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COMPARISON OF IMPACT STRENGTH & MICROHARDNESS OF FOUR DIFFERENT COMMERCIALLY AVAILABLE ACRYLIC DENTURE TEETH- AN IN VITRO STUDY

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Abstract:

This study aims to investigate the impact strength and mirohardness of four different commercially available acrylic denture teeth- Premadent (Super dental products, India), Acryrock (Ruthinium), Quest (Quest dental material corporation, Aichi, Japan), Resistal (Industrias dentales ltda, P O box-816, Medellin, Colombia South America). Four different brands of acrylic teeth are grouped as Group-A: Premadent, Group-B: Acryrock , Group-C: Quest , Group-D: Resistal . 10 maxillary right central incisor were taken for testing impact strength and 10 mandibular right first molar teeth were taken for micro hardness test in each of the four groups. So total number of samples were (40+40) = 80. Testing of the prepared samples was done with the help of ZWICK Izod Impact tester (GERMANY) & Vickers micro hardness tester (LECO, MODEL NO LV 700, USA).

Descriptive statistical analysis was performed to calculate the means with corresponding standard deviation. Also One Way Analysis of variance followed by post hoc Tukey's Test was performed with the help of Critical Difference at 5% and 1% level of significance to compare the mean values of more than two groups. $p<0.05$ was taken to be statistically significant.

Vickers Micro Hardness of Resistal (Group D) was the lowest of all and that of Quest (Group-C) was the highest of all.
One way Analysis of variance showed that there was significant difference in Vickers Micro Hardness of the four groups ($F_{3,36}=88.98;p<0.0001$).
The Impact strength value of Group-C (Quest) was the lowest of all and Group-A(Premadent) was the highest of all.
One way Analysis of variance showed that there was significant difference in impact test value of the four groups ($F_{3,36}=4.98;p=0.0054$).

Key words:

Impact strength, Microhardness,

Izod impact test, Vicker's microhardness test.

INTRODUCTION:

A healthy dentition is of utmost importance for the wellbeing & improved quality of life[1] of an individual. The mouth reflects a person's health and well-being throughout life. Oral diseases can have an impact on many aspects of general health and health conditions can in turn have an impact on oral health. Despite advances in preventive dentistry, edentulism is still a major public health problem worldwide. Edentulism is a debilitating & irreversible condition. It can be either partial or complete. Sudden loss of teeth by accidental injuries, non-restorable situation and mobility which indicates only extraction, creates partial edentulism. Missing teeth impairs aesthetics, affects speech, efficacy in chewing and create psychological trauma. Prosthodontic rehabilitation is important to improve aesthetics, functions & integrity of stomatognathic system. Artificial teeth play an important role to restore function, aesthetics, speech, appearence & to set up a positive socio-psychological goal.

Artificial teeth are an inevitable part of denture. Ideal requirements[6] of artificial denture teeth should be durable bond with the denture base material, resistance to oral fluids/solvents, high heat-distortion temperatures, no permanent deformation under forces of mastication, high impact strength to withstand fracture teeth in case of accidental trauma or fall of denture especially in anterior teeth, high abrasion resistance with little or no wear to maintain the predetermined vertical dimension of occlusion and withstand parafunctional movements, aesthetically pleasing, colour stability, good surface texture, and ease of characterization to produce a natural appearance, easily adjusted and refined by grinding and easily polished. Many materials & techniques have been employed over the years for the fabrication of artificial tooth. Replacements for decaying or lost teeth have been made for thousands of years. Skillfully replacement of teeth were made as early as 700 B.C.E using ivory & bone.[2]

Alexis Duchateau (1774) was the first to fabricate porcelain teeth. Porcelain teeth exhibit superior aesthetic qualities, excellent colour stability, and high abrasion resistance as compared with resin teeth. But there are some disadvantages with porcelain teeth. A major drawback of porcelain teeth is their method of attachment to the resin bases. Detachment of porcelain teeth from the resin bases is a major drawback for these teeth. Porcelain teeth cause significant wear of opposing enamel and metallic occlusal surfaces. The teeth are quite brittle and easily crack or chip on impact. Higher density of Porcelain increases their weight. Mismatches in the coefficient of thermal expansion of porcelain and resins produce stresses in the resin base, which may lead to distortion of the bases & high cost.[6] Porcelain teeth are not kind to the underlying mucosa and residual alveolar bone.

