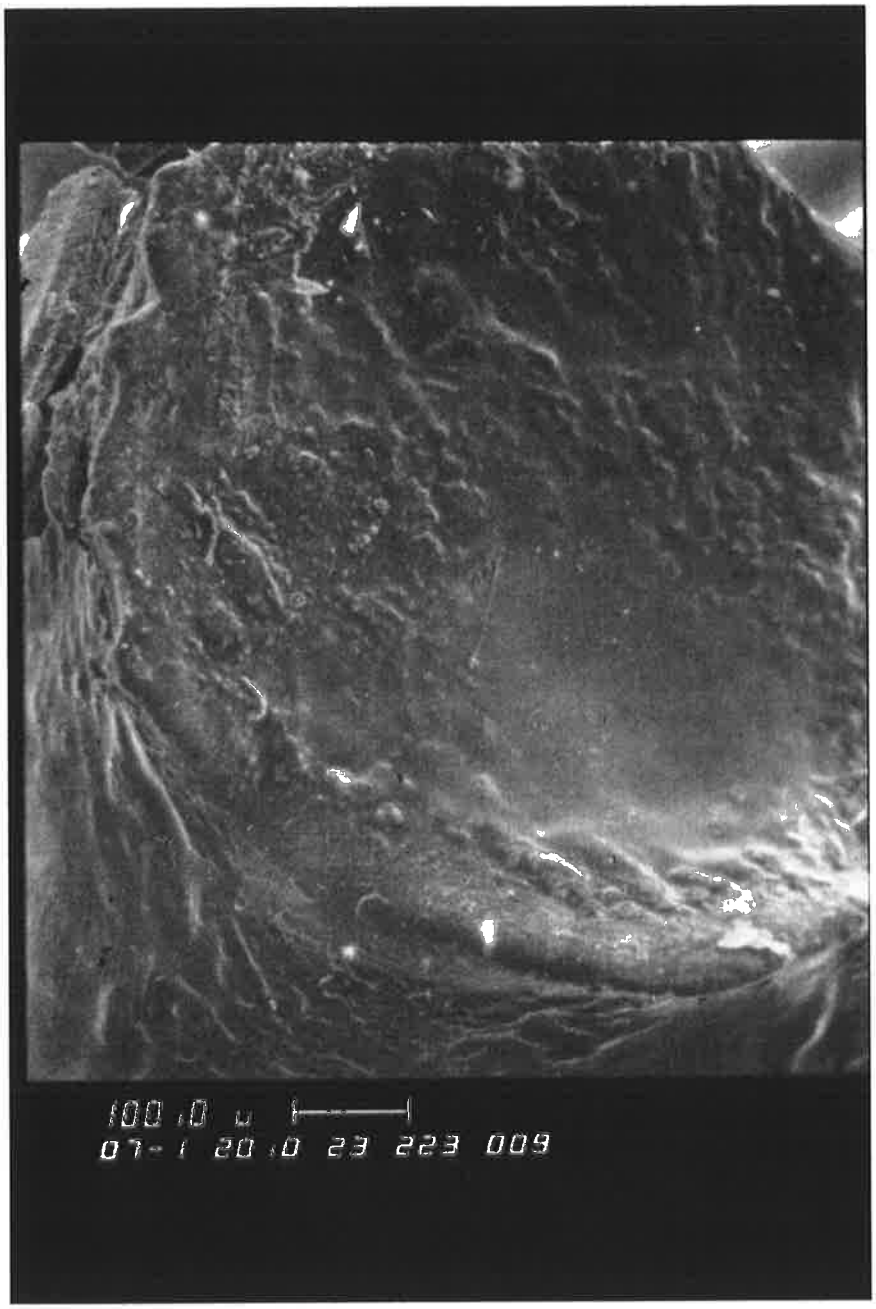

100.0 µ
07-1 20.0 23 223 009

Figure 7.3.5.2.b

S.E.M. micrograph of a very sticky resin surface following removal of an instrument. (Magnification : X 20).

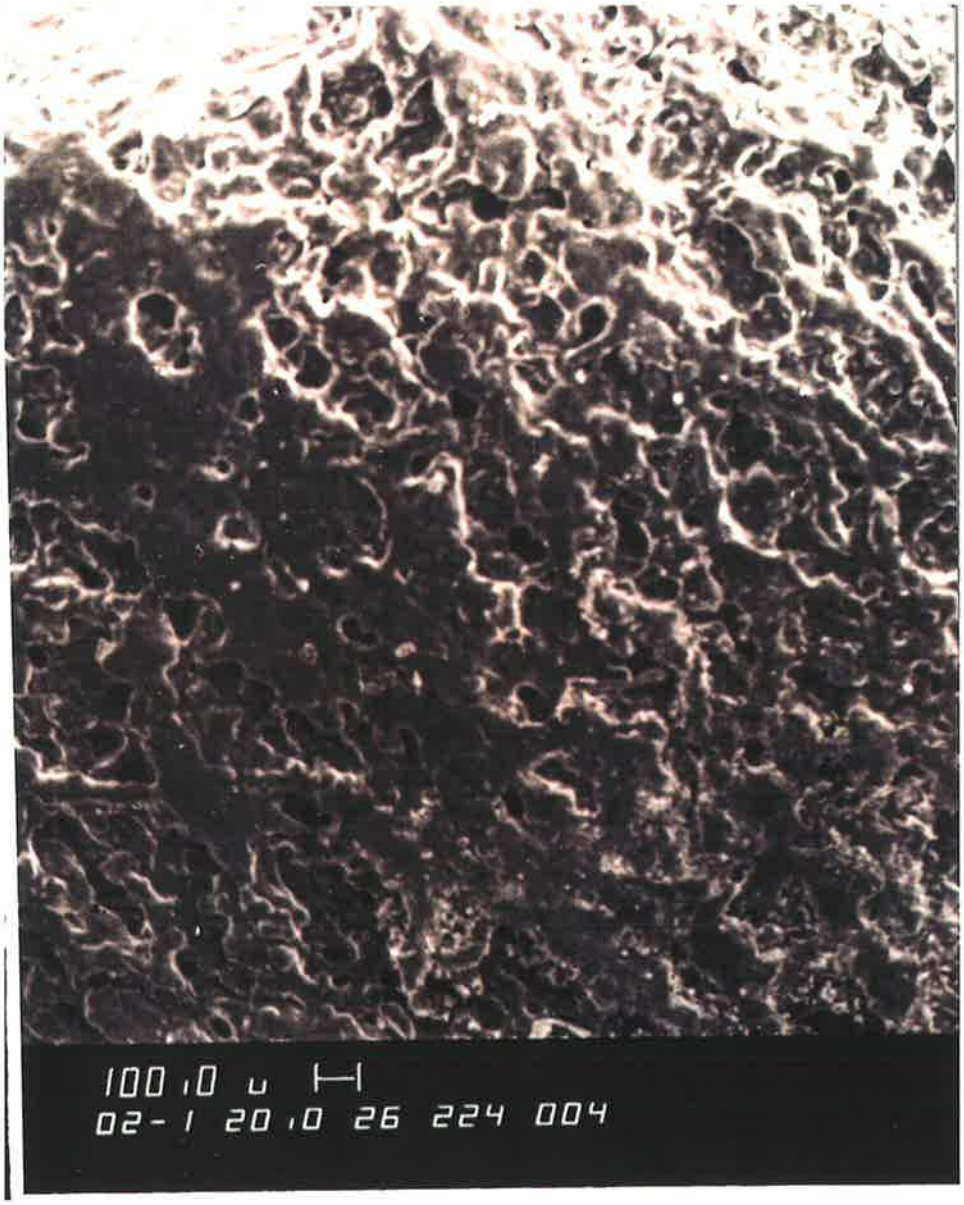

100.0 u H
02-1 20.0 26 224 004

Figure 7.3.5.2.c

S.E.M. micrograph of a less sticky resin surface following removal of an instrument. (Magnification : X 200).

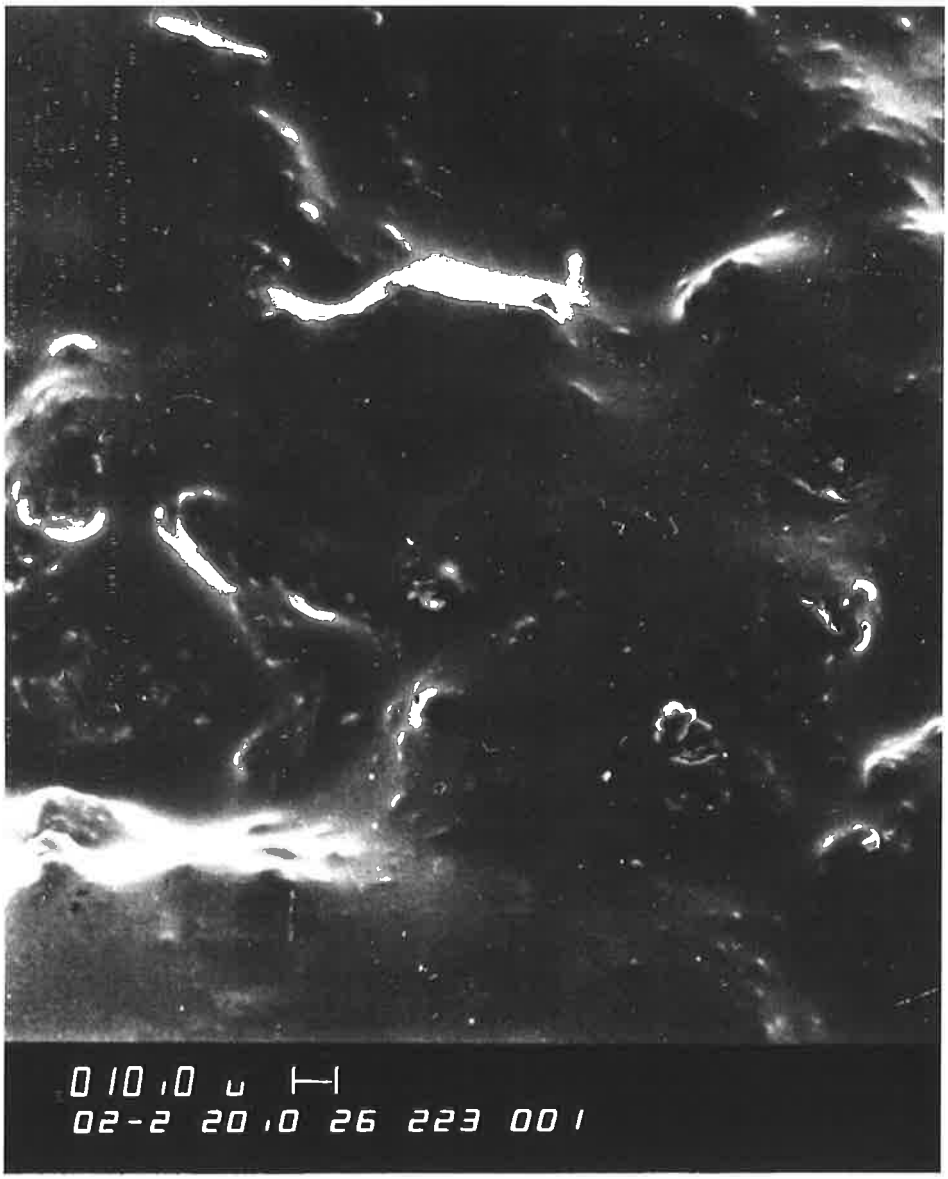

0 10 ,0 u
02-2 20 ,0 26 223 001

Figure 7.3.5.2.d

S.E.M. micrograph of a less sticky resin surface following removal of an instrument. (Magnification: X 200)

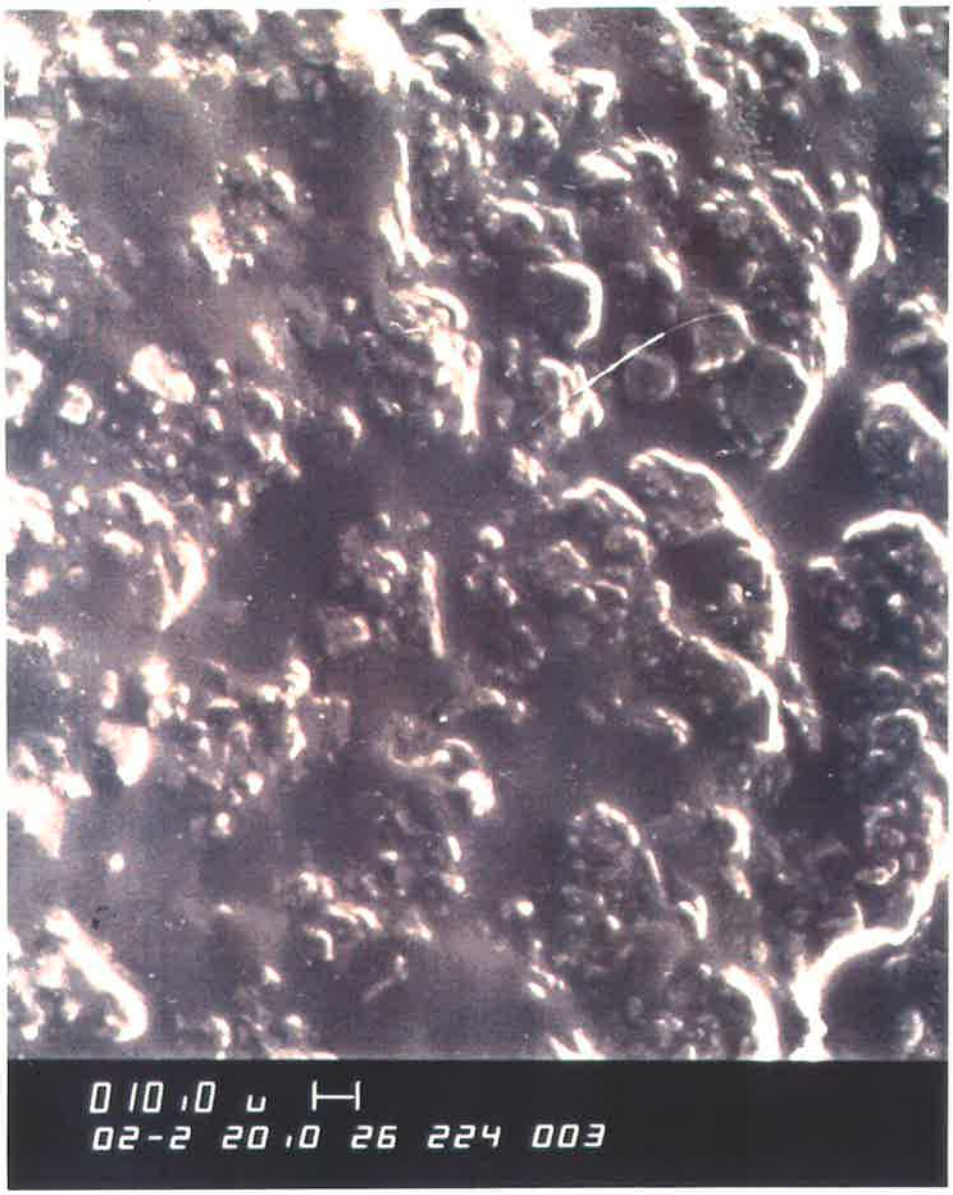

0 10.0 u H
02-2 20.0 26 224 003

Figure 7.3.5.3.a

Diagram and photograph of wave form following the cutting of a resin increment from the end of the delivery tube with a plastic instrument.

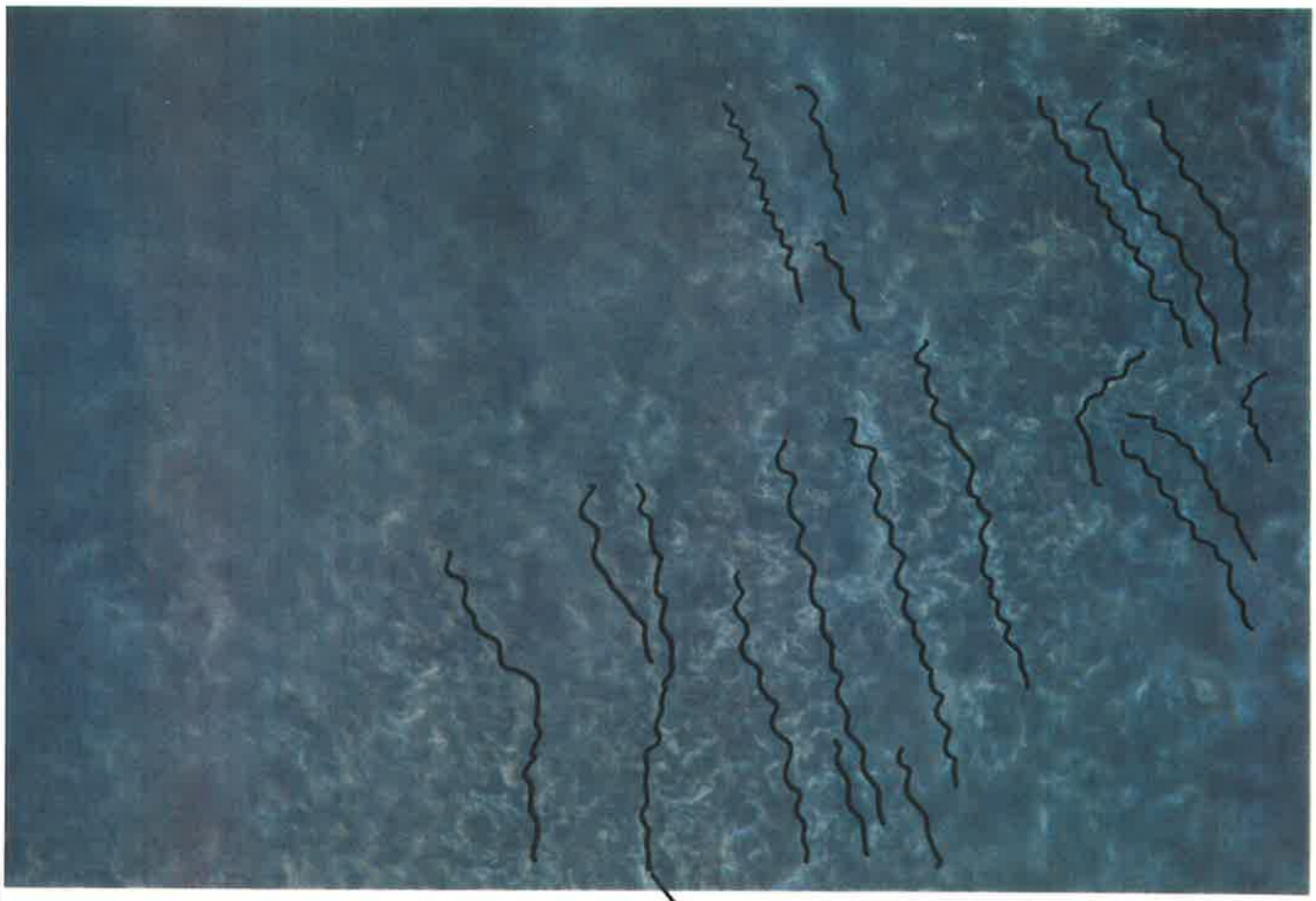

10 µm
wavy ridges

Figure 7.3.5.3.b

S.E.M. view of wave form created by cutting an increment off the delivery stream.

