Gallium alloy versus high copper amalgam: a comparative evaluation of corrosion resistance and microleakage in the primary teeth

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In vivo *corrosion and* in vitro *microleakage of a gallium based and a high copper amalgam alloys were evaluated. Twenty-five primary molars each were restored with Galloy and DPI alloy respectively and evaluated, over a period of three months, for various aspects of corrosion in the oral cavity. Additionally ten primary molars were utilized for evaluation of microleakage by dye penetration after having them restored with the two materials. Gallium alloy restorations showed better marginal adaptation, clinically when compared to amalgam restorations. No significant difference was observed for the degree of microleakage around gallium alloy and amalgam restorations.*
J Clin Pediatr Dent 24(4): 315-319, 2000

INTRODUCTION

Dental Amalgam has served as an excellent and versatile restorative material for many years despite the periods of controversy. The ease of manipulation, cost effectiveness and durability are the main reasons for the success of this material. Several times since the introduction of amalgam restoration to the United States in the 19th century, the public has expressed concern about the use of mercury in dental amalgam.[2]

However, drawbacks to amalgam restoration include: lack of adhesion to the mineralized tissues, lack of esthetics and the unavoidable use of mercury, which may be regarded as harmful component to the patients health.[3] Although there is evidence to support the view that the amount of mercury to which, patients and practitioners are exposed during the placement, removal and function of dental amalgam restoration is within currently acceptable limits. However, the argument that any exposure to mercury is unacceptable is rapidly gaining momentum.[4]

In a report from the National Board of Health and Welfare of Sweden, it was asked whether amalgam is recommendable restorative material. It was suggested that efforts should be made to develop a new filling material. A metallic material having the advantage of amalgam without any mercury content could be an attractive alternative.[5]

Gallium was first recognized, as early as 1928 by A. Puttkammer, as a substitute for mercury in amalgam. Further studies from 1950-1956 by Smith and Caul showed the potential for the use of gallium in a dental restorative system.[6] Gallium is a metal that has the second lowest Melting point (29.75˚C) next to mercury (-38.87˚C). To assist alloying at room temperature, the gallium should be liquid, which can be achieved by addition of other metals such as Indium.[7]

Waterstrat[7] in 1969 introduced gallium-palladium-tin alloys, which were shown to be superior to amalgam in terms of marginal seal and resistance to flow at mouth temperature and had a thermal expansion comparable to the human teeth. Recently, new Gallium based alloys, (Gallium Alloy GF®, Tokuriki Honten, Tokyo, Japan and Galloy®, SDI, Victoria, Australia) have been introduced as direct metallic restorative alternatives to mercury based restorations. It was confirmed that the Galloy® was biocompatible and the material had no apparent harmful effects to the pulp in primary teeth. Hence, Galloy® could serve as a restorative material for primary molars until the replacement by permanent teeth.

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The physical properties of Gallium alloy such as compressive strength, tensile strength, creep, hardness and wear have been found to be comparable to those of amalgam.[1,4] The corrosion resistance of gallium alloy is inferior to high copper amalgam, the durability of this alloy as dental restorative is not expected to be as good as that of amalgam.[9]

This study was designed to examine the clinical performance and *in-vivo* corrosion behavior of a commercially available gallium alloy, Galloy®, when placed in primary molars and *in-vitro* evaluation of microleakage as compared to a control with high copper amalgam restorative material.

MATERIALS AND METHODS

The restorative materials used in this study were gallium alloy (Galloy® SDI, Victoria, Australia) non gamma-2 amalgam alloy (DPI Alloy, DPI, Mumbai, India), methylene blue, 5 grams.

Sixteen children, seven boys and nine girls, between the ages of 5 to 7 years were selected for this study. These children were selected from those attending, The Department of Pedodontics and Preventive Dentistry in A.B. Shetty Memorial Institute Of Dental Science for routine dental treatment. The children were in good health and had no medical complications.