In early 1930's Resin teeth were introduced & thereafter majority of prosthesis are constructed with acrylic resin teeth. Acrylic resin teeth have some advantages over porcelain teeth which includes chemical bonding with denture base material, less breakage, high resiliency, easy occlusal & proximal adjustments while making denture and after insertion on patient's mouth, less trauma to denture bearing areas, light weight.[3] However acrylic teeth have some unfavourable characteristics like susceptible to wear abrasion, less harder and toughness. Due to the advantages and cost effectiveness and availability of acrylic teeth it replaced porcelain teeth later and is still widely used for fabrication of denture.

Hardness is considered to be related to wear resistance & is most commonly examined mechanical property indicator for artificial tooth material. It has been observed that in the oral cavity posterior denture teeth wear faster than anterior teeth causing loss of vertical dimension of occlusion.[5]
Moreover Wearing away of denture teeth will affect both functions & aesthetics of a denture. As acrylic teeth are susceptible to wear abrasion so it wears away faster. wear resistance has an important role which is related to micro-hardness of acrylic teeth.[5]
Impact strength is useful to clinician, when selecting artificial teeth for the patients with, removable denture against natural teeth, neuromuscular abnormalities, para-functional activities, overdentures, implants and in old age individuals where accidental fall of dentures is common as there would be greater need of teeth with improved impact strength in these conditions.
This study can be useful to the clinicians when selecting artificial teeth for denture as there would be greater need of teeth with improved impact strength & hardness.
The purpose of the study was to evaluate the impact strength and microhardness of four different commercially available acrylic teeth- Group-A: Premadent, Group-B: Acryrock ,Group-C: Quest , Group-D: Resistal.

MATERIALS AND METHODS

This is an in vitro study of four different commercially available brands of acrylic teeth regarding their impact strength and micro hardness.

Testing of the prepared samples was done with the help of ZWICK Izod Impact tester (GERMANY) & Vickers micro hardness tester (LECO, MODEL NO LV 700, USA).

List of materials were used as followed: 1.Premadent cross linked acrylic teeth (Fig. no-1), 2.Acryrock cross linked acrylic teeth (Fig. no-2), 3.Quest full mouth set acrylic resin teeth (Fig. no-3), 4.Resistal cross linked acrylic teeth (Fig. no-4), 5.Elastomeric impression materials (Addition silicones)(Fig. no-5), 6.Dental plaster(Fig. no-6), 7.Modelling wax (Fig. no-6), 8.Heat cure acrylic denture base resin (Fig. no-7), 9.Epoxy resin and Hardener (Fig. no-8), 10.Vinyl gloves, 11.Mask.

List of instruments/ equipments were used as followed: 1. Rubber bowl(Fig. no-9), 2.Plaster spatula(Fig. no-9), 3. Wax knife(Fig. no-9), 4- Wax spatula(Fig. no-9), 5.Lecron carver(Fig. no-9), 6. Metallic scale(Fig. no-9), 7. BP blade (No-15)(Fig. no-9), 8. Digital caliper(Fig. no-9), 9. Scissor (Fig. no-9), 10. Micro torch(Fig. no-9), 11. Conventional heat curing denture flasks(Fig. no-10), 12. Denture trimming & polishing kit with trimming burs, stones, sand paper mandrels & polishing buff. (Fig. no-11), 13. Vibrator(Fig. no-12), 14. Vickers micro hardness tester (LECO, MODEL NO LV 700, USA)(Fig. no-13), 15. ZWICK Izod Impact tester (GERMANY) (Fig. no-14), 16. Automated polishing machine Struers, Labopol-5, Netherland (Fig-34).