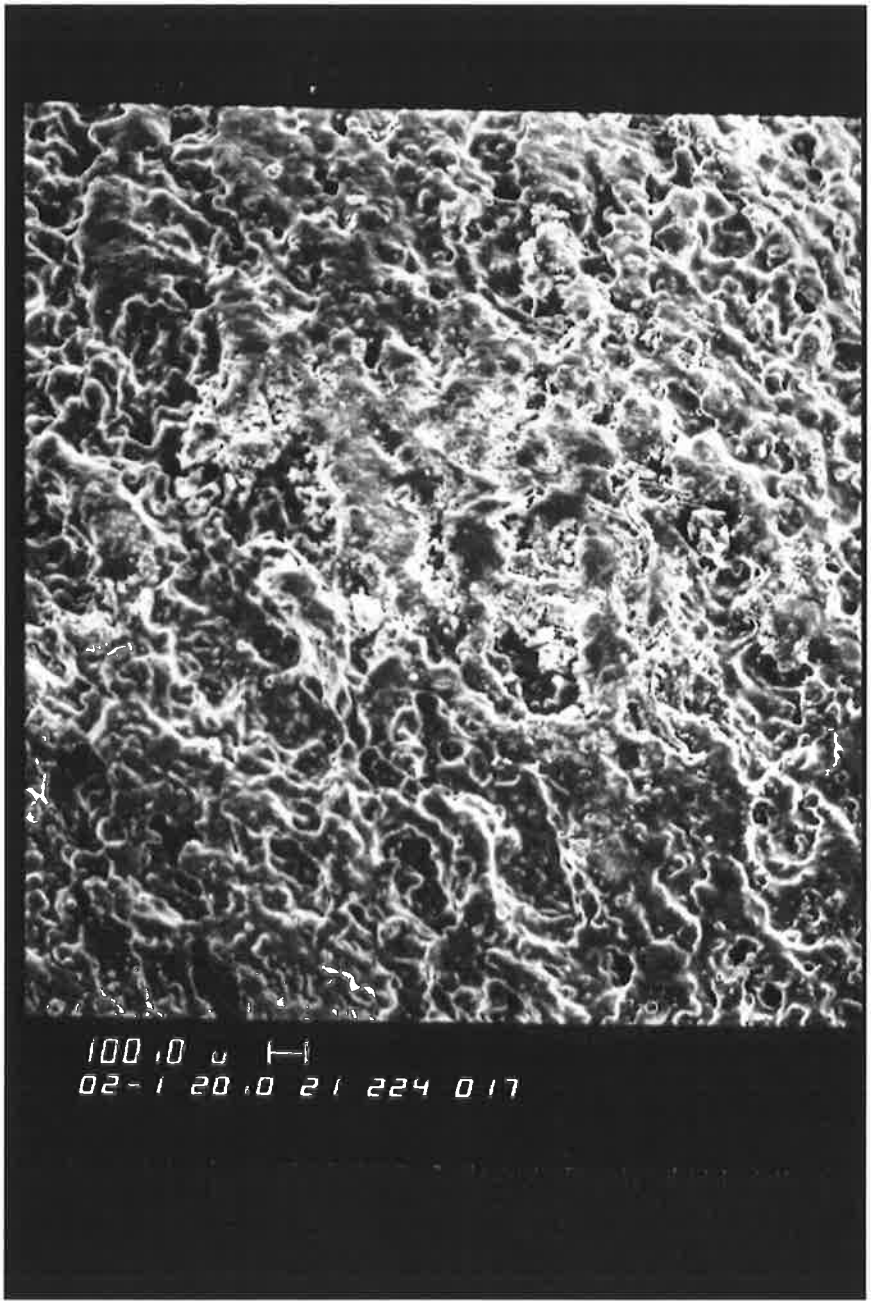
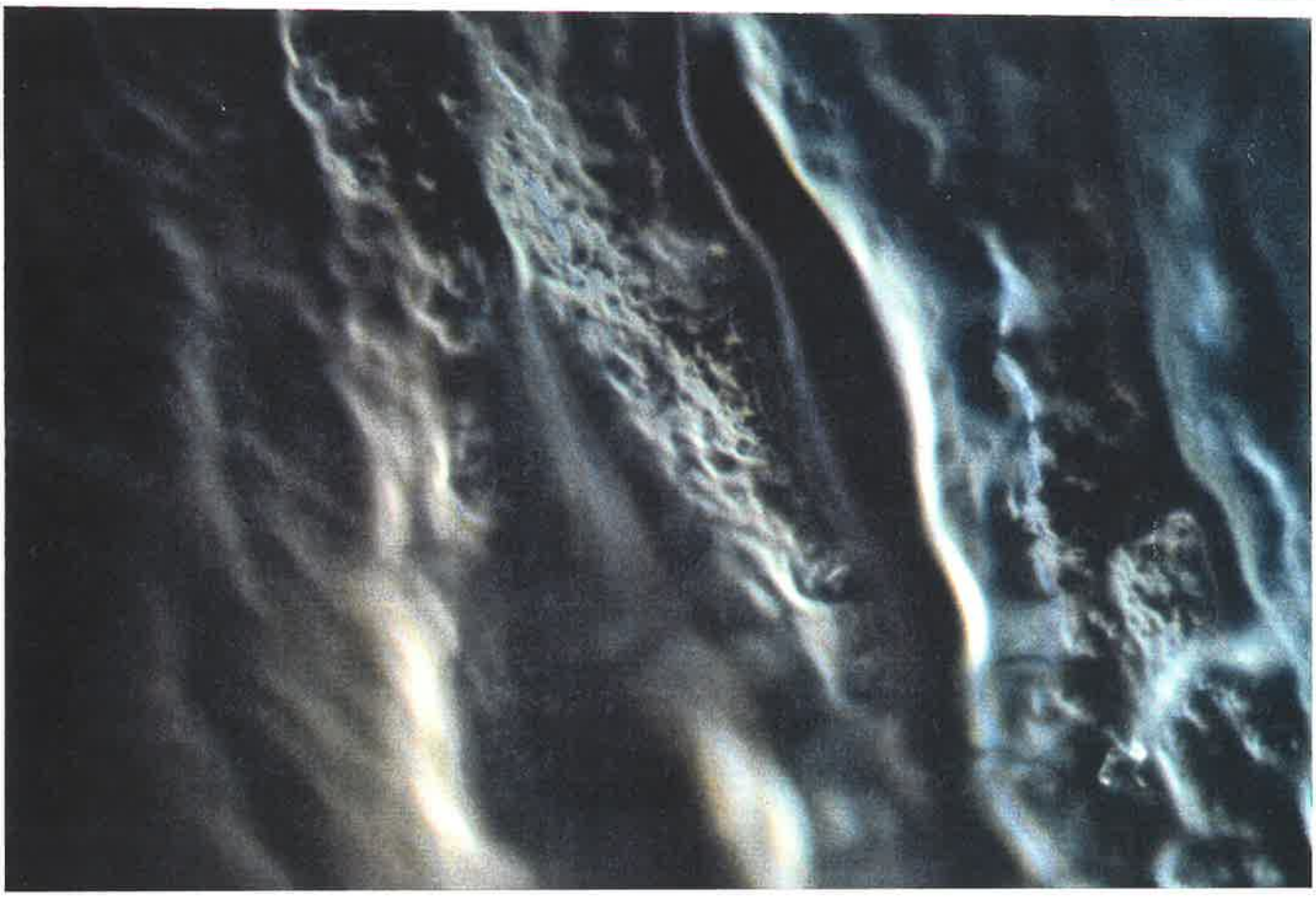

100.0 u
02-1 20.0 21 224 017

Figure 7.3.5.3.c

Polarised dark field view of wave form created by cutting an increment off the delivery stream. Magnification : X 420



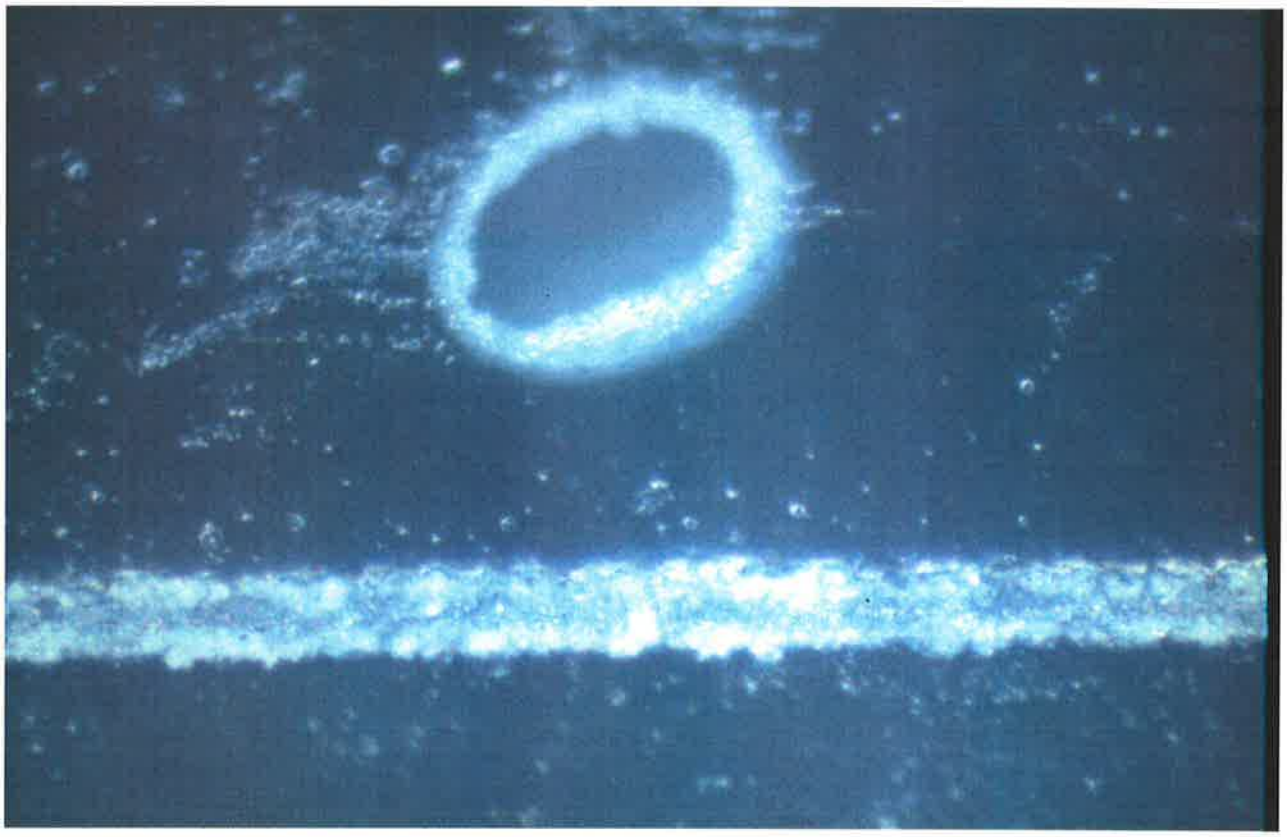
10 µm

7.3.6 MATRICES.

Porosities occur at random points on the surface of the resin against the matrix, (figure 7.3.6.a). They tend to be of the order of 100 micrometers in diameter or less. Other porosities occur immediately below the surface in the resin rich layer, as shown in figures 7.3.6.b & c. These are often disturbed during finishing proceedures, as seen in figs.9.2.2.6 a-t. In figure 7.3.6.a the porosity is open and would clinically be a ready site for debris collection.

Figure 7.3.6.a.

Porosity of approximately 100 micrometers diameter on the surface of a small particle posterior composite. This surface was covered with a clear matrix band during polymerisation.



100 μm.

Figure 7.3.6.b.

Micro-porosity in the resin rich surface layer of posterior composite resin. This photograph was taken using phase contrast light microscopy, Magnification : X 420 .

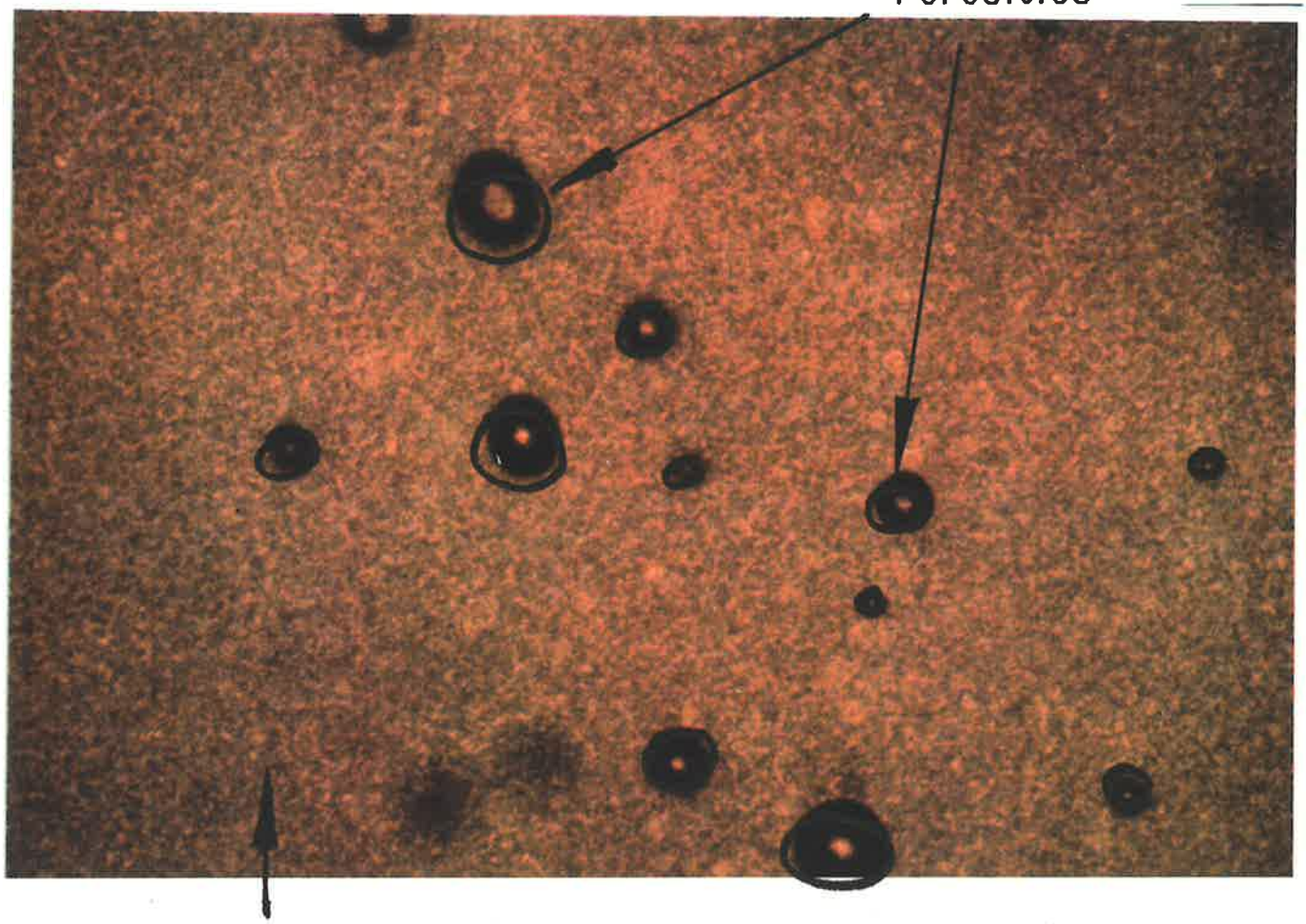
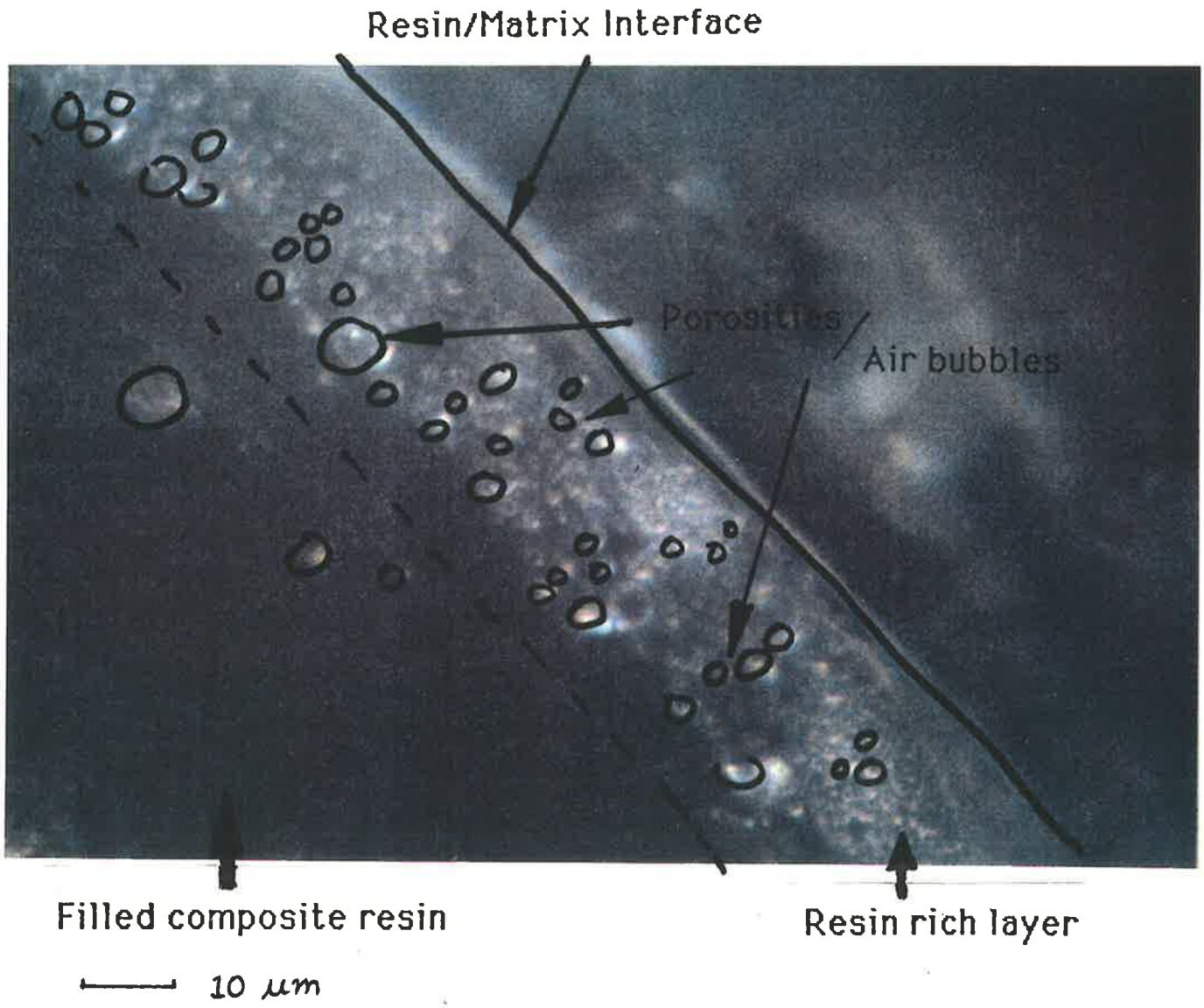

Porosities
Filled composite resin
10 μm

Figure 7.3.6.c.

Micro-porosity in the resin rich surface layer of posterior composite resin. This section was cut at right angles to the proximal surface and photographed in bright field incident light, Magification : X 420 .

These porosities are readily observed microscopically, but difficult to record photographically.


Resin/Matrix Interface
Porosities
Air bubbles
Filled composite resin
Resin rich layer
10 μm

7.4 DISCUSSION

It would appear that no matter how posterior composite resins are handled it is extremely easy to incorporate porosities, at the very least there would be submicron porosity from the manufacturer of the material with the occasional larger bubble or void occuring in packaging faults. Almost all aspects for placement of resins are subject to the risk of porosity incorporation. Handling the resins with instruments is of particular interest in this regard, with those resins directly injected into the cavity showing a lower risk than those resins which are cut from the end of the delivery tube and transferred to the cavity by means of an instrument. Direct injection provides a system where resin is pushing resin into the cavity, reducing the amount of packing required by an instrument.

The resins which tended to gloss over when left a little while before curing did not retain larger manipulation marks from instruments as much as those that are very resistant to slumping.