Only those teeth requiring restoration with silver amalgam were selected. Each patient was in need of two to six restorations. Under standardized conditions, caries excavation and preparation of cavity, as for amalgam restorations were done for fifty teeth. Resin modified light cure glass ionomer cement [Fuji II. L.C. Glass Ionomer Cement] was used as cavity base for all the restorations. Twenty-five Galloy® restorations and twenty-five DPI Alloy® restorations were done according to the recommendations of the manufacturers.

On the day of restoration, the restorations were examined using a mouth mirror and an explorer. The restorations were appraised subjectively for (1) luster, (2) surface texture (3) marginal breakdown and (4) tooth discoloration at the margin. The criteria, which were established for evaluation of each of these characteristics, are provided in Table 1.[10]

The patients were recalled for examination after a period of six weeks and twelve weeks respectively. Of the sixteen children initially involved in the study, thirteen returned. These children provided a total of forty restorations for evaluation.

The restorations were blindly evaluated by three examiners. The same examiners were employed throughout the study. Kendall coefficient of concordance with correlation between the three examiners showed that there was a strong agreement in their findings. Hence, first observer's readings were taken and subjected to students unpaired 't' test to compare the four criteria assigned for Galloy® and amalgam.

MICROLEAKAGE STUDY

Ten unrestored primary molars, which were collected from various private dental clinics were utilized in this study. These were free of any observable fracture lines. The teeth were stored in saline after extraction, and later mounted in aluminum rings containing acrylic, where in only half of the root was embedded. The teeth were embedded parallel to the long axis of the ring.

Class V cavities were prepared on the buccal surface of all the teeth maintaining uniform depth of 1.5mm. The prepared samples were divided randomly into two groups of five teeth each. Group I teeth with standardized Class V cavity restored with gallium alloy. Group II teeth with standardized Class V cavity restored with silver amalgam.

Water was used as the medium for thermocycling and the samples were cycled through baths of 5˚C ± 1˚C and 55˚C ± 1˚C with a dwell time of 5 seconds and run through 100 cycles and followed by drying the specimen with blotting paper.

Methylene blue, 5% dye solution was prepared. Prior to immersion, the teeth were thoroughly dried with blotting paper and the tooth surface were then coated with nail varnish except the area of restoration with one millimeter margin all around. The specimens were then immersed in the dye solution for 24 hours at room temperature.

The specimens were later sectioned longitudinally into two halves in mesiodistal direction using a standardized diamond disc, under running water. One half of each specimen was used to assess microleakage using the dye method.

The extent of dye penetration was observed under light microscope with a magnification of 10 x 10 [Polyvar-2 Reichert Jung] using the grades[11] [Table-2].

The microleakage was also observed and scored by three observers with the same grading scale. Kendall coefficient of concordance with correlation between the three evaluators showed there was a strong agreement in the findings. Hence, the first readings were taken and subjected to Mann-Whitney 'U' test to compare the microleakage seen around Galloy® and amalgam restorations.

Table 1. Rating criteria for surface characteristics examined

Characteristic	Scoring Criteria	Assigned Value
Luster	Severely discolored	1
	Darkened	2
	Dull	3
	Little or no change	4
Surface Texture	Rough and pitted	1
	Rough	2
	Slight roughness	3
	Smooth	4
Marginal Breakdown	Ditching to DEJ	1
	Visible ditching	2
	Alight catch with explorer	3
	No catch with explorer	4
Tooth discoloration at interface	Severe	1
	Moderate	2
	Slight	3
	No discoloration	4

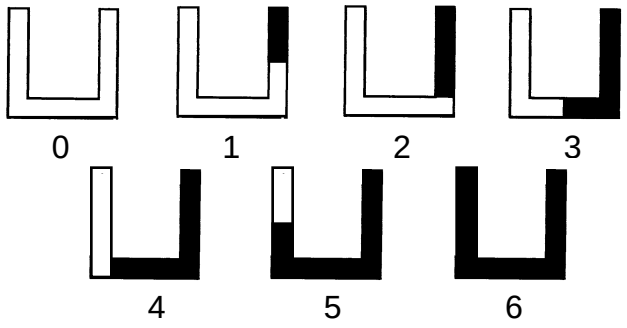

TABLE 2. Scoring Criteria for Dye Penetration

Grade 0 - No evidence of dye penetration.