Preparation of sample for Impact strength

Maxillary right central incisor was used from each of the four groups (10 samples in each group) to determine the Impact strength. An aluminium die having dimensions 60mm x 12.7mm x 12.7 mm was made (Fig. no-16). Addition silicone putty impression material (Photosil, DPI, India) was used for making an impression of the above mentioned aluminium die (Fig. no-17). After setting of addition silicone, the die was removed (Fig. no-18). Melted modelling Wax(DPI, INDIA) was poured in sufficient quantity to compensate the shrinkage of wax after setting. Wax block was allowed to cool down to room temperature & removed from the putty impression after 30 min (Fig. no-19 &20). A total number of 40 wax blocks were prepared, each having the dimensions (60 mm x 12.7 mmx 12.7 mm). 10 Right Maxillary central incisor teeth from each of the four selected brands of acrylic teeth (chosen for the study) were taken & embedded upon the base of the wax blocks in such a manner so that cervico-incisal distance of 10 mm from the middle of incisal edge to the highest cervical contour is visible after embedding for standardization (Fig. no-21 & 22). Wax blocks were polished and the samples were flasked & dewaxed. Heat cure acrylic resin (DPI,India) was mixed, packed & cured following manufacturer's instructions (Fig. no-23,24 & 25). After polishing the samples, they were numbered accordingly for easy identification i.e: Group-A- Sample no:1 to 10, Group B- Sample no:1 to 10, Group-C-Sample no:1 to 10, Group-D-Sample no: 1 to 10.

The ZWICK Izod Impact tester (GERMANY) was used for testing the Impact strength. The base of each sample was clamped vertically on a vise which was struck by the swing of pendulum released from a fixed distance (Fig. no-26). The steel striking nose fractured the teeth at impact site. All the specimens were tested using a 2-joule pendulum. Bucco-lingual width of specimens at fractured site was measured using digital calliper (Fig. no-27). Impact strength was determined by dividing the impact energy by the thickness of test specimen in mm at the site of fracture.

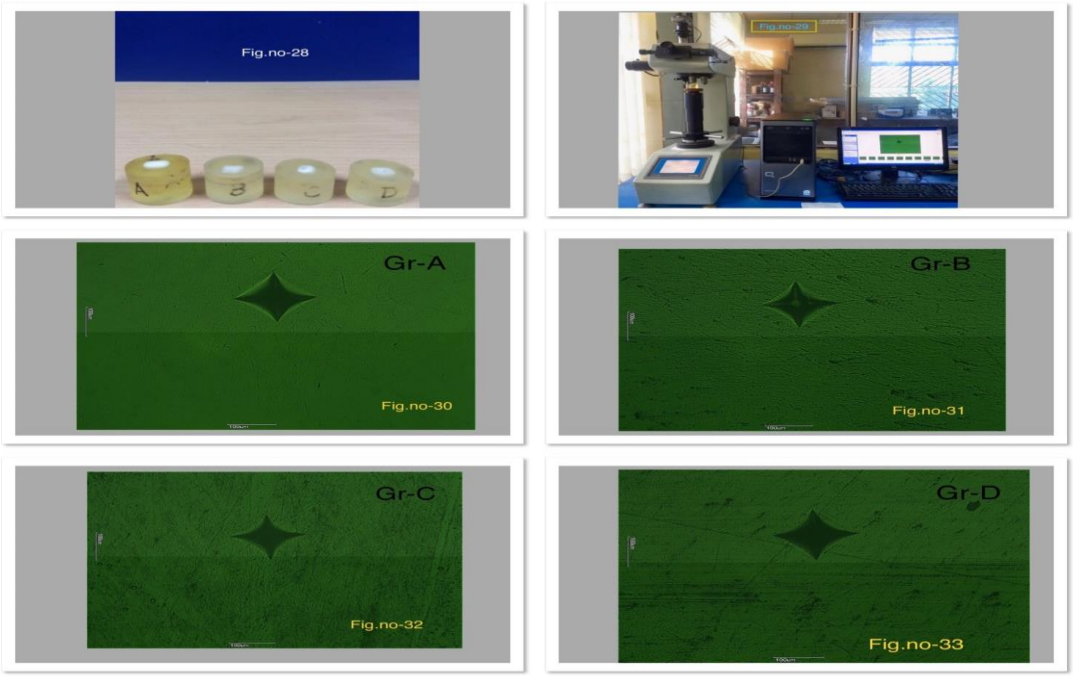
Preparation of sample for Micro hardness