7.5 CONCLUSIONS.

All the resins tested demonstrated porosity from the manufacturing process. All resins were also found to have other forms of induced porosity, regardless of the care with which they were handled. Highly filled resins which do not slump or smooth over during the filling process are more likely to incorporate voids. Those resins which are not highly filled, i.e. those that do slump, are often stickier. These resins are particularly susceptible to porosity from instrument handling.

CHAPTER 8. POLYMERISATION CONTRACTION

8.1 INTRODUCTION

Unlike the new dental amalgam alloys of today, which have very little volumetric change when they set, the dental class II composite resins have a volumetric shrinkage during setting of between 2 and 5 percent. This contraction tends to vary according to the formulation of the material, but the type and ratio of the monomers used and the filler loading have a large influence on the final result. The self curing resins tend to have an even contraction, using the free or open surface as a reservoir to accomodate volumetric contraction as demonstrated in diagram 8.1.a. The photo-initiated resins tend to contract towards the light source and any volumetric change is met by drawing from those areas furthest away from the source as demonsrtated in diagram 8.1.b. The most significant clinical aspects of this phenomenon are:

1. That the integrity of the marginal seal is placed in jeopardy, particularly the proximal gingival margin.

2. The risk of intercuspal flexure, or even fracture.

Various reports have linked post operative sensitivity to both these points and recurrent caries to marginal seal. An illustration of this contraction is shown in figure 8.3.1.a, where the marginal integrity has broken and blue dye has entered the gap.

Figure 8.1.a

Diagram of self-curing resin undergoing polymerisation. The contraction forces are towards the centre and the top surface has been drawn down from the original, (shown here by a dotted line), to the new surface, (the complete line), to replace the lost volume. The bulk of the resin is shown in white, and the surrounding tooth, in red.

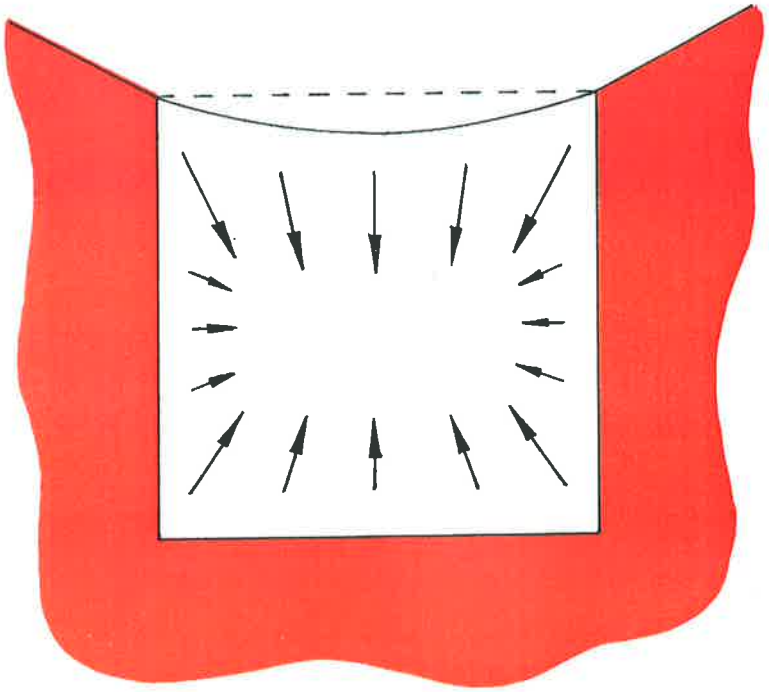
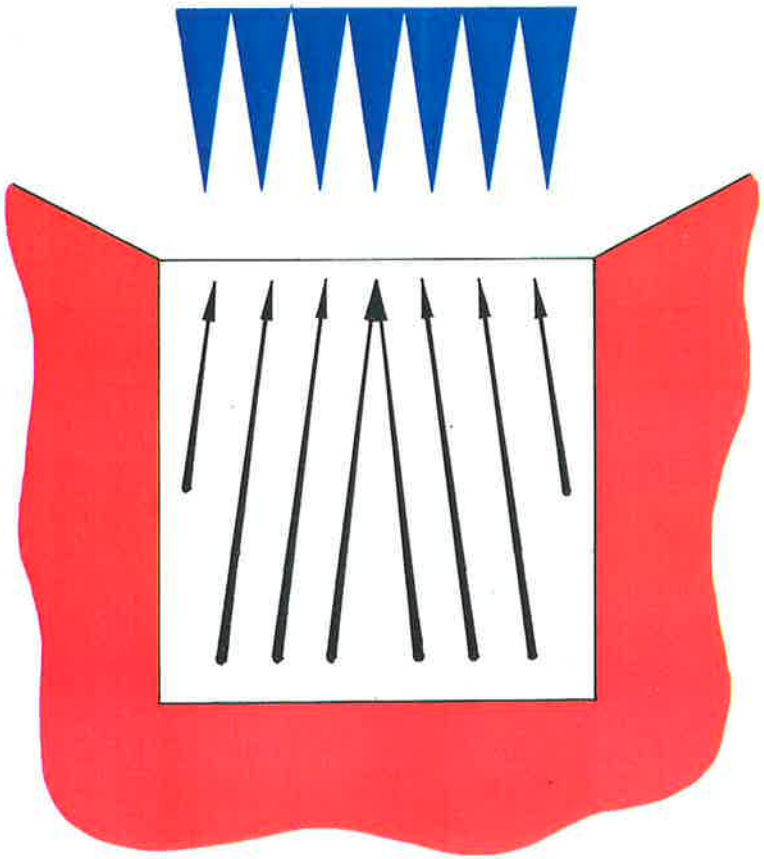


Figure 8.1.b

Volumetric contraction pattern during curing of a photo-initiated resin. The contraction, (black arrows), is towards the visible curing light, (blue arrows). The bulk of the resin is shown in white, and the surrounding tooth, in red. Loss of volume is likely to be met by resin drawn from the deeper areas lining the cavity, causing contraction stresses on the resin/tooth bond. Where these tensile stresses are too great, contraction gaps are likely to form at the expense of the integrity of the dentine bond.



8.2 MATERIALS AND METHODS

Freshly extracted third molars were used in this experiment. Cavities were cut in these teeth as described in chapter nine of this report. The Auto Matrix[23] system was used. The steel matrix bands limit the application of the curing light to the occlusal direction for one group. In the second group the clear matrix and curing sequence as described in the Sandwich technique in chapter 9 were used. All teeth were then coated in wax, with only the proximal portion exposed. The teeth were then immersed in methylene blue dye for 24 hours. At the completion of the immersion phase the teeth were mounted in resin and sectioned in the mesio-distal axial plane on a diamond saw with water coolant. As a control another group of teeth were immersed in methylene blue dye with only the glass ionomer portion of the restoration completed. These teeth were also sectioned as above. All teeth were then observed under a microscope and the results observed.

8.3 Results

The results are listed in table 8.3. These results indicate that shrinkage due to occlusal curing disrupts the dentino-glass-ionomer bond at the gingival floor and the gingival margin of the proximal box, (figure 8.3.1a). The bond between the glass ionomer and the resin is not broken, (figure 8.3.1.b).

[23]Caulk Auto Matrix; L. D. Caulk, Milford, Delaware, U.S.A.

Table 8.3

Results for testing the effect of the direction of application and the type of matrix band on the integrity of the gingival margin seal.

Table 8.3

Direction of cure		Occlusal	Gingival
Type of matrix	Number Placed	Number Showing Leakage	
Clear	4	2	0
Metal	4	3	N/A

Figure 8.3.1.a

Photograph of the contraction gap formed at the gingival margin during curing from the occlusal, using a metal matrix band. The contraction gap is actually formed by the disruption of the glass ionomer-dentine bond, (Magnification : X 420). The glass-ionomer-resin bond is shown in figure 8.3.1.b.

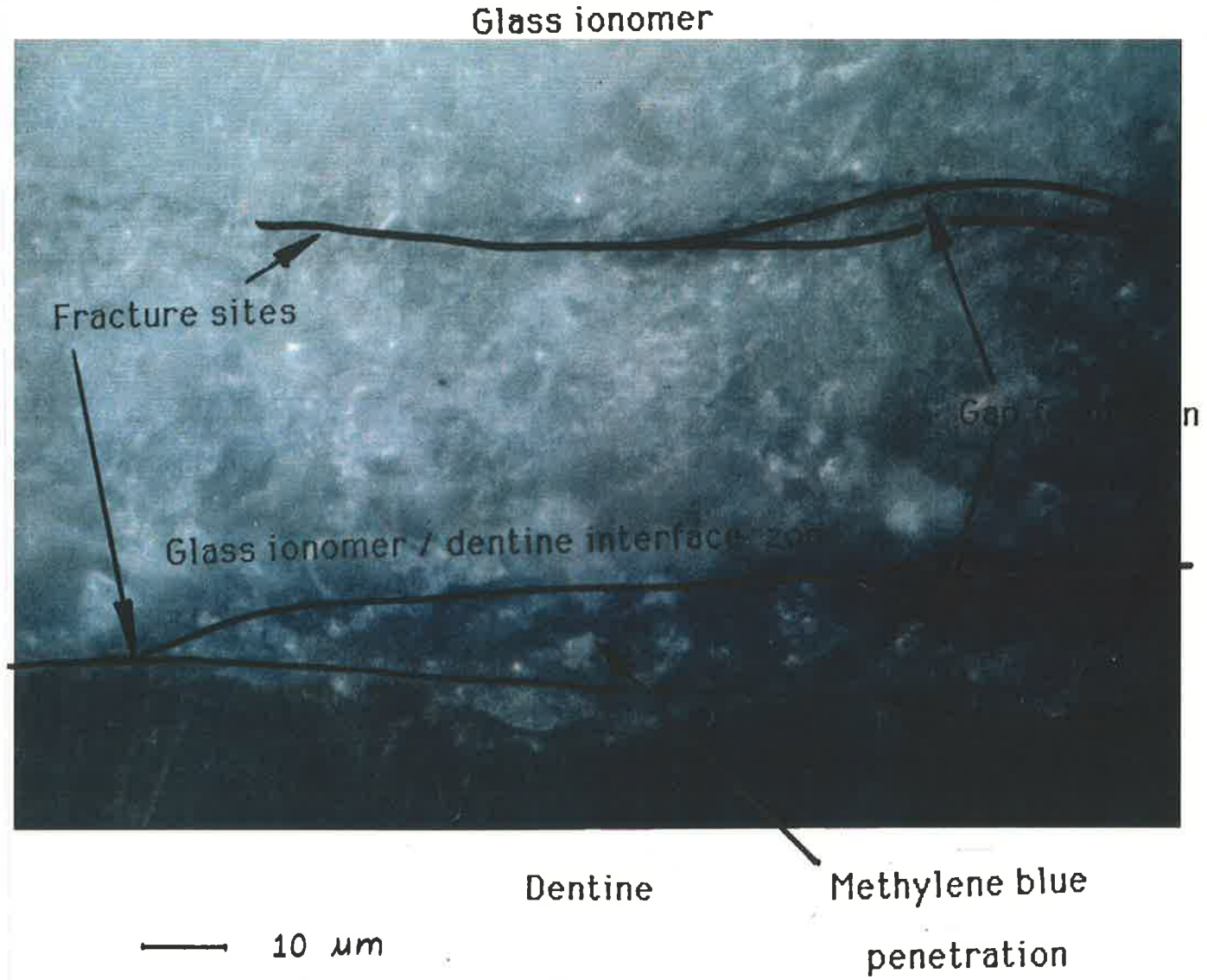
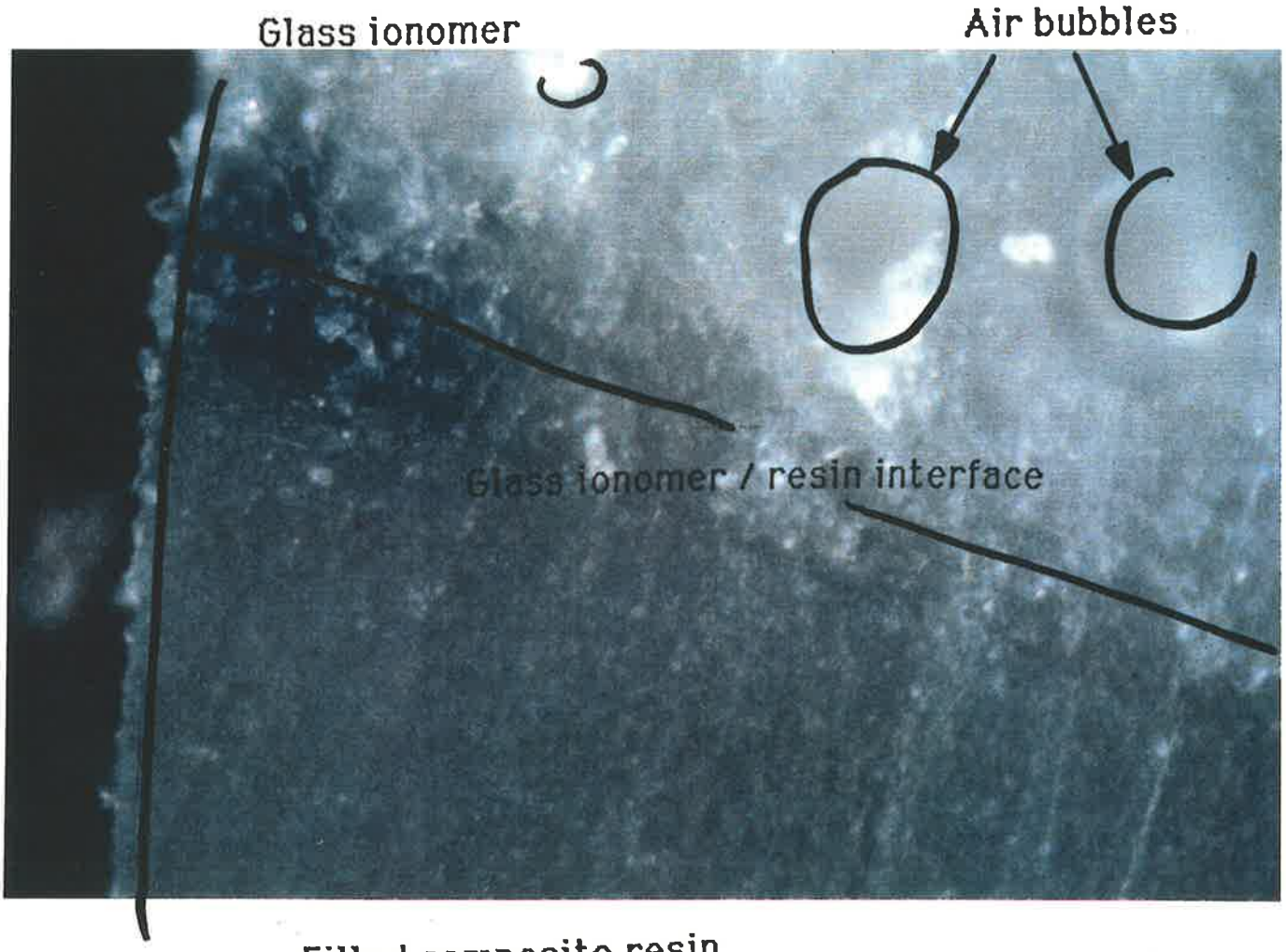

Glass ionomer
Fracture sites
Glass ionomer / dentine interface
Dentine
Methylene blue
penetration
10 µm

Figure 8.3.1.b

Photograph of the bond between the glass-ionomer and the restorative resin from the same specimen as that shown in figure 8.3.1.a. Note that the bond is not broken. Magnification: X 420.


Glass ionomer
Air bubbles
Glass ionomer / resin interface
Filled composite resin
10 µm

8.4 DISCUSSION

The performance of the class II posterior resin restoration is dependent on the ability to protect the pulp from microleakage. The opening of the gingival margin seal to produce gaps is an area of great concern. By combining laboratory knowledge and known clinical techniques, it is possible to reduce the two main areas which may add to the problem. Good depth of cure can be achieved using wedges and clear matrix bands. Good bonding can be achieved by encouraging the material to shrink towards the cavo-surface margin. Occlusally placed increments of depths greater than 2 mm must be treated with caution where a 40 second cure has been used, as this is the level that most resins appear to have a conversion rate reduction.

The other factor is the placement of the light. An occlusally placed light will usually be held back from the surface of the resin by the cusps of the teeth or any other obstruction. In the laboratory, the measurements are taken where the light has been placed directly on to the resin sample, separated only by a thin clear matrix strip. The normal laws of light transmission (the inverse square law) mean that the light intensity has suffered a reduction. This leaves the area at or near the gingival margin with a lower conversion rate, but the area above is shrinking directly towards the light. The result is that the gingival margin must be at a larger risk than, for example the occlusal margin, to gap formation.

8.5 CONCLUSION

Polymerisation contraction still occurs with the present resin systems. Increased filler loadings, that is increased volume filler fractions, and higher molecular weight monomers have significantly reduced the contraction. Where this is coupled with the clinical technique described in chapter 9 and based on the work in chapter 6 the effects of polymerisation contraction can be reduced. The contraction can be directed in such a way, that the portion of the increment furthest from the visible light cure generator provides an unbonded surface, which may act as a reservoir.

CHAPTER 9. WEAR : IN VIVO PILOT STUDY

9.1 INTRODUCTION.

The pilot study was designed to compare the wear of two posterior composite restoratives and one glass ionomer restorative to a silver amalgam control. The study also enabled observations about placement techniques to be made.

9.2 MATERIALS AND METHODS.

9.2.1 MATERIALS

The restorative materials used in this pilot study were P-30[24], Herculite syringeable[25], Ketac-Silver[26] and Dispersalloy[27] (used as a comparison). Ketac-Fil[28] was used in the sandwich technique as a base and dentine adhesive under both composite resins. Ketac-Fil was also used as the restorative at the gingival margin of the Class II restorations, where a composite resin was used as the main restorative. Mesio-distal sectional diagrams depicting how they were used appear in figures 9.2.1.a, b & c. Ketac-Bond was used as a lining under the Dispersalloy.

The in vivo study was conducted according to the clinical protocol found in appendix G.

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[24] P-30; 3M Co., Minnesota, U.S.A.

[25] Herculite syringeable; Kerr, Romulus, Michigan, 48174 U.S.A.

[26] Ketac-silver; ESPE, Fabrik Pharmazeutischer, Paraparete, G.M.B.H., D-8031, Seefeld/Oberbay.

[27] Dispersalloy; Johnson & Johnson Dental Products Company. 20 Lake Drive,CN 7060,East Windsor,N.J. 08520

[28] Ketac-fil; ESPE, Fabrik Pharmazeutischer, Paraparete, G.M.B.H., D-8031, Seefeld/Oberbay.

Figure 9.2.1.a

Mesio-distal sectional diagram of a molar with a 3 surface Class II cavity with an amalgam restoration.

The blue area represents the Dispersalloy and the red area represents the Ketac-Bond base or lining.