Grade 1 - Dye penetration less than or up to half of one wall.

Grade 2 - Dye penetration more than half of one wall but not involving the floor.

Grade 3 - Dye penetration involving one full wall and less than half of the floor.

Grade 4 - Dye penetration involving one full wall and more than half the floor, but not involving the other wall.

Grade 5 - Dye penetration involving one wall, floor and part of other wall also.

Grade 6 - Dye penetration involving both the walls and the floor.

OBSERVATIONS

Interexaminer variability was checked by the Kendall coefficient of concordance in Tables 3 and 4 for Galloy® and amalgam restorations respectively. The 'W' values indicate a strong agreement between the scores given by the three examiners. Thus readings given by Examiner-I were taken for further analysis.

Table 3. Inter-examiner Variability for Gallium Restorations.

Surface Characteristics of Galloy® Restorations	Kendall Coefficient of Concordance 'W'		Chi Square (Test of Significance)	Remarks
Luster	W = 0.2857	x2 = 4.00	p > 0.05	N.S*
Texture	W = 0.3714	x2 = 5.20	p > 0.05	N.S
Marginal Breakdown	W = 0.2580	x2 = 3.85	p > 0.05	N.S
Tooth Discoloration	W = 0.0357	x2 = 0.50	p > 0.05	N.S

*NS = Not Significant

Table 4. Inter-examiner Variability for Amalgam Restorations.

Surface Characteristics Amalgam Restorations	Kendall Coefficient of Concordance 'W'		Chi Square (Test of Significance)	Remarks
Luster	W = 0.1143	x2 = 1.60	p > 0.05	N.S*
Texture	W = 0.1143	x2 = 1.60	p>O.05	N.S
Marginal Breakdown	W = 0.1443	x2 = 1.82	p >0.05	N.S
Tooth Discoloration	N = 0.0000	x2 = 0.00	p > 0.05	N.S

*NS = Not Significant

Table 5 shows the mean and standard deviation grades of the four characteristics observed for Galloy® and amalgam restorations respectively.

Table 6 shows the comparison of the four surface characteristics observed for Galloy® and amalgam applying students unpaired 't' test: Marginal breakdown was observed to be significantly greater in the silver amalgam restorations as compared to Galloy® restorations. No significant differences were observed when comparing the luster, texture and tooth discoloration immediately after restorations, and during the observation period for both the amalgam and Galloy® restorations.

Table 7 shows comparison of the microleakage scores given by the three observers using Kendall coefficient of concordance. The 'W' values indicate a strong agreement between the scores given by the three observes. Thus, readings given by observer - 1 was taken for further analysis.

Table 8 shows comparison between the microleakage that had occurred around Class V Galloy® and amalgam restorations. The result indicates no significant difference in the degree of microleakage around both the Galloy® and amalgam restorations.

Table 5. Mean and Standard Deviation Grades of Four Surface Characteristics Observed.

	Luster	Texture	Marginal Breakdown	Tooth Discoloration
Galloy®	3.25 ± 0.411	3.10 ± 0.553	3.05 ± 0.394	3.80 ± 0.410
Amalgam	3.05 ± 0.510	3.15 ± 0.366	2.80 ± 0.523	3.75 ± 0.444

Table 6. Test of Significance of Four Surface Characteristics

	't' value	Test of Significance	Remarks
Luster	1.370	p > 0.05	NS
Texture	0.338	p > 0.05	NS
Marginal Breakdown	2.055	p < 0.05	S*
Tooth Discoloration	0.370	p > 0.05	NS

* S = Significant

Table 7. Inter-examiner Variability for Microleakage Study.