10 mandibular right first molar teeth from each of the four groups (10 samples in each group) were taken for determination of micro hardness. A cylindrical metallic base former which comes as accessories with vicker's micro hardness testing machine with both end open, having inner radius of 1 inch, was used to prepare each of the sample (Fig no-28 & 35). Each molar tooth was taken and block out of the central fossa was done using modelling wax. Molar tooth was placed on a glass plate with their occlusal table facing the glass slab after application of separating media on glass plate. Metallic base former (mentioned previously) was then placed upon glass plate with the molar teeth at the center. Separating media was applied on the inner surface of the metallic base former for easy removal of prepared samples. Epoxy resin (lapox ultra, India) was mixed with hardener at a ratio of 10:1(Fig.no:8) & poured into metallic base former. After 24 hours from the time of pouring, each sample was retrieved by application of gentle manual pressure from it's metallic base former. Each sample was smoothened with automated polishing machine (Struers Labopol-5, Netherland, Fig no- 34) & polishing paste.

Removal of block out wax was done from the occlusal fossa of embedded molar (Fig. no-29). 10 samples from each of the four group (mentioned previously) were prepared. So total number of samples were 40.

Vickers micro hardness tester (LECO, MODEL NO LV 700, USA) was used to find out the micro hardness. A diamond indenter was pressed into the specimens under a load of 0.3kgf for 15 sec. The area of indentation was then measured using a ruler under microscope. Vickers hardness number was then calculated as the load divided by the area of indentation (Fig. no-30,31,32,33 & 34).

VHN=Load Kgf/ Impression area(mm)2



After the testing of samples, the collected data was subjected to statistical analysis.

RESULT AND STATISTICAL ANALYSIS

Table -1: The values of Vickers micro hardness test (VHN) for each of the 10 samples for all the 4 groups

Vickers Micro Hardness

	Premadent (Gr-A)	Acry Rock (Gr-B)	Quest (Gr-C)	Resistal (Gr-D)
	VHN	VHN	VHN	VHN
1	18.44	18.78	19.76	17.86
2	18.48	19.09	19.34	18.27
3	18.84	18.94	19.78	18.54
4	18.67	19.11	20.02	18.39
5	18.78	19.36	19.83	18.23
6	18.74	19.11	19.59	18.23
7	18.72	19.66	19.87	17.88
8	18.72	19.32	20.07	18.04
9	18.74	19.52	19.55	18.31
10	18.56	18.91	19.87	18.48

2) Table 2: Shows the mean, median and range of vickers hardness value of all the 4 groups of samples

Descriptive Statistics	Premadent Gr-A (n=10)	Acry Rock Gr-B (n=10)	Quest Gr-C (n=10)	Resistal Gr-D (n=10)
Mean±sd	18.67±0.13	19.18±0.28	19.77±0.22	18.22±0.23
Median	18.72	19.11	19.805	18.25
Range	18.44 - 18.84	18.78 - 19.66	19.34 - 20.07	17.86 - 18.54

Group-A (Premadent) is with a mean of 18.67±0.13 and a range of 18.44 - 18.84.

Group-B (Acryrock) is with a mean of 19.18±0.28 and a range of 18.78 - 19.66.

Group-C (Quest) is with a mean of 19.77±0.22 and a range of 19.34 - 20.07.

Group-D (Resistal) is with a mean of 18.22±0.23 and a range of 17.86 - 18.5.
Vickers Micro Hardness (VHN) of Resistal (Group D) was the lowest of all and that of Quest (Group-C) was the highest of all.