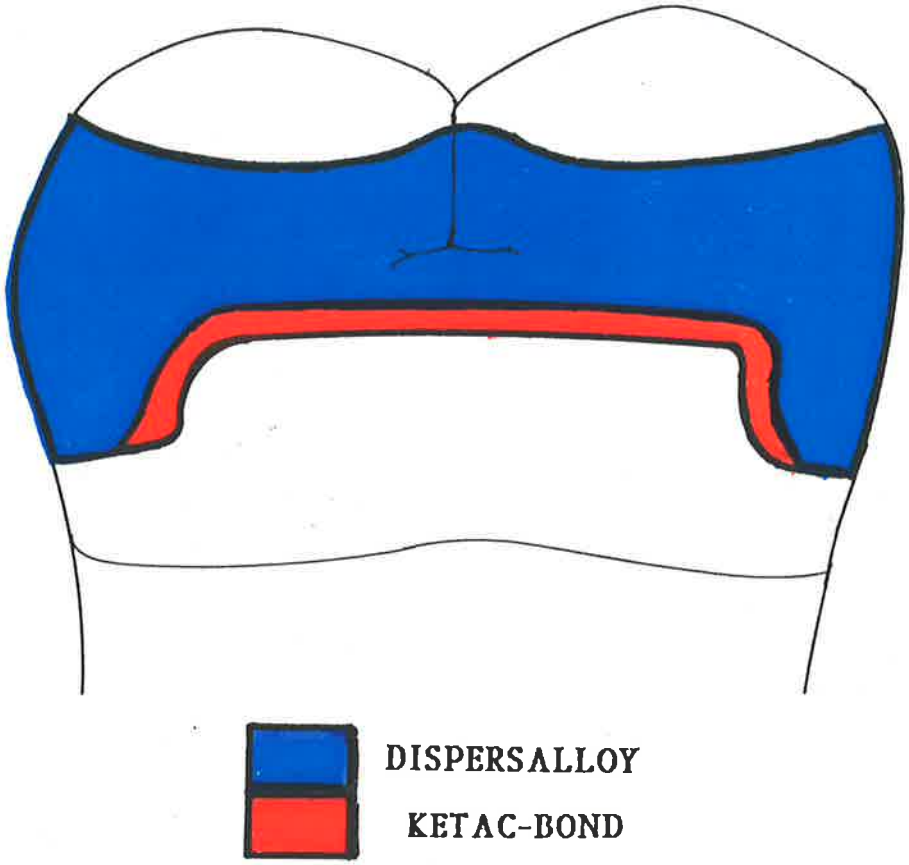

DISPERSALLOY
KETAC-BOND

Figure 9.2.1.b

Mesio-distal sectional diagram of a molar with a 2 surface Class II cavity and a glass-ionomer restoration.

The restorative for this type of restoration was Ketac-Silver.

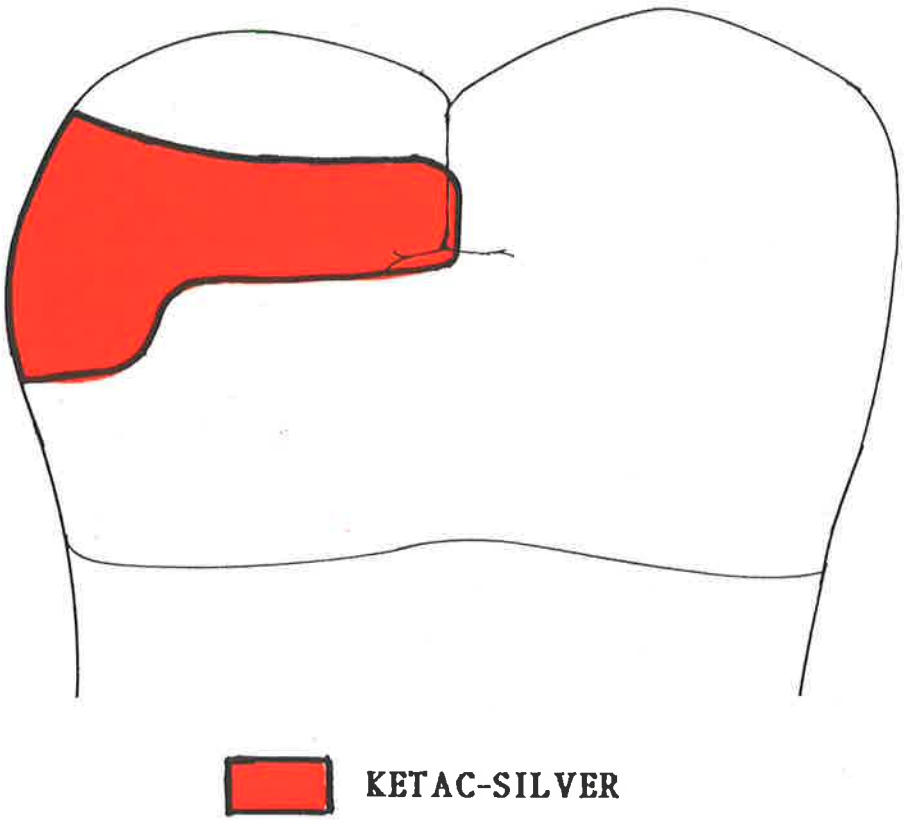
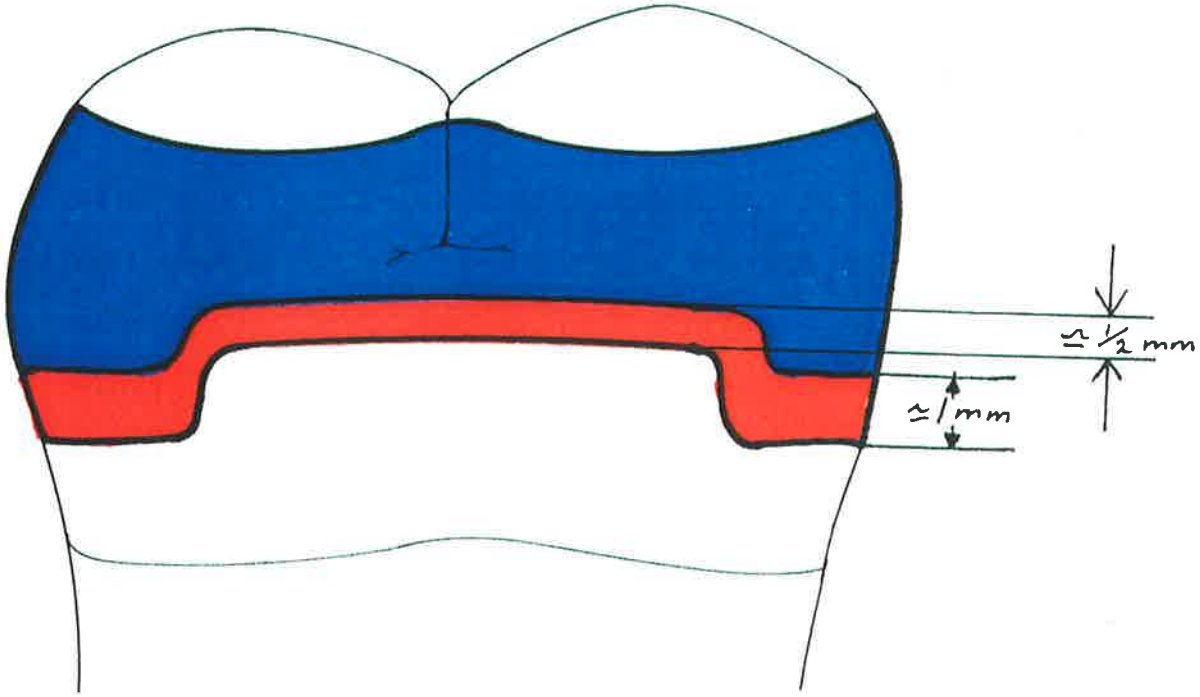

KETAC-SILVER

Figure 9.2.1.c

Mesio-distal sectional diagram of a molar with a 3 surface Class II cavity and "Sandwich Technique" posterior resin restoration.

The composite resin, represented by the blue area, was either P-30 or Herculite.

The red area represents the adhesive base layer which was Ketac-Fil.



KETAC-FIL

P-30/HERCULITE

9.2.2 METHODS - CLASS II POSTERIOR RESINS

9.2.2.1 PREPARATION OF THE TOOTH

It is desirable to have separation of the teeth prior to restoration using orthodontic separating elastics, to produce sufficient additional interproximal space to allow the creation of tight contact points, with minimal damage to the periodontal ligament and root surface. If this is not possible, another system is to progressively wedge the teeth apart at the time of restoration. This was the system employed in the pilot project.

The teeth were first marked in centric occlusion for occlusal contacts. This was used to minimize the risk of an occlusal contact on a cavo surface margin.

Following analgesia of the tooth or teeth to be restored, the area was isolated with rubber dam. The teeth were then cleaned with a non-fluoridated pumice and water slurry in a rubber cup. Pre-wedging was then employed to gain separation; wedges were introduced to the relevant proximal regions and progressively adjusted as time elapsed. Wedging on top of the rubber dam also reduced leakage and provided further retraction of the interdental papilla.

9.2.2.2 CAVITY FORM

Conservative cavity forms with rounded line angles were employed. Bevels were not placed on axial and gingival interproximal walls, or in areas with occlusal contacts. Margins close to areas of high occlusal stress were left with approximately 90^{o} or greater angles with no attempt to bevel. See figures 9.2.2.2.a, b & c. The burs used, were a pear-shaped diamond (fig. 9.2.2.2.d. for bulk cutting), and a 12 blade tungsten carbide pear-shaped bur (fig. 9.2.2.2.e. for finishing).

Figure 9.2.2.2.a, top.

Cavity outline form: mesial view, showing rounded line angles and butt style cavo-surface margins in areas of high stress or difficult access.

Figure 9.2.2.2.b, middle.

Cavity outline form: buccal view, showing rounded internal line angles, with a butt style gingival margin in the proximal box.

Figure 9.2.2.2.c, bottom.

Cavity outline form: occlusal view, showing rounded internal line angles, with a butt style gingival margin on the proximal box axial walls. In the conservative Class II posterior composite restoration it is extremely difficult to pack highly-filled resins into small fine bevels against matrix bands without porosity or voids at the artificial line angle formed by the cavity wall and the matrix band.

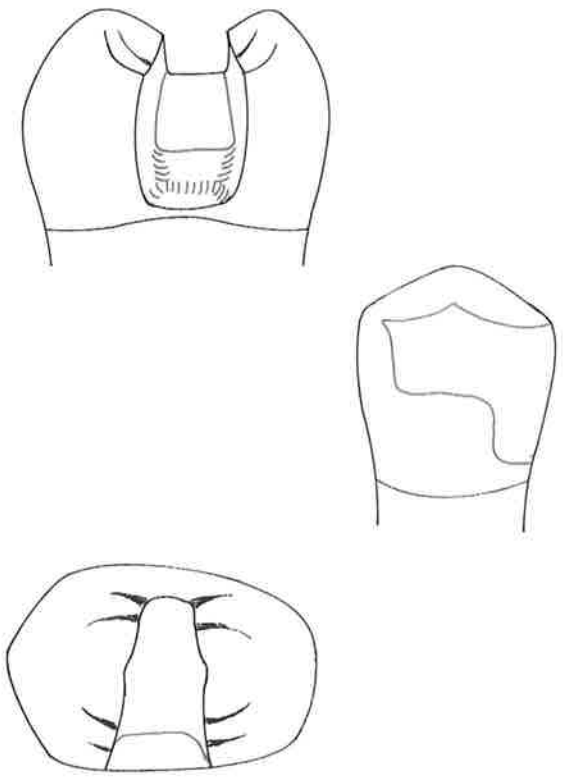
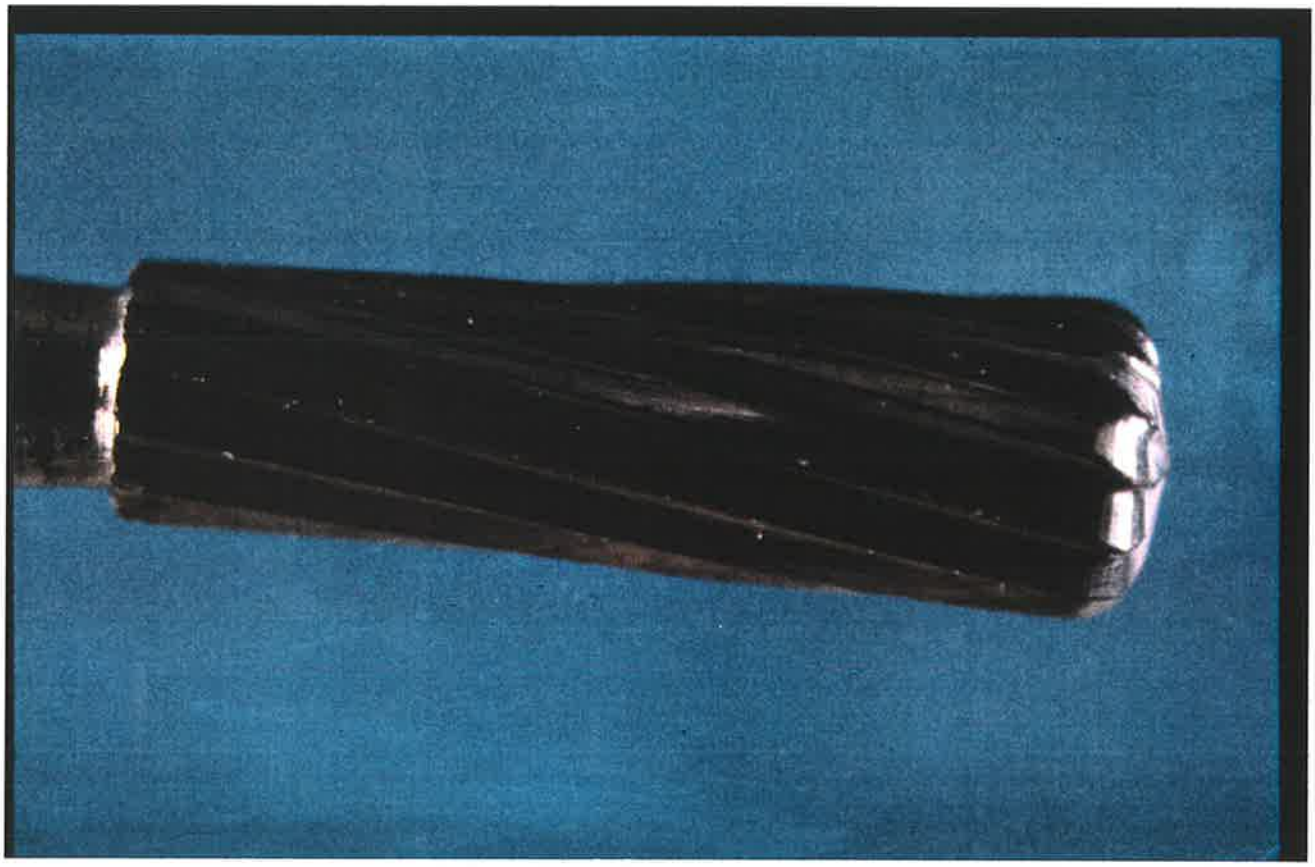


Figure 9.2.2.2.d

Pear-shaped diamond bur used for the main cavity outline form. The diameter is 1.2mm

Figure 9.2.2.2.e

Tungsten carbide bur for finishing main cavity outline form. The diameter is 1.2 mm.



9.2.2.3 SANDWICH TECHNIQUE

The "Sandwich Technique" for glass-ionomer/composite resin combination restorations was employed principally to protect the gingival margin of the proximal box against secondary caries due to microleakage, as it is a technique known to provide a stable dentine bond. The glass-ionomer also provided protection for the pulp by sealing the dentine and acted as a dentine-bonding agent.

After cavity preparation the smear layer on the dentine was removed by the application of 10% polyacrylic acid for 10 seconds. This was then rinsed away by the application of copious quantities of water for 30 seconds. The surface was carefully air dried, wedges removed, and a clear plastic matrix band placed around the tooth. Light transmitting[29] wedges were used to replace the normal wedges in the interproximal areas.

Ketac-Fil was then used as a base, (see diag. 9.2.1.c.). After placement, the material was sealed with Visio-Bond and allowed to mature for 15 mins. The base was then carefully cut back, removing the Visio-Bond and exposing mature glass-ionomer for etching. The base and enamel were then etched for 60 seconds[30] using the normal ortho-phosphoric acid gel supplied for the "acid-etch" technique. The preparation was then rinsed with copious quantities of water for 30 seconds and carefully air dried.

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[29] Luciwedge : Hawe-Neos U.S.A.

[30] Following recent research, the recommended time has been amended to 20 seconds.

9.2.2.4 RESIN PLACEMENT

Bonding resin matching the restorative resin was applied according to the manufacturer's instructions and cured for 40 seconds. The sequence of resin placement used two vertical/oblique increments to complete the majority of the proximal box and initial parts of the occlusal floor, followed by an occlusal increment to complete the occlusal anatomy. Each increment was individually cured for at least 40 seconds before the next increment was placed, the direction of cure being from the same side as the increment, that is, from a buccal direction for the buccal increment and from a lingual direction for the lingual increment. This was to ensure that any polymerisation contraction was towards the proximal and gingival margins to reduce the risk of excessive marginal stresses and contraction gap formation. See diagrams under figures 9.2.2.4.a,b,c &d. In larger cavities, the first resin increment was a horizontal layer of about 1 mm over the Ketac-Fil base in the proximal box. This increment was cured first using the light transmitting wedge as the light pathway. See diagrams under figures 9.2.2.4.e,f,g,h & i for the sequence.

The P-30 was cut from a section of material extruded from the tube onto a mixing pad by a small plastic instrument and then placed into the cavity. Final adaptation was performed with a highly-polished stainless steel ball burnisher 1.0 mm in diameter.

Herculite was syringed directly into the cavity and final adaption was also achieved with the ball burnisher.

Figure 9.2.2.4.a, top left.

The gingival floor is covered by a Ketac-Fil base, (shown here in red), which is about 1 mm thick.

Figure 9.2.2.4.b, top right.

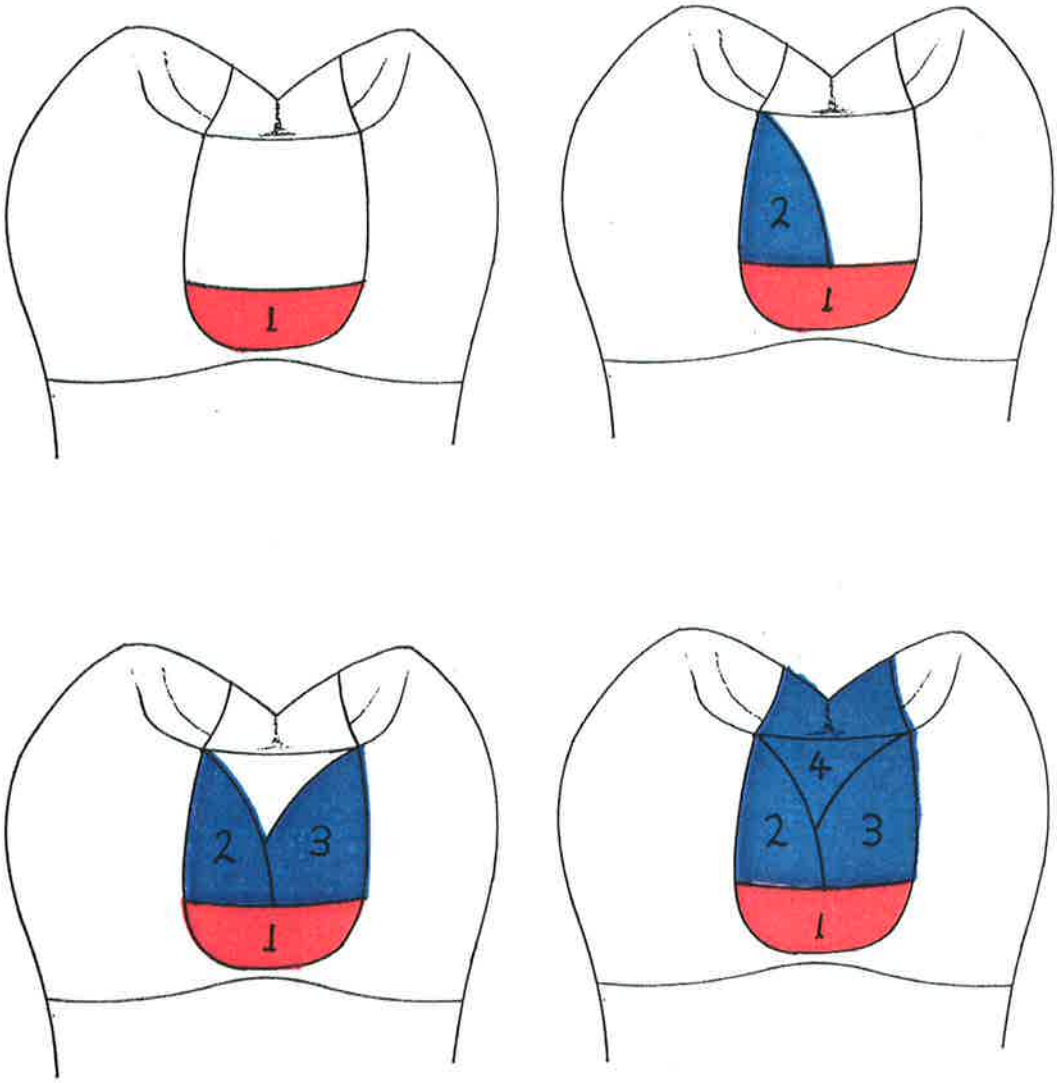
The first vertical/oblique resin increment, (shown in blue).