	'W' value	Test of Significance	Remarks
Galloy	W = 0.00	x2 = 0 p > 0.05	NS
Amalgam	W = 0.25	x2 = 3 p > 0.05	NS

Table 8. Comparison of the Microleakage around Gallium and Amalgam Restorations.

	'Z' value	Test of Significance	Remarks
	0.627	P > 0.05	NS

Table 9. Mean and Standard Deviation Grades of Four Surface Characteristics Observed.

	Luster	Texture	Marginal Breakdown	Tooth Discoloration
Galloy®	3.25±0.411	3.1±0.553	3.05±0.394	3.8±0.41
Amalgam	3.05±0.51	3.15±3.66	2.8±0.523	3.75±0.444

Table 10. Test of Significance of Four Surface Characteristics.

	't' value	Test of Significance	Remarks
Luster	1.37	p>0.05	NS
Texture	0.338	p>0.05	NS
Marginal Breakdown	20.55	p>0.05	S*
Tooth Discoloration	0.37	p>0.05	NS

* S - Significant

Table 11. Inter-Examiner Variability for Microleakage Study.

	'W' value	Test of Significance	Remarks
Galloy	W = 0	$x^2 = 0$ p>0.05	NS
Amalgam	W = 0.25	$x^2 = 3$ p>0.05	NS

Table 12. Comparison of the Microleakage Around Gallium and Amalgam Restorations.

'Z' value	Test of Significance	Remarks
0.627	p>0.05	NS

DISCUSSION

Currently the clinical studies performed on gallium based alloys were with gallium alloy G.F® [2,12,13] Very few clinical studies were done with Galloy® in the primary teeth.

The present study was performed both *in vivo* and *in vitro* comparing Galloy® and high copper amalgam keeping corrosion and microleakage as parameters for evaluation.

Method of clinical evaluation for corrosion resistance was adapted from Duperon.[10] In our study the surface characteristics like luster, texture and tooth discoloration for both the materials were equally good and showed no statistically significant differences. The Galloy® restorations showed better marginal adaptation than amalgam restorations when statistically analyzed The result of this assessment are in conformity with the observations of Osborne and Berglund.[1,14]

Under the conditions outlined during the short time of 3 months, no major problems with Galloy® restorative system were confronted. The surface of the restorations were rough indicating no sign of self polishing and the lack of luster was in explanation with the resistance of material to wear.

Dye penetration study was employed for *in vitro* microleakage detection, which statistically showed no significant difference in the degree of microleakage between the two materials. Though excellent microleakage profile of Galloy® as compared to amalgam was exhibited by Winkler,[15] this was not noticed in the current study.

As experienced during earlier research, the handling of Galloy® was difficult because of the wetting properties. This characteristic made the material stick to all the condensing and carving instruments, but could be easily cleaned off. The fresh mix of Galloy® was initially very plastic, but quickly became somewhat difficult to handle. As it is obvious, the main advantage of the material is the elimination of exposure of children to mercury when compared with the mercury exposure they might receive from amalgam. The Galloy® has the same esthetic problem as amalgam.[9]

A long-term clinical evaluation may be necessary for the wider and universal use of this material as a substitute to silver amalgam.

SUMMARY AND CONCLUSION

The salient features of this study may be summarized as:

1. No significant differences were observed when comparing the luster, texture and tooth discoloration immediately after restoration and during the observation period for both the amalgam and Galloy® by restorations.
2. Clinically the marginal adaptation was observed to be significantly better in the Galloy® restorations as compared to the amalgam restorations.
3. The degree of microleakage around Galloy® and amalgam restorations showed no significant difference.

The clinical performance of Galloy® was equally good when compared to high copper amalgam during the observation period.

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