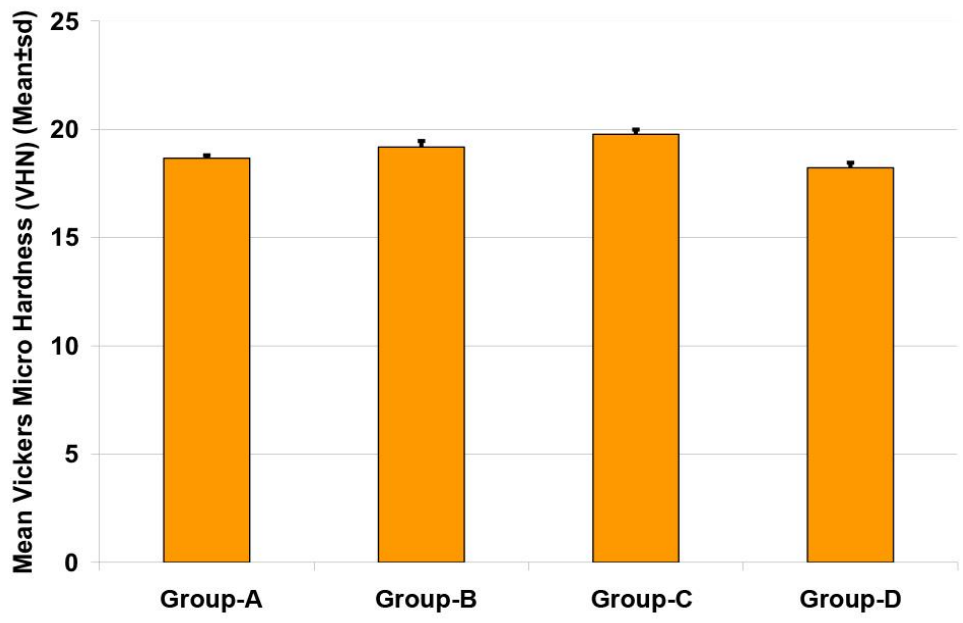


Figure 1 depicts the mean Vickers micro hardness (VHN) of different groups of samples.

Table 3: Represents the one way analysis of variance (ANOVA) which shows the comparison of Vickers micro hardness (VHN) among different groups of samples.

Source of Variation	Sum of square	Degrees of freedom	Mean sum of square	F-value	p-value
Between Groups	13.2911	3	4.43038	88.98	<0.0001 S
Within Groups	1.7924	36	0.049791		
Total	15.0835	39			

S-Statistically Significant

One way ANOVA showed that there was significant difference in Vickers Micro Hardness (VHN) of the four groups ($F_{3,36}$=88.98;p<0.0001).

4) Table -4: Tukey's Critical Difference (CD)

Tukeys Critical Difference	Value
At 5% level of significance(CD5)	0.44
At 1% level of significance(CD1)	0.79

5. Table-5: Comparison of Vickers Micro Hardness (VHN) of the four groups.

Comparison Group	Differences of means	p-value
Comparison with Group-A		
Group-A Vs Group-B	-0.51	<0.05 S
Group-A Vs Group-C	-1.10	<0.01 S
Group-A Vs Group-D	0.45	<0.05 S
Comparison with Group-B		
Group-B Vs Group-C	-0.59	<0.05 S
Group-B Vs Group-D	0.96	<0.01 S
Comparison with Group-C		
Group-C Vs Group-D	1.55	<0.01 S

S-Statistically Significant

The differences of means Group-A Vs Group-B, Group-A Vs Group-D and Group-B Vs Group-C were higher than that of Tukeys Critical Difference at 5% level of significance. Thus the pair wise differences of these means were statistically significant at 5% level of significance ($p<0.05$).

The differences of means Group-A Vs Group-C and Group-B Vs Group-D and Group-C Vs Group-D were higher than that of Tukeys Critical Difference at 1% level of significance. Thus the pair wise differences of these means were statistically significant at 1% level of significance ($p<0.01$).