Figure 9.2.2.4.c, bottom left.

The second vertical/oblique resin increment, (also shown in blue).

Figure 9.2.2.4.d, bottom right.

The final increment (also blue), is placed to finish the occlusal.



Glass Ionomer

Resin

Figure 9.2.2.4.e, top left.

The gingival floor is covered by a Ketac-Fil base, (shown here in red), which is about 1 mm thick.

Figure 9.2.2.4.f, top right.

The first resin increment, (blue), is a horizontal layer, covering the glass-ionomer base. This is cured only from the gingival, via the light transmitting wedge, to ensure maximum conversion of monomer components into the polymer at the gingival margin to provide the best seal.

Figure 9.2.2.4.g, bottom left.

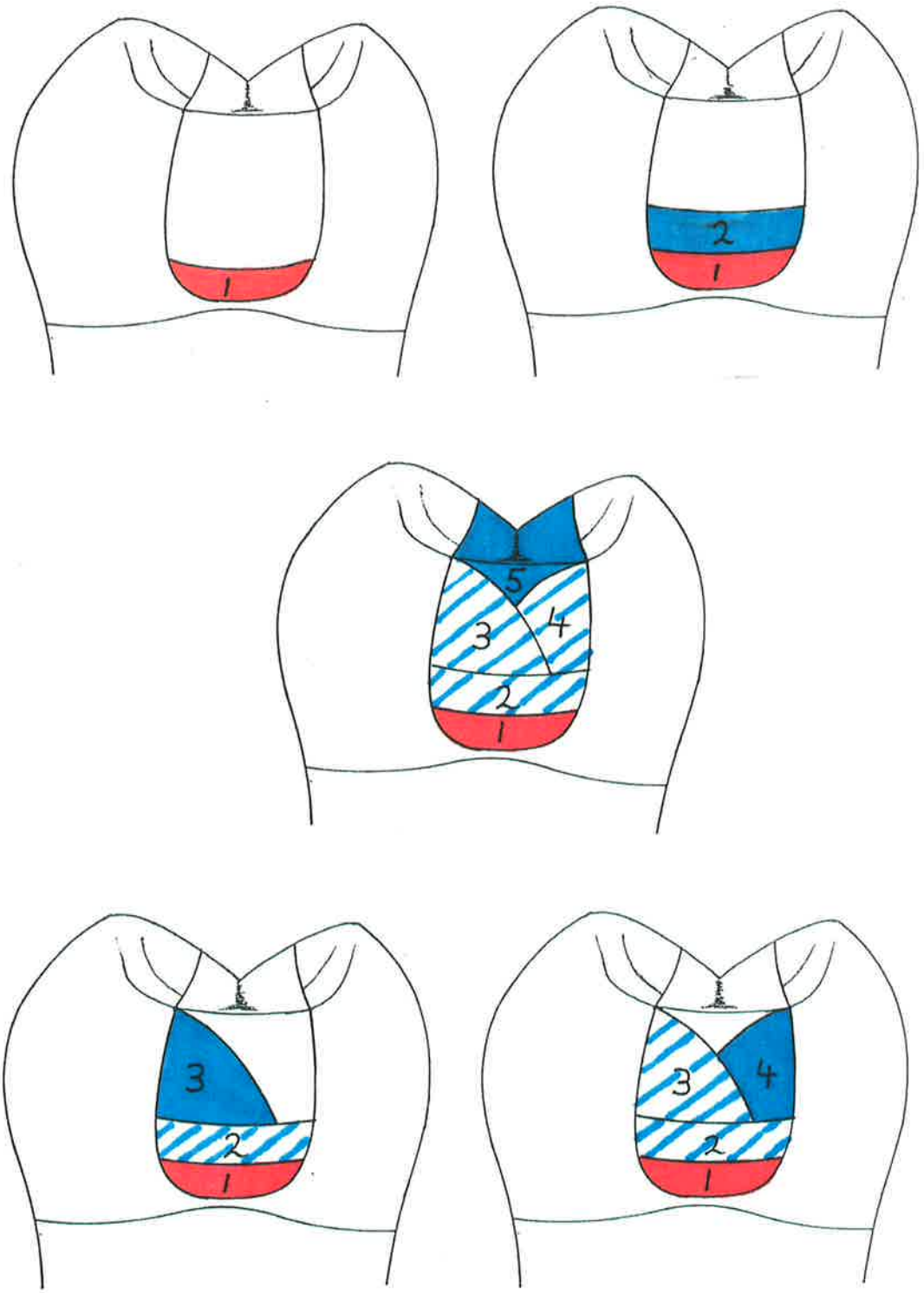
The first vertical/oblique resin increment, (shown in blue).

Figure 9.2.2.4.h, bottom right.

The second vertical/oblique resin increment, (also shown in blue).

Figure 9.2.2.4.i, centre.

The final increment (also blue), is placed to finish the occlusal.


1
2
1
5
3
4
2
1
3
2
1
3
4
2
1

9.2.2.5 CURING

All resin increments were cured with a Translux CL[31] visible-light curing generator for a period of 40 seconds. The first increments in the Class II restorations were always cured via the light-transmitting wedge, from the side of the first vertical/oblique increment. Subsequent vertical increments were cured from the side on which they were placed.

9.2.2.6 FINISHING

Finishing was done at the completion of the restoration. The posterior resin restorations were trimmed with either composite finishing diamonds or tungsten carbide burs followed by 3M Soflex discs and/or Shofu Quasite[32] finishing points. All finishing was done with water spray and a slow-speed handpiece.

A series of profilometer[33], SEM and light microscope illustrations are presented in figures 9.2.2.6.a-t, comparing relative surface roughnesses of the different finishing discs, while figures 9.2.2.6.u,v and w relate to the finish produced with the Shofu Quasite finishing points.

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31 Translux CL; Kulzer Australia Pty. Ltd.

32 Shofu Quasite Points; Shofu Dental Products, C/- Clements Stanton, P.O. Box 110, North Ryde, N.S.W. 2113.

33 Profilometer: Range, 1 micron; Cut off, 0.8 &0.25; X2 100V ; Speed, 2 mm/second. Surftest III, Mitutoyo Mfg. Co. Pty. Ltd. Japan Heath /Schlumberger Strip chart recorder, Heath Co. Benton Harbor, Michigan.

Figure 9.2.2.6 a, top left

Photograph of a coarse "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used.

Figure 9.2.2.6 b, top right

Phase contrast photomicrograph of the surface of the resin specimen shown in figure 9.2.2.6.a, following the application of the coarse disc. Note the rough scratched surface from the cutting action of the abrasive on the disc and the collection of debris in the open porosities. Magnification 420 times.

Figure 9.2.2.6 c, bottom left

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.a. Magnification 20 times.

Figure 9.2.2.6 d, bottom right

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.a. Magnification 200 times.

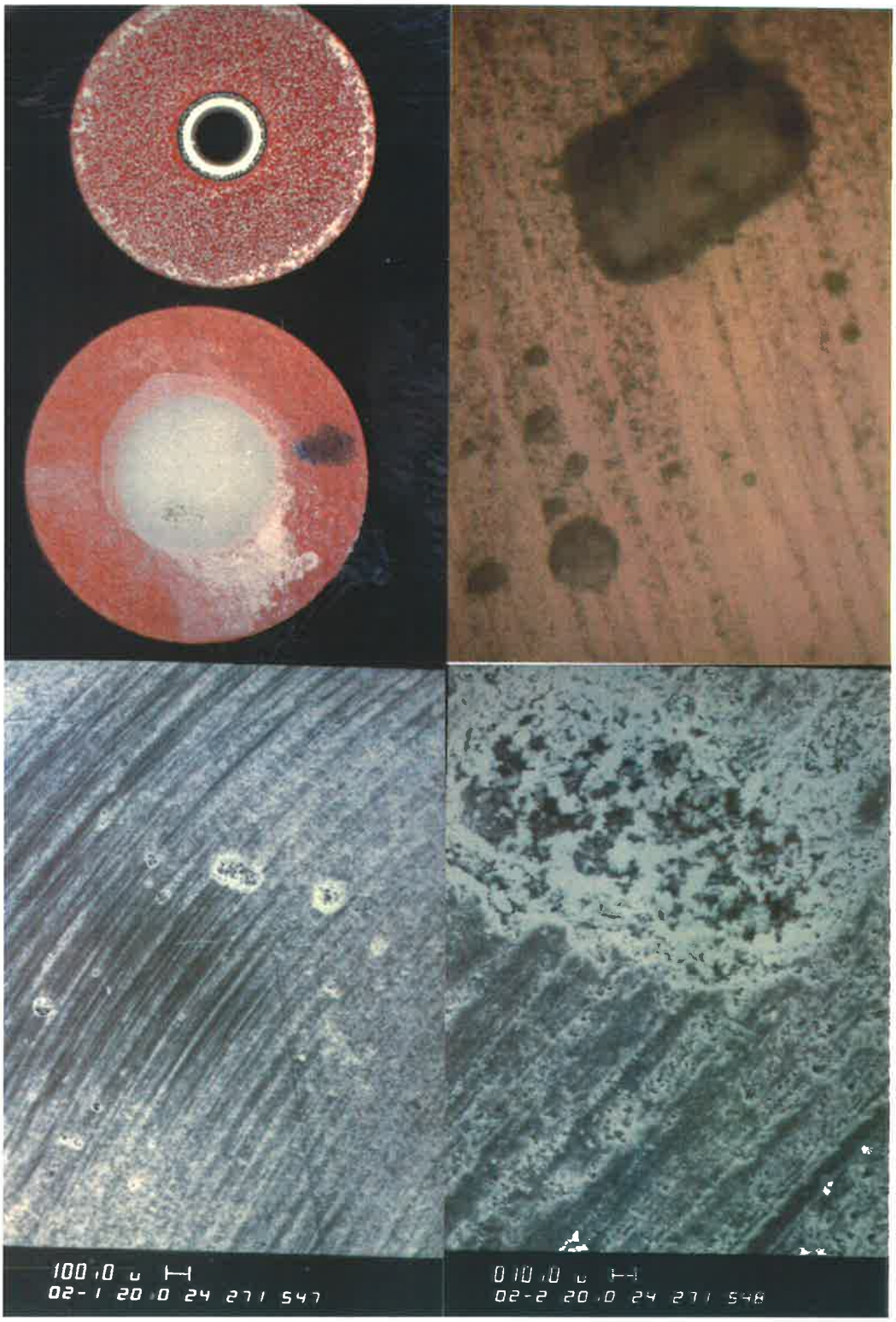

100.0 u H
02-1 20.0 24 271 547
010.0 u H
02-2 20.0 24 271 548

Figure 9.2.2.6 e, top left

Photograph of a medium "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used

Figure 9.2.2.6 f, top right

Phase contrast photomicrograph of the surface of the resin specimen shown in 9.2.2.6.e, following the application of the medium disc. Note the rough scratched surface from the cutting action of the abrasive on the disc and the collection of debris in the open porosities. Magnification 420 times.

Figure 9.2.2.6 g, bottom left

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.e. Magnification 20 times.

Figure 9.2.2.6 h, bottom right

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.e. Magnification 200 times.

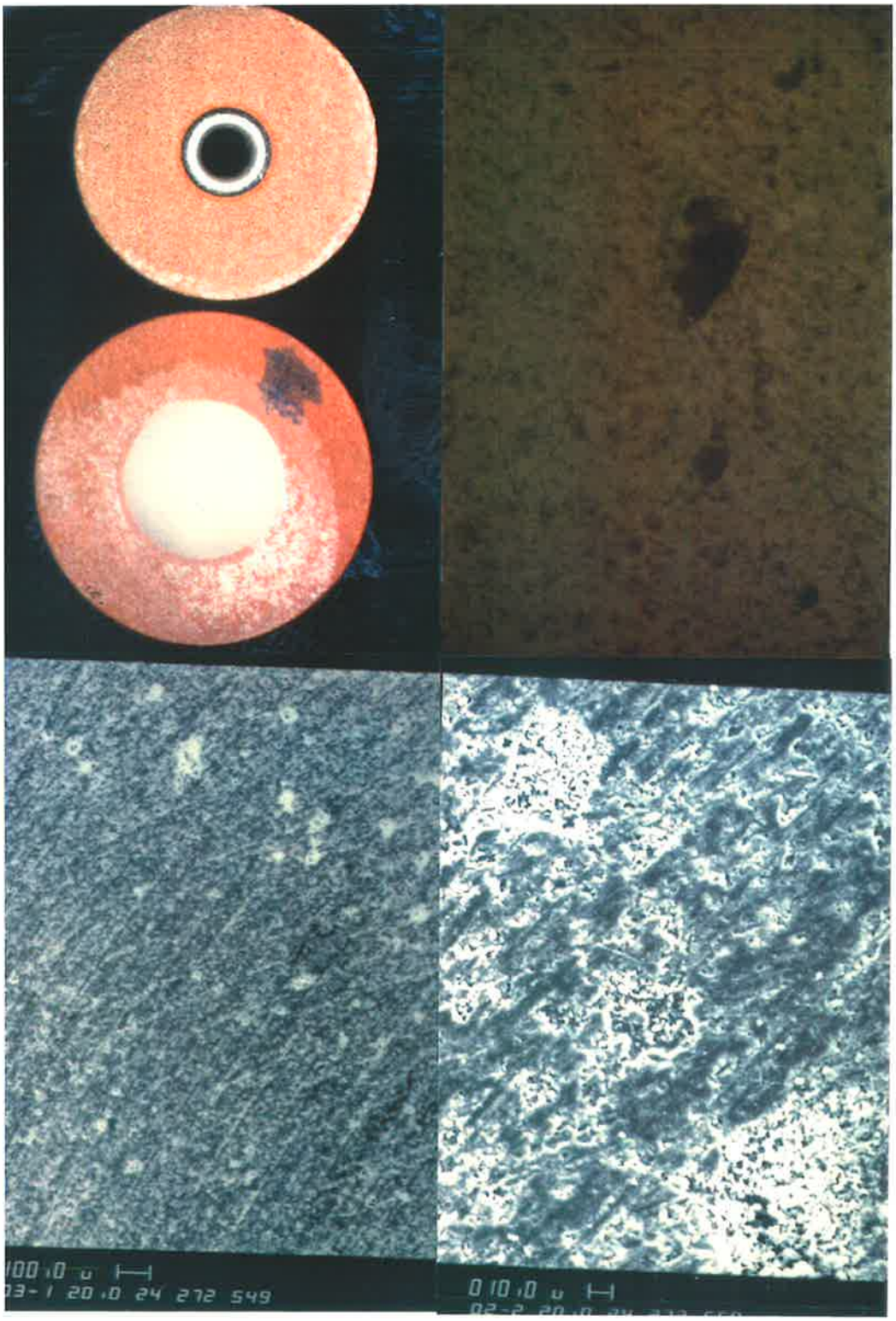

100.0 u
23-1 20.0 24 272 549
0 10.0 u

Figure 9.2.2.6 i, top left

Photograph of a fine "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used

Figure 9.2.2.6 j, top right

Phase contrast photomicrograph of the surface of a resin specimen following the application of the fine disc. Note that the rough scratched surface from the cutting action of the abrasive on the disc is beginning to smooth over, even give a smeared appearance and the collection of debris in the open porosities is more concentrated. Magnification 420 times.

Figure 9.2.2.6 k, bottom left

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.i. Magnification 20 times.

Figure 9.2.2.6 l, bottom right

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.i. Magnification 200 times.

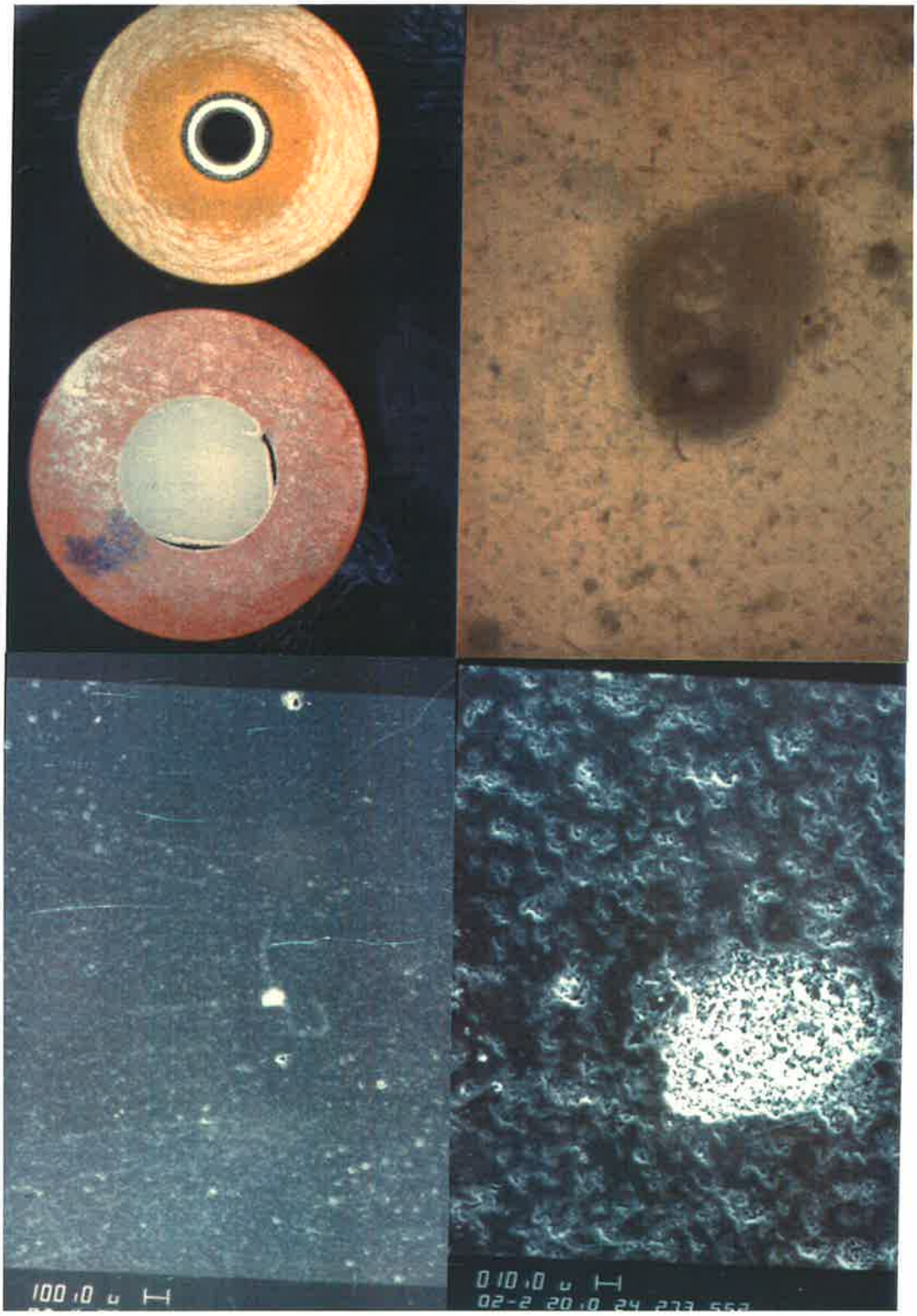

100.0 u H
010.0 u H

Figure 9.2.2.6 m, top left

Photograph of a super fine "Soflex XT " finishing disc and the specimen that appears in the next three photographs, on which it was used.