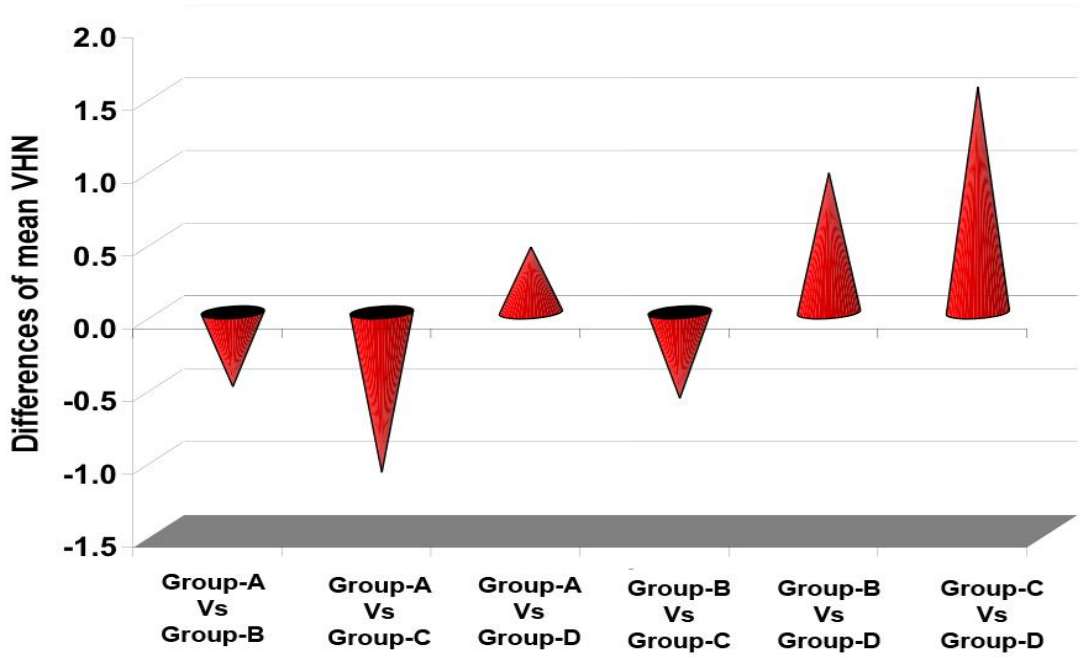


Figure 2: Compares the differences of mean Vickers micro hardness (VHN) of four groups

Table 6: Represents the master chart showing the distribution of impact strength value of all the samples of four different groups. (Gr-A, Gr-B, Gr.-C, Gr-D).

Impact strength value

	Premadent (Gr-A)	Acry Rock (Gr-B)	Quest (Gr-C)	Resistal (Gr-D)
1	0.55	0.25	0.25	0.26
2	0.70	0.70	0.50	0.50
3	0.65	0.54	0.30	0.28
4	0.70	0.58	0.30	0.40
5	0.35	0.40	0.35	0.45
6	0.35	0.61	0.25	0.25
7	0.55	0.04	0.30	0.35
8	0.45	0.54	0.40	0.30
9	0.60	0.45	0.38	0.42
10	0.55	0.35	0.44	0.36

Table 7: Represents the mean, median and range of impact strength value of different groups of samples.

Comparison of Impact strength value of the four groups.

Descriptive Statistics	Premadent (n=10)	Acry Rock (n=10)	Quest (n=10)	Resistal (n=10)
Mean±sd	0.55±0.13	0.45±0.19	0.35±0.08	0.36±0.08
Median	0.55	0.495	0.325	0.355
Range	0.35 - 0.70	0.04 - 0.70	0.25 - 0.50	0.25 - 0.50

The Impact strength value of Group-C (Quest) was the lowest of all and Group-A(Premadent) was the highest of all.