Figure 9.2.2.6 n, top right

Phase contrast photomicrograph of the surface of the resin specimen shown in figure 9.2.2.6.m following the application of the super-fine disc. Note that the rough scratched surface from the cutting action of the abrasive on the disc is beginning to smooth over, even give a smeared appearance and the collection of debris in the open porosities is more concentrated. Magnification 420 times.

Figure 9.2.2.6 o, bottom left

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.m. Magnification 20 times.

Figure 9.2.2.6 p, bottom right

Scanning electron micrograph of the same specimen shown in figure 9.2.2.6.m. Magnification 200 times.

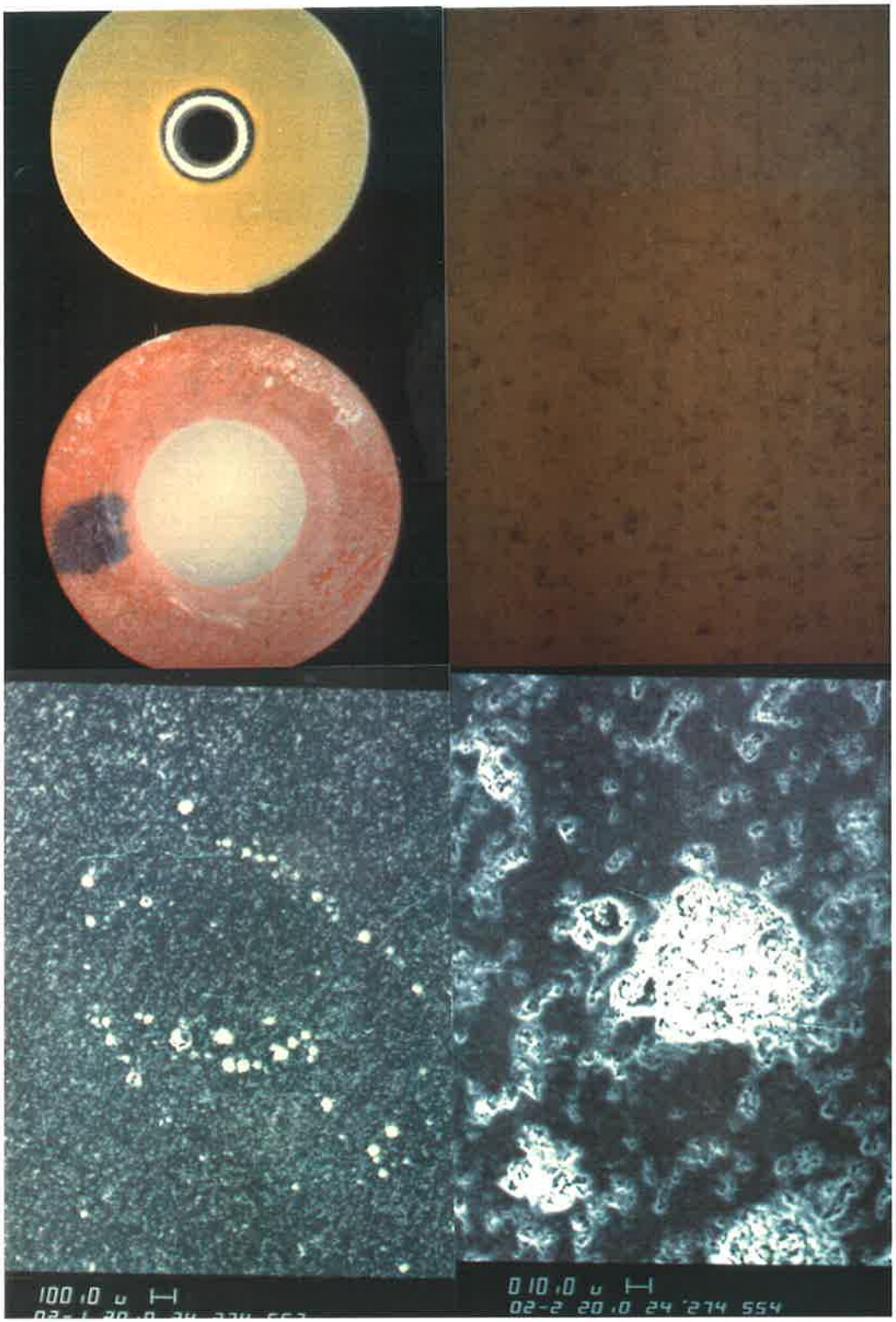

100.0 u H
010.0 u H

Figure 9.2.2.6 q

Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.a.

Figure 9.2.2.6 r

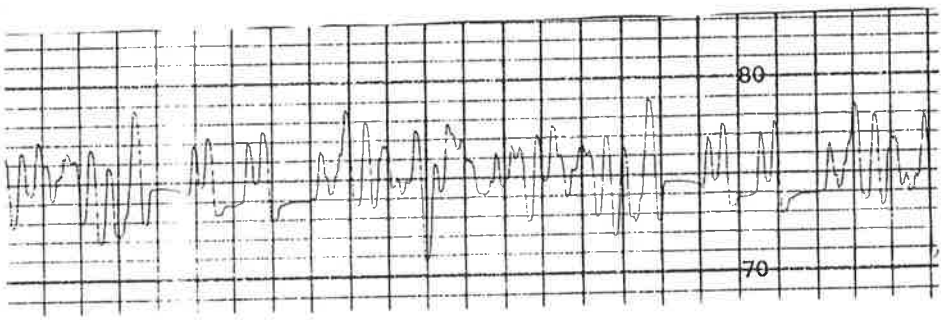
Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.e.

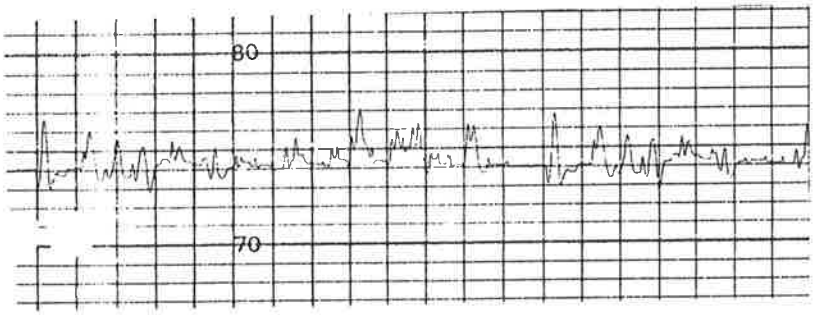
Figure 9.2.2.6 s

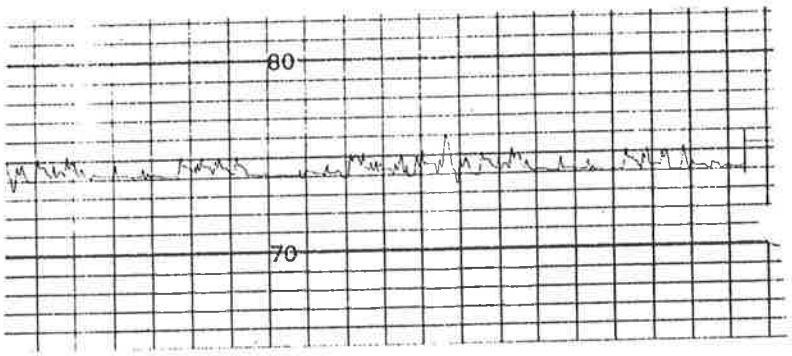
Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.i.

Figure 9.2.2.6 t

Strip chart recording from profilometer test of the specimen used in figure 9.2.2.6.m.


80
70


80
70


80
70

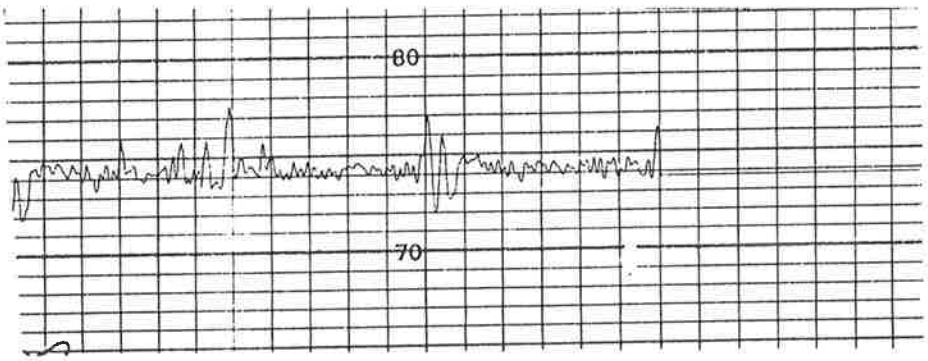

80
70

Figure 9.2.2.6.u, top

Phase contrast photomicrograph of the surface of a resin specimen shown following the application of the Shofu Quasite finishing point. Note that the surface of the disc is beginning to smear over. The collection of debris in the open porosities is concentrated. Magnification 420 times.

Figure 9.2.2.6.v, bottom left

Scanning electron micrograph of the same specimen surface photographed shown in figure 9.2.2.6.u. Magnification 20 times.

Figure 9.2.2.6.w, bottom right

Scanning electron micrograph of the same specimen surface photographed in figure 9.2.2.6.u. Magnification 200 times.


100.0 u H
02-1 20.0 24 275 555


010.0 u H
02-2 20.0 24 275 556

9.2.3 METHODS - CLASS II GLASS-IONOMER

The glass-ionomer, Ketac-Silver, was used in very conservative Class II cavities. The tooth was prepared in the same way as described in sections 9.2.2.1. and 9.2.2.2. The dentinesurface was then prepared in the same manner as that described in section 9.2.2.3. for the base in the sandwich technique. The encapsulated material was then mixed according to the maufacturer's instructions, placed in the cavity and allowed to mature for 6 minutes. Preliminary carving was achieved with a Hollenbach carver prior to set. The final finishing was carried out in the manner as described in section 9.2.2.6.

9.2.4 METHODS - CLASS II AMALGAM

The tooth was prepared in the manner described in sections 9.2.2.1 and 9.2.2.2 with the exception of pre-wedging for separation and transparent matrix bands. Ketac-Bond was used as a lining material and Dispersalloy as the amalgam. Finishing was completed with Shofu[34] brown and green cups and points, "Brownies and Greenies", at least 24 hours later.

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[34] Shofu Greenies and Brownies; Shofu Dental Products, C/- Clements Stanton, P.O. Box 110, North Ryde, N.S.W. 2113.

9.3 ASSESSMENT METHOD

Recording the finished restoration was done with photographs and polyvinylsiloxane impressions. The photographs were produced using Fujichrome DX 135-36 film, ISO rating, 100, and a 100mm macro lens on a 35 mm SLR body at a set magnification of 1:1. The lighting was provided with a Sunpak GX8R ringflash at full power with the lens aperture at f22. Front surfaced mirrors were used where direct vision was difficult. At each six monthly recall, additional polyvinylsiloxane impressions and photographs were taken.

The impressions were produced by applying a light-bodied polyvinylsiloxane[35] carefully to the surface to avoid air bubbles and then applying a heavy-bodied tray material. The impressions were either supported in a small impression tray, or simply with a piece of cotton gauze as a supporting matrix, see figure 9.2.5.a. The impressions were then poured up in Araldite D[36] and after allowing them to set, the resulting replicas were mounted on S.E.M. stubs, coated with a standard gold/palladium coating of approximately 0.5 nanometers, and photographed on a Scanning Electron Microscope, using Kodak Technical Pan X 120 film[37]. The method for producing the replicas using Araldite D is found in appendix H. The replicates and photographs were compared with standard photographs and replica casts.

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[35]Reprosil; De Trey Division, Dentsply Ltd. Weybridge, Surrey England.

[36]Biopot: Bond Plastics Pty., Ltd., 45 Phillips Street, Thebarton, South Australia 5031.

[37]Kodak Technical Pan X ; Eastman Kodak Company. Rochester, N.Y. 14650.

9.4 OBSERVED CLINICAL FAILURE: CASE REPORT

This clinical case was referred by the Primary Care Unit of the Adelaide Dental Hospital. A clinical summary of treatment carried out so far appears in Appendix C. For the purposes of this study, polyvinylsiloxane impressions were made of the teeth from which replicas were constructed and observed on the SEM. The results for this case will be published in the future.

9.5 RESULTS

The results are shown in tables 9.5.a and b. In addition, a series of photographs of the restorations in situ, and scanning electronmicrographs of the replica models, are used to illustrate some of the changes seen during the study. Some replica models had distinct spheres on the surface due to bubbles in the impression. These bubbles were possibly caused by "gassing" while the impression was setting. "Gassing" is the result of hydrogen gas production given off during the setting reaction of the polyvinylsiloxane impression material.

Figure 9.2.5.a.

Photograph of a recording impression from which a replica was made in Araldite D.

The yellow-orange material is the light-bodied polyvinylsiloxane and the green is the heavy body. Underneath is a small piece of cotton guaze which was placed onto the heavy body impression material before it set. This added further support to the impression after it set, in a similar fashion to fibre reinforcement.

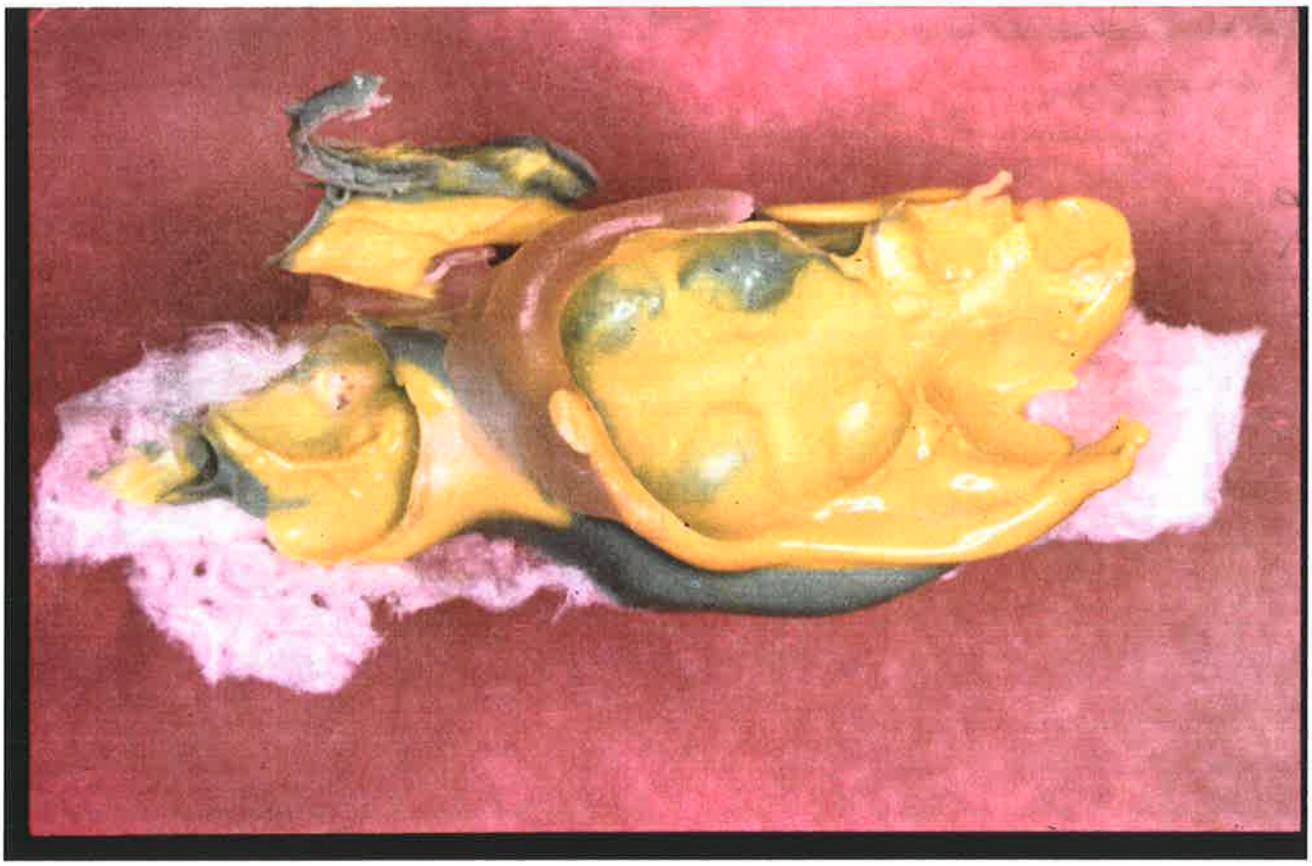


Table 9.5 a

Results of the in vivo pilot study for the behaviour of Dispersalloy, P-30, Herculite and Ketac-Silver.

Restoration Material	Numder Placed	Remaining at each 6 mth. recall 1st	2nd	3rd.
Dispersalloy	8	8	8	8
P - 30	8	8	8	8
Herculite	7	7	7	7
Ketac-Silver	3	3	2	2

Table 9.5.b

Results for staining, loss of anatomic form, bulk fracture and sensitivity at the 12 month review

Restoration Material	Stained margins	Loss of Anatomic Form.	Bulk Fracture	Sensit-ivity
Dispersalloy	-	-	-	-
P - 30	8	8	0	1
Herculite	4	3	1	0
Ketac-Silver	-	3	2	-

Figure 9.5.1.a, top view.

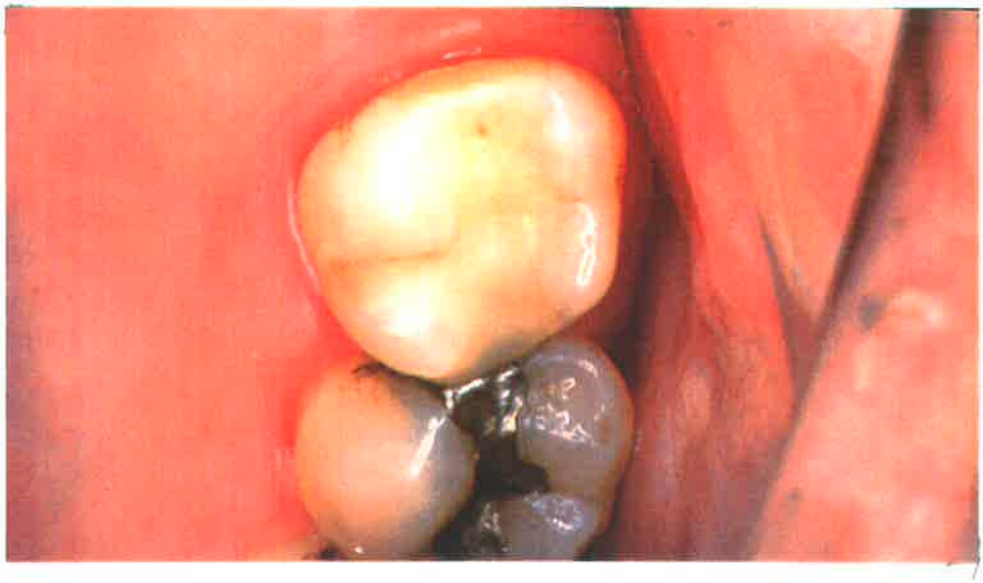
This restoration is seen at the six-month recall. It is a P-30 MOD restoration. The surface and margins have started to stain. A S.E.M. photomicrograph of the margin of this restoration at insertion can be seen in figure 9.5.1.n.

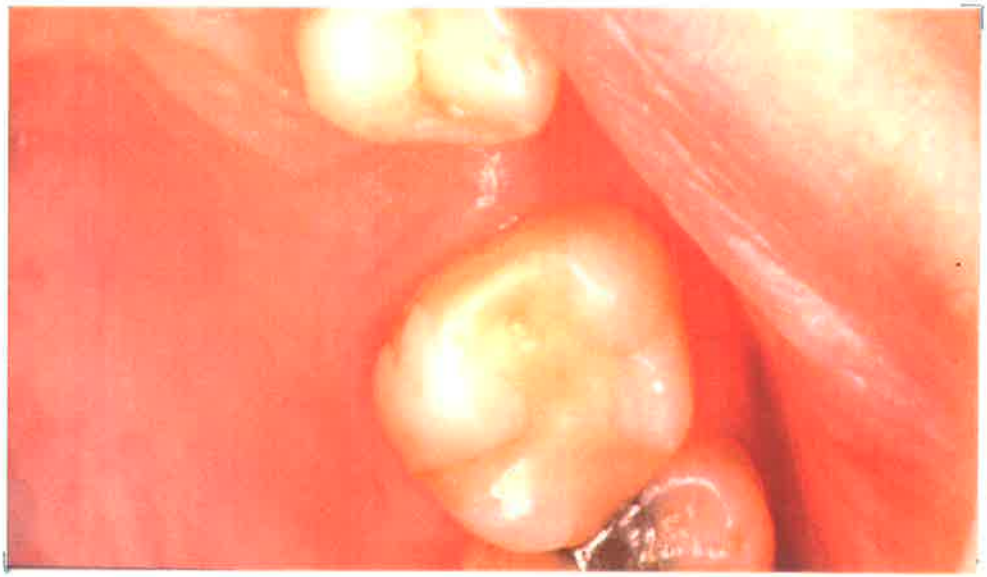
Figure 9.5.1.b, middle view.

The same restoration as above, at the twelve-month recall. The surface and margins are stained even further.

Figure 9.5.1.c, bottom view.

The eighteen-month recall for the same restoration as above, with even further deterioration. There is however, no bulk failure or any other clinical signs or symptoms to indicate failure of this restoration.





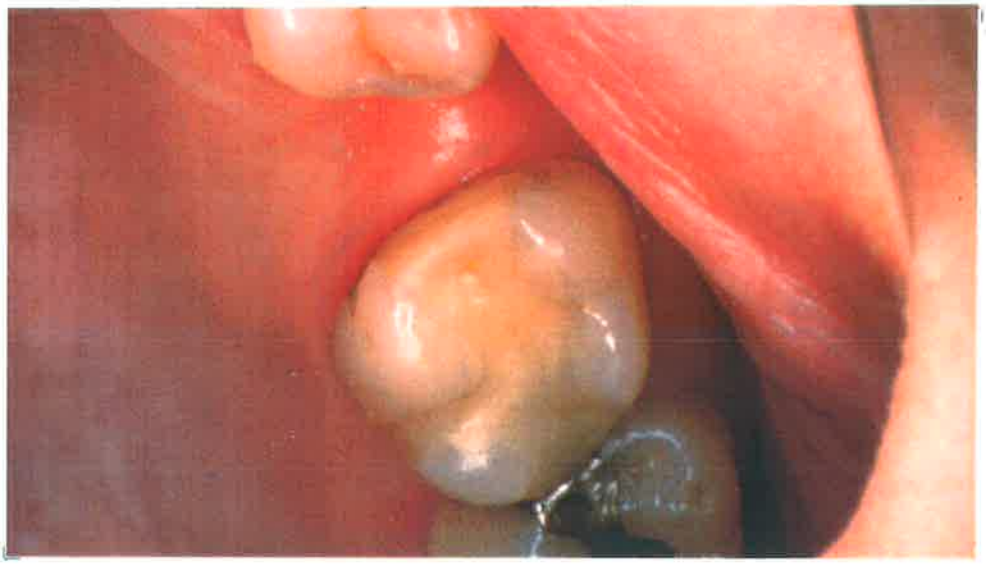


Figure 9.5.1.d, top view

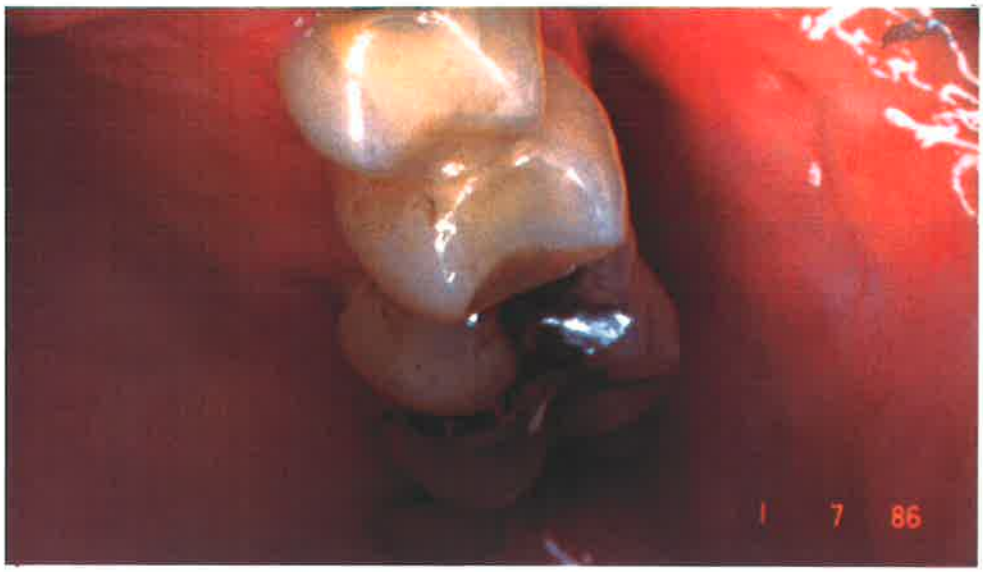
The photograph for this series of restorations was taken at the polishing appointment after insertion. The 27 (obscured) has had a MO Ketac-Silver restoration, the 26 has a MODL Dispersalloy restoration, the 25 and 24 have MOD Herculite restorations. The six-month recall did not show any significant deterioration.

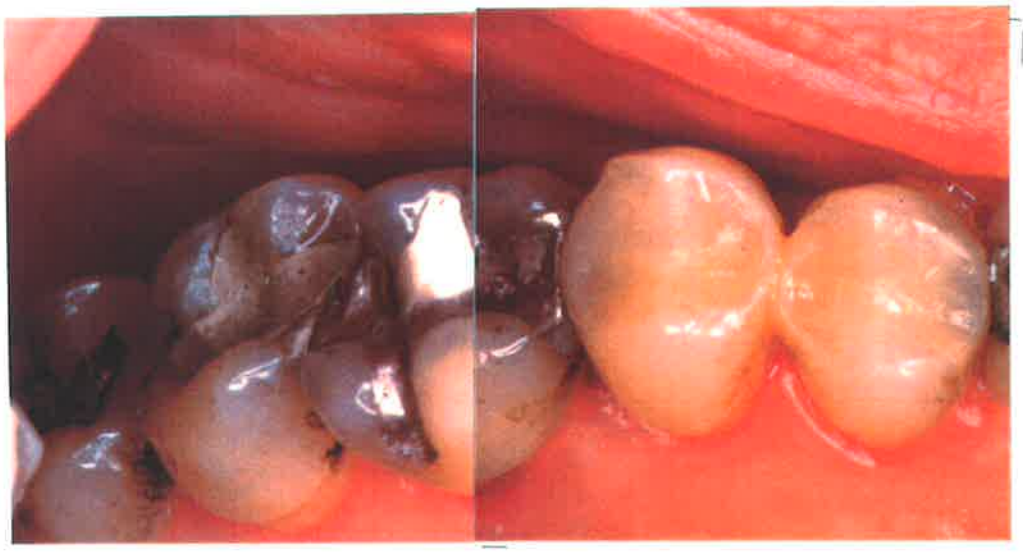
Figure 9.5.1.e, middle view.

This composite photograph was taken at the twelve-month recall, and showed a large bulk fracture of the mesio-lingual aspect of the marginal ridge of the Ketac-Silver restoration in the 27, and a smaller fracture in the distal marginal ridge of the Dispersalloy restoration of the 26. The restorations in the 24 and 25 demontrated some surface staining, but were in much better condition than the P-30 restoration in the 16, shown in figures 9.5.1.a, b and c. The restoration in the 27 was replaced at this recall with Dispersalloy.

Figure 9.5.1.f

This photograph was taken at the eighteen-month recall. As with the previous photograph, the Dispersalloy of the 26 has deteriorated, but the surfaces of the 24 and 25 are still good. The 25 does however have some small occlusal wear marks, (figure 9.5.1.o).


1 7 86



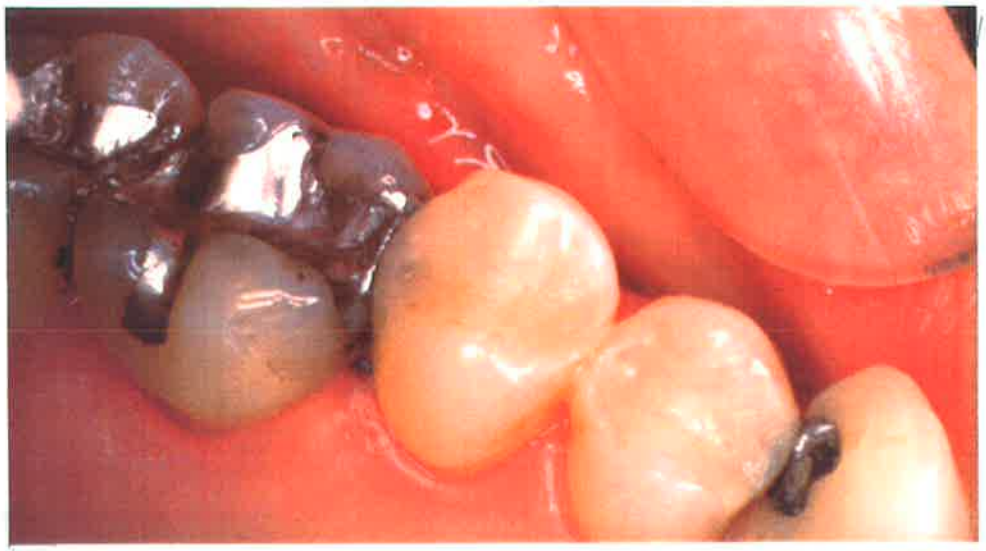


Figure 9.5.1.g, top view.

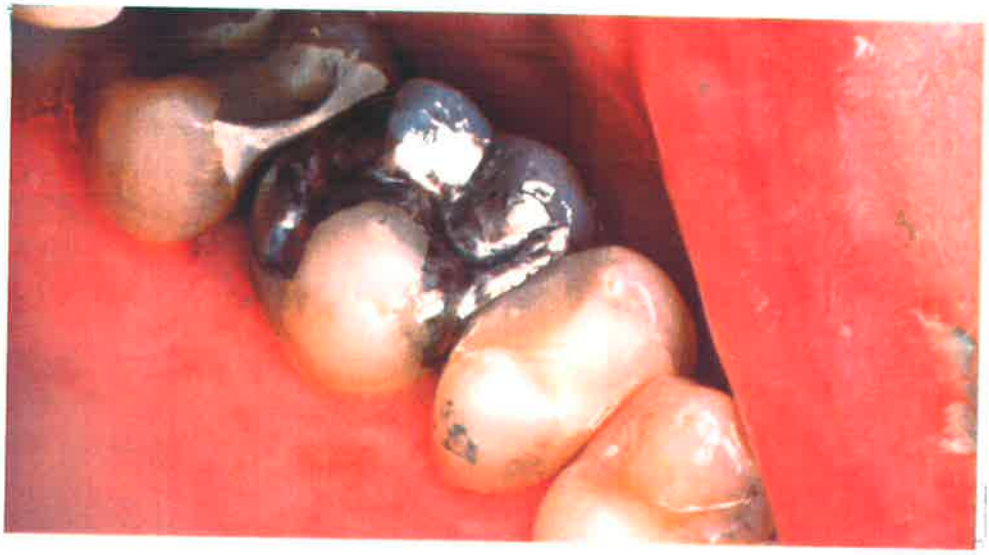
This photograph was taken at the polishing appointment after insertion of the restorations in this quadrant. The 27 was restored with a MO Ketac-Silver, the 26 was restored with a MODL Dispersalloy amalgam, and the 25 was restored with a MOD Herculite posterior composite. There is a large, sub-surface porosity in the distal marginal ridge of the composite which to date has not developed any communications with the surface.

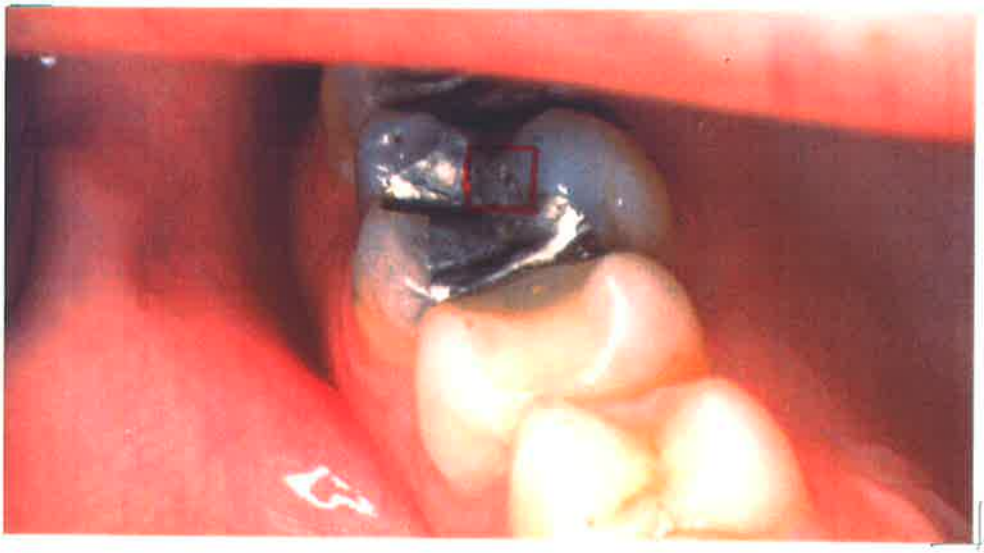
Figure 9.5.1.h, middle view.

This photograph is taken of the same series as above at the twelve-month recall. The only significant feature was the beginnings of significant marginal corrosion and breakdown with the amalgam. The area outlined in red appears in the scanning electron micrograph in figure 9.5.1.j.

Figure 9.5.1.i, bottom view.

This photograph is taken of the same series as above, but at the eighteen-month recall. The significant features are the considerable loss of form and fracture of the Ketac-Silver and loss of amalgam on the distal marginal ridge of the 26, (figure 9.5.1.k). The mesial marginal ridge of the 25 also had a bulk fracture, which was a thin section of restorative material overextended past the cavo-surface margin. This is seen more clearly in figures 9.5.1.l and m.





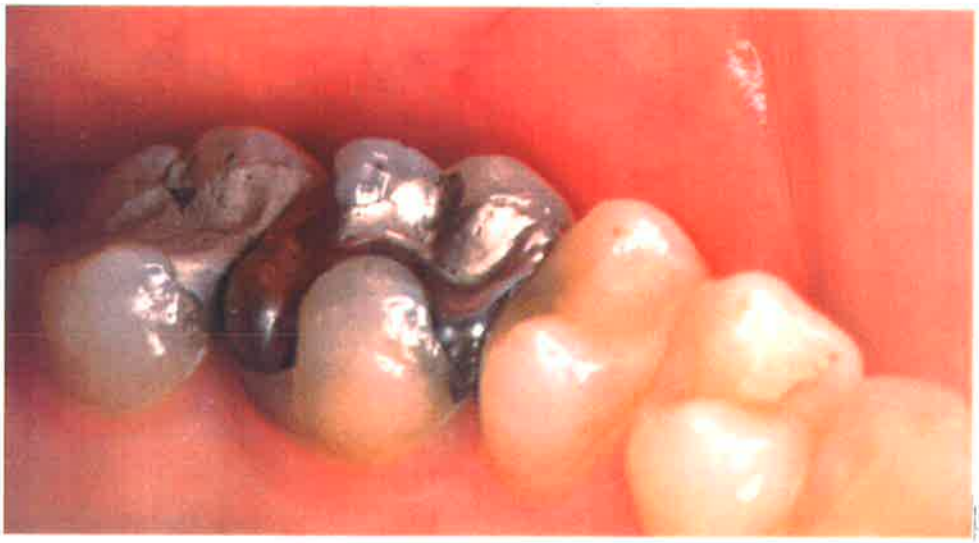
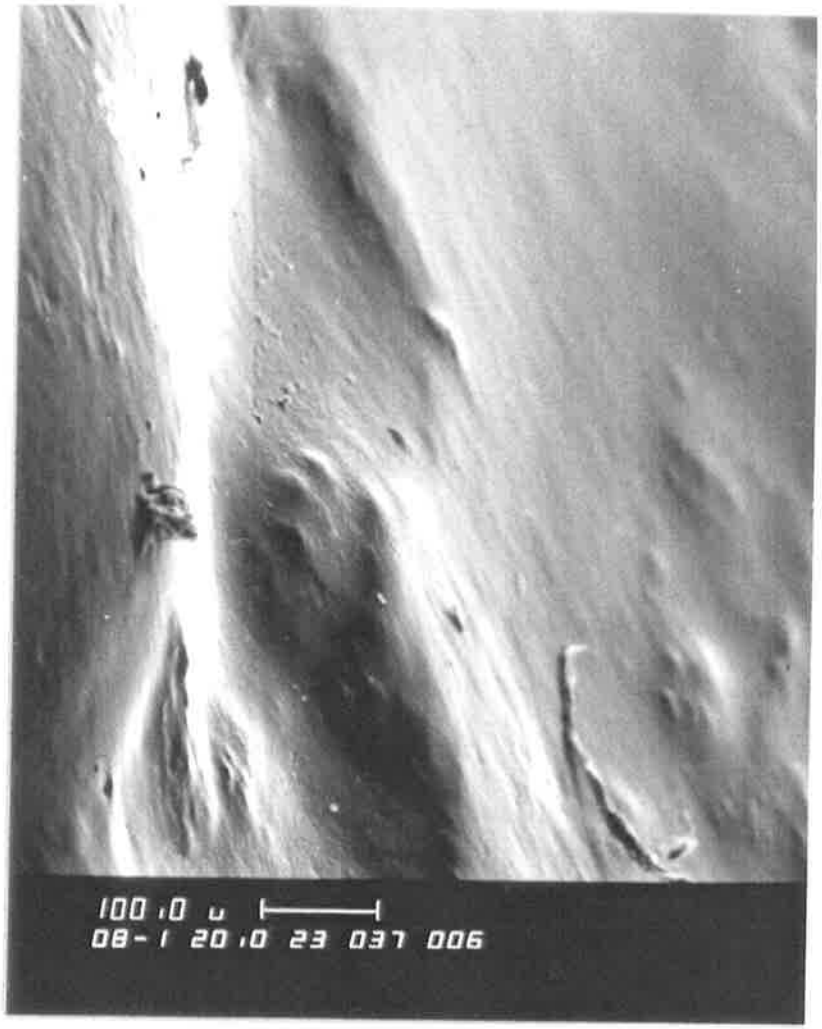


Figure 9.5.1.j, top view.

Fractured and abraded amalgam margin of the 26. This photomicrograph was taken from the area outlined in red in figure 9.5.1.h. at the twelve-month recall. Magnification : X 80.

Figure 9.5.1.k, bottom view.

Scanning electron micrograph of the fractured distal marginal ridge from the 26 shown in figure 9.5.1.i, taken at the eighteen-month recall. Magnification : X 20.


100.0 u
08-1 20.0 23 037 006

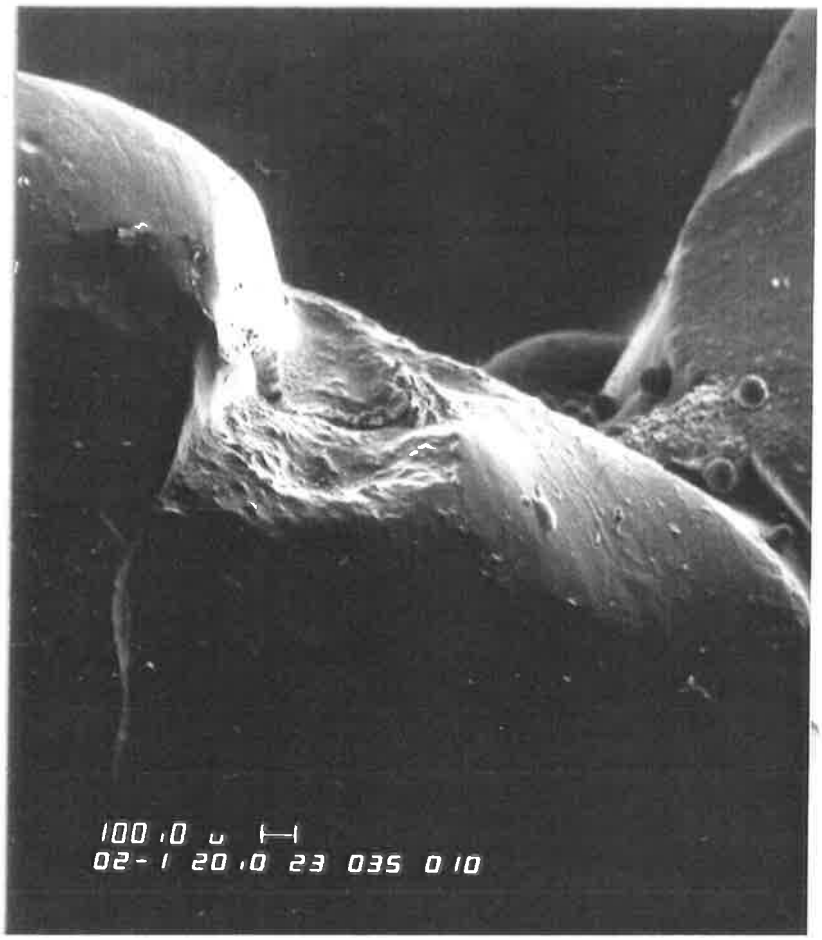
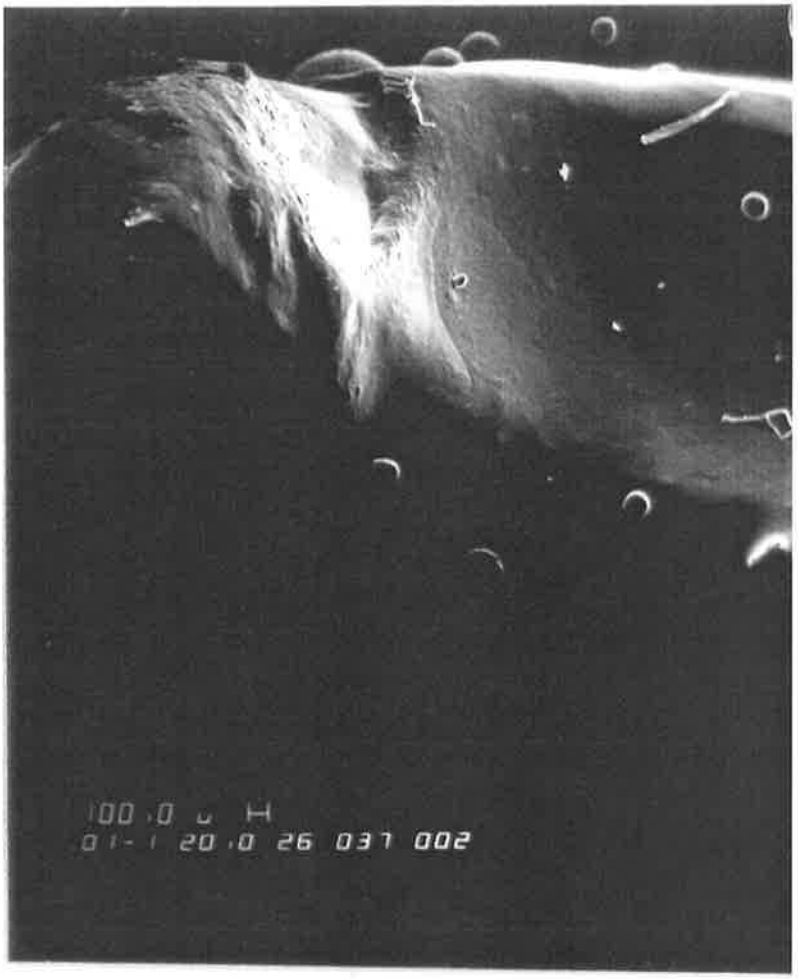

100.0 u
02-1 20.0 23 035 010

Figure 9.5.1.l, top view.

Scanning electron micrograph of the mesial marginal ridge of the 25, (figure 9.5.1.i), taken at the eighteen-month recall. This shows the bulk fracture of a thin section of composite which was extended beyond the cavo-surface margin. Magnification : X 10.

Figure 9.5.1.m, bottom view.

Scanning electron micrograph of the mesial marginal ridge of the 25, (figure 9.5.1.i), taken at the eighteen-month recall. A higher powered view of the fracture seen in the figure above. Magnification : X 50.


100.0 u H
01-1 20.0 26 037 002

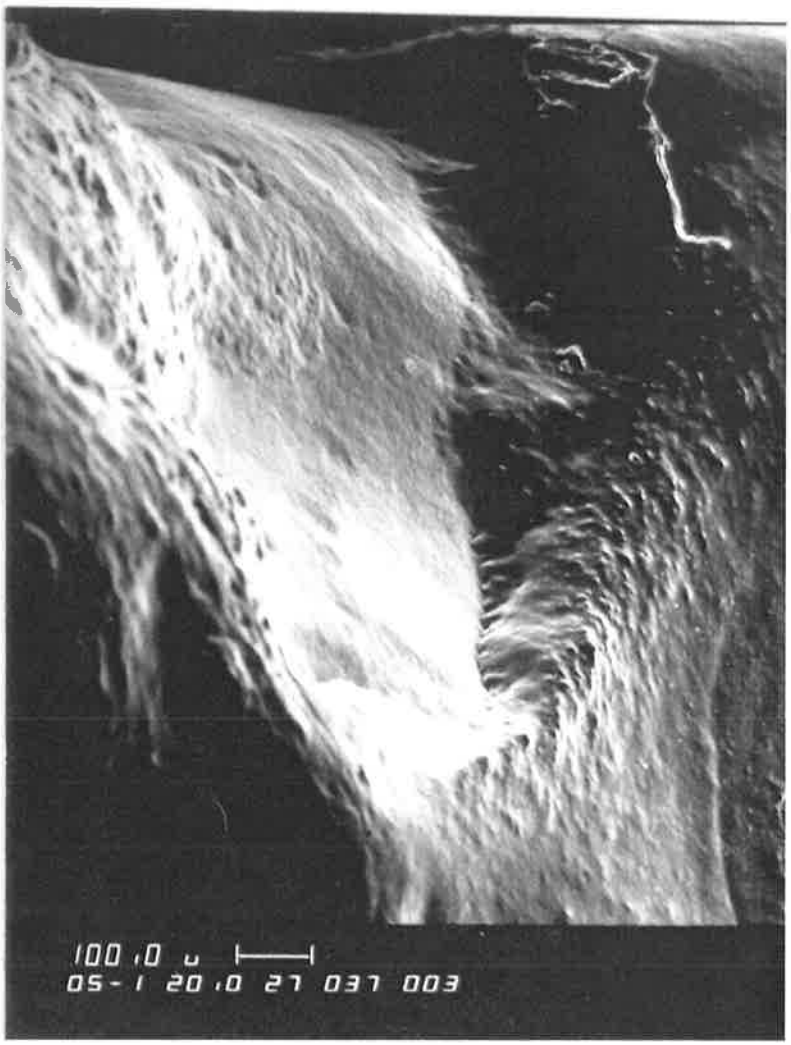

100.0 u
05-1 20.0 27 037 003

Figure 9.5.1.n

Scanning electron micrograph of the margin of the P-30 restoration seen in figure 9.5.1.a, b and c. The surface in this photograph was finished with a Shofu Quasite finishing point. The structure on the left is enamel and the rougher surface on the right is the resin restoration. Magnification : X 100.

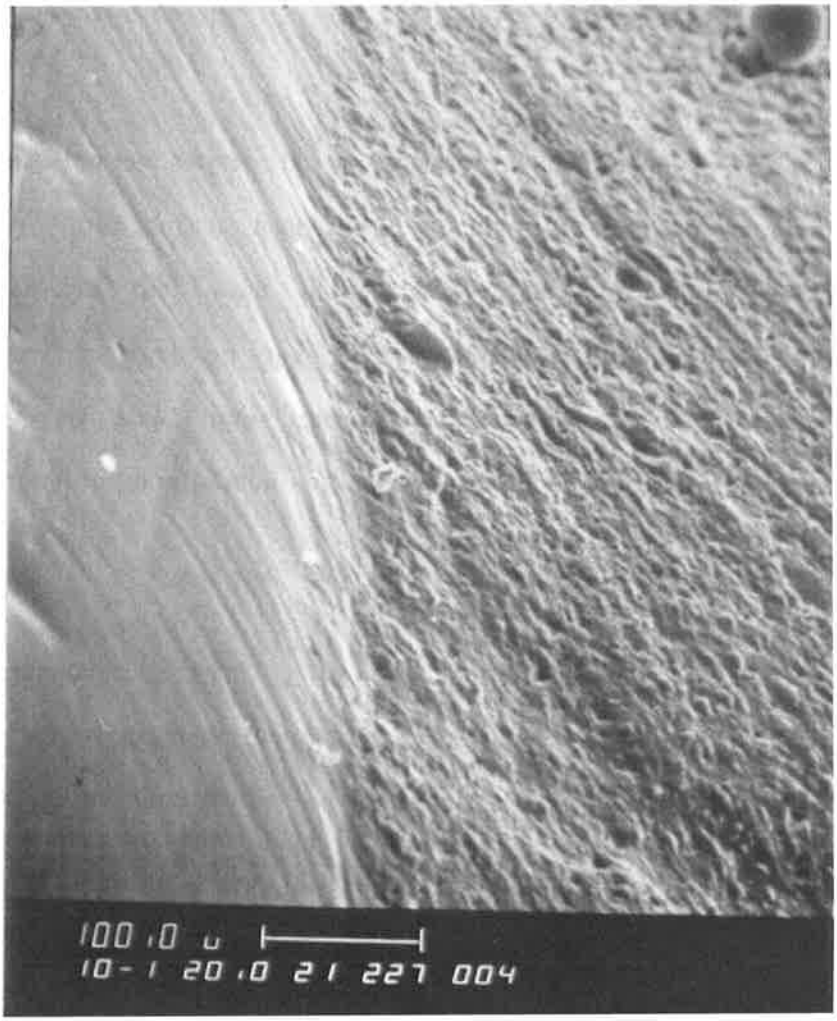
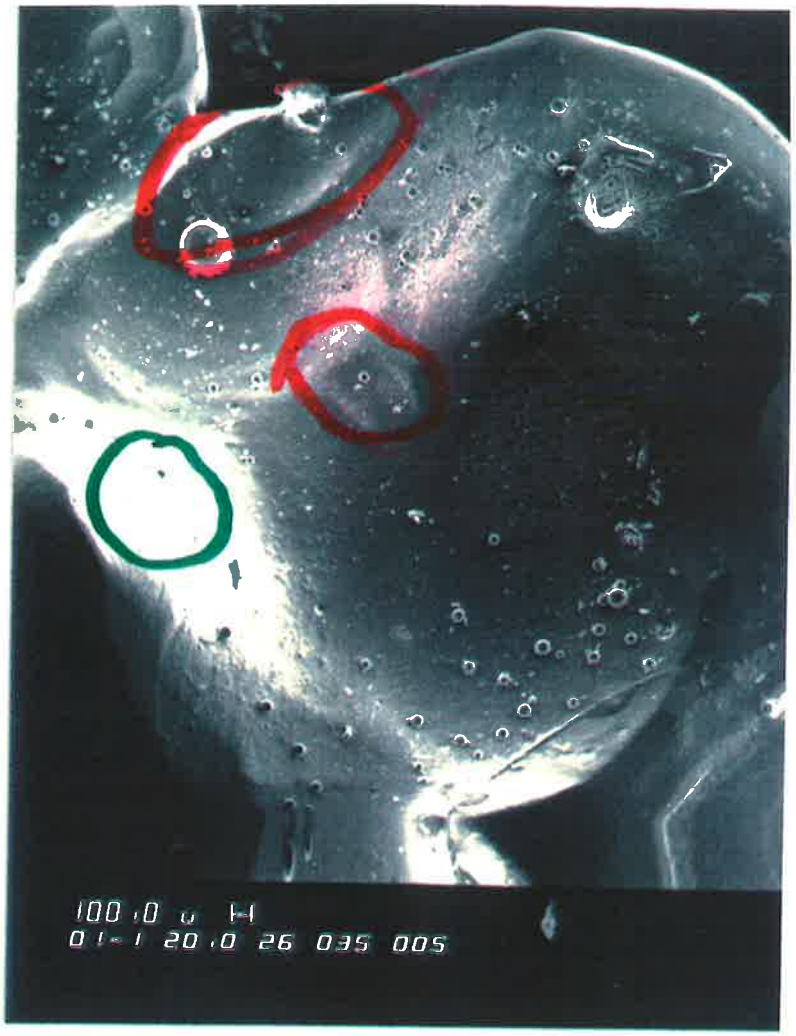

100.0 u
10-1 20.0 21 227 004

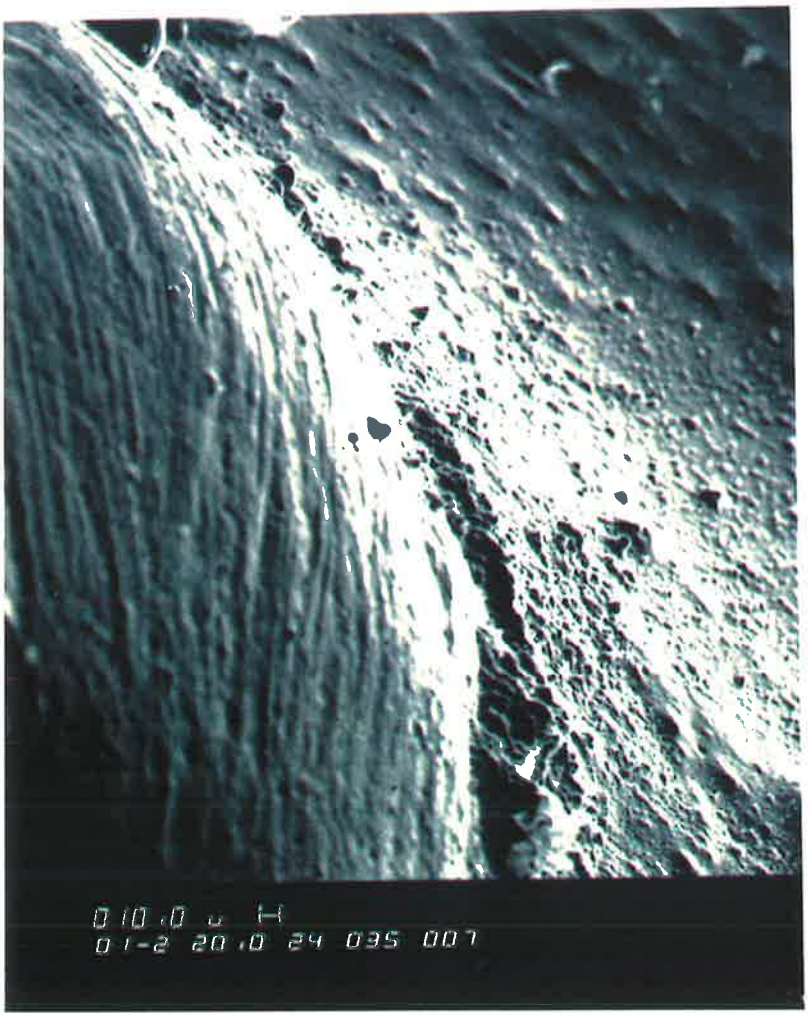
Figure 9.5.1.o, top view.

Scanning electron micrograph of the surface of the Herculite restoration in the 25, seen previously in figure 9.5.1.f. The wear marks are outlined in red. Magnification : X 10.

Figure 9.5.1.p, bottom view.

Scanning electron micrograph of the surface of the Herculite restoration in the 25. This view shows the extent of the marginal deterioration in the area outlined in green in the figure above. This micrograph is the same magnification as that seen in figure 9.5.1.n. At eighteen months, this margin is a little rougher than the P-30 margin at zero months. However the adjacent occlusal surface is far superior. Magnification : X 100.


100.0 μ H
01-1 20.0 26 035 005


010.0 μ H
01-2 20.0 24 035 007

9.6 DISCUSSION

Although the sample size for this pilot study is relatively small, it did serve to highlight a number of technique sensitivities in the placement of Class I & II resin restorations.

The results indicate a need to be cautious when using Ketac-Silver for Class II cavities. This material demonstrated a higher degree for loss of form and marginal ridge fracture than the other materials. Clinically , however, this is a very convenient material to use in minimal Class I and V situations.

The posterior resins had not shown any complete failures at the completion of this report. There is a difference between the two materials used, particularly for surface roughness and staining. This is possibly due to the filler particle size difference. The smoother material, Herculite, has an average particle size of 0.6 µm, whilst P-30 has an average particle size of 3.5 µm[38]. The difference becomes even more apparent when looking at the particle size distribution for the two materials. P-30 has a particle size breakdown that includes; 17% between 10 and 50 µm, 68 % between 1 and 10 µm and 23 % up to 1 µm ; while Herculite has 24 % between 1 and 10 µm and 76 % of the particle size, less than 1 µm.

This major difference in particle size distribution is possibly responsible for the difference in staining and surface roughness seen between the two restoratives. Progressive increases in staining of both the open surfaces and the margins, were seen throughout the duration of the study, although none warranted replacement at any stage.

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[38] Information is from the manufacturer's literature.

Thin sections of posterior composite in occlusal stress bearing areas do appear to be subject to fracture. This would indicate that insufficient bulk of material which could be caused by bevels, should be avoided in these areas.

Most of the restorations observed demonstrated some loss of anatomic form. This ranged from minor progressive even surface loss, to quite heavy losses seen in the Class II Ketac-Silver restorations. In addition, all the materials demonstrated bulk fractures of some kind. These fractures are probably related to the angle at the cavosurface margin, particularly in the occlusal areas. A method for verifying this would be to take a polyvinylsiloxane impression of the cavity after preparation and prior to placing the filling. This could then be compared with the replica impressions of restored teeth, and areas where the restoration has chipped at the margin could then be related to the cavo-surface angle. A correlation could then be undertaken to see if thinner restortives at the margin were the problem and what other factors, such as the occlusion, were to blame. The one Herculite restoration which did not show any appreciable wear was placed in a fashion designer/seamstress bruxist, who wears an occlusal splint most of the time because she has a persistent daytime habit of lightly grinding her teeth while working. This person also demonstrated a lower loss of material from a Class I Ketac-Silver restoration.

Porosity was a feature of all the restoratives, with Ketac-Silver being by far the worst. An example of the open porosities after some occlusal wear can be seen in the occlusal surface of the restoration of the 27 in figure 9.5.1.e.

9.7 CONCLUSION

The conclusion that can be drawn from this limited data so far, is that posterior composite restoratives need to be used with caution because they are subject to staining, marginal leakage, abrasion and wear, loss of substance due to breakdown and are limited in their overall physical properties. It is therefore recommended that they only be used in conservative Class I and II situations where the size can be kept minimal. Ketac-Silver was not an ideal material to be used in conventional Class II situations. All materials used in this study showed some degree of deterioration over the short time that they were monitored.

Aesthetically the smaller particle filled composite Herculite, appeared to be better than the larger particle filled composite P-30, and both were considered to have better aesthetics than the amalgam or the glass-ionomer, Ketac-Silver.