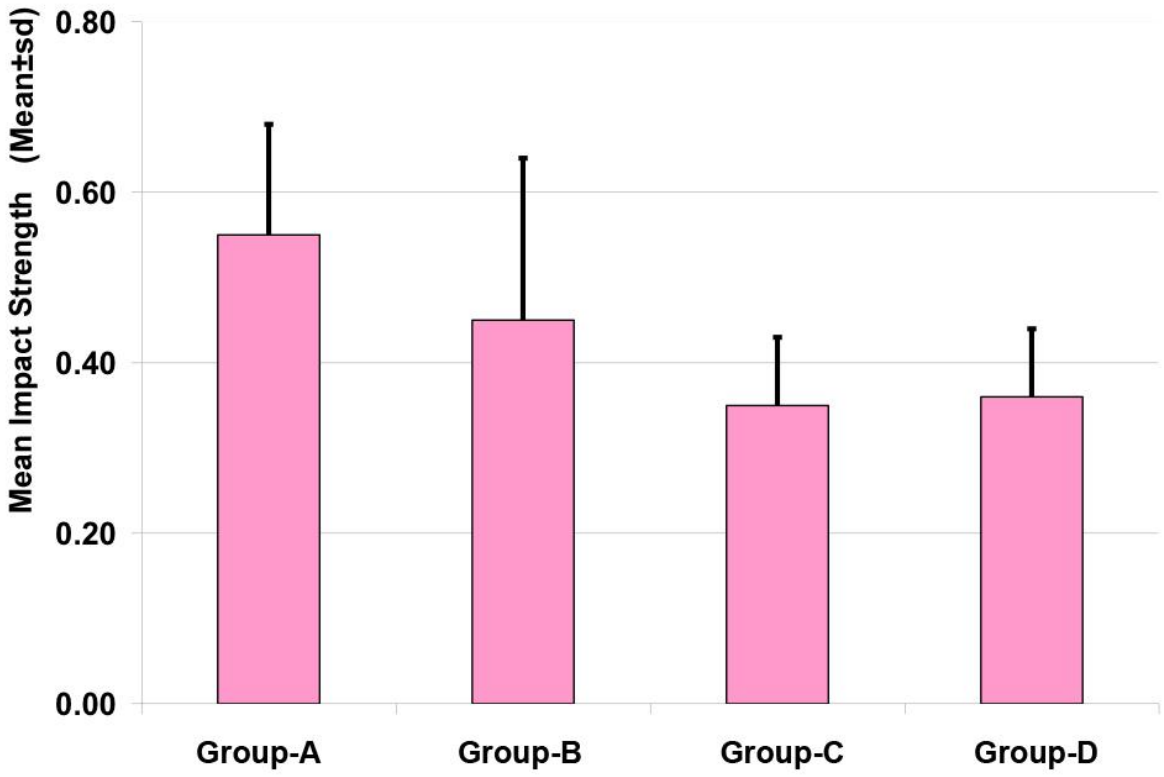


Figure 3: Compares the mean impact strength of different groups of samples

Table 8: Represents the one way analysis of variance (ANOVA) which shows the comparison of impact strength value among different groups of samples

Source of Variation	Sum of square	Degrees of freedom	Mean sum of square	F-value	p-value
Between Groups	0.25542	3	0.085143		
Within Groups	0.61531	36	0.017092		
Total	0.87073	39		4.98	0.0054 S

S-Statistically Significant

One way ANOVA showed that there was significant difference in impact test value of the four groups ($F_{3,36}$=4.98;p=0.0054).

Table-9: Represents the value of critical difference (CD) at 5% and 1% level of significance. This forms the basis of Tukey's test.
Tukey's Critical Difference (CD)

Tukeys Critical Difference	Value
At 5% level of significance(CD5)	0.08
At 1% level of significance(CD1)	0.16

Table-10: Comparison of Impact strength of the four groups & Difference of means of impact strength of four groups

Comparison Group	Differences of means	p-value
Comparison with Group-A		
Group-A Vs Group-B	0.10	<0.05 S
Group-A Vs Group-C	0.20	<0.01 S
Group-A Vs Group-D	0.19	<0.01 S
Comparison with Group-B		
Group-B Vs Group-C	0.10	<0.05 S
Group-B Vs Group-D	0.09	<0.01 S
Comparison with Group-C		
Group-C Vs Group- D	-0.01	>0.05 NS

S-Statistically Significant
NS-Statistically not significant

The differences of means Group- A Vs Group-B, and Group-B Vs Group-C were higher than that of Tukeys Critical Difference at 5% level of significance. Thus the pair wise differences of these means were statistically significant at 5% level of significance ($p<0.05$).

The differences of means Group-A Vs Group-C, Group-A Vs Group-D and Group-B Vs Group- D were higher than that of Tukeys Critical Difference at 1% level of significance. Thus the pair wise differences of these means were statistically significant at 1% level of significance ($p<0.01$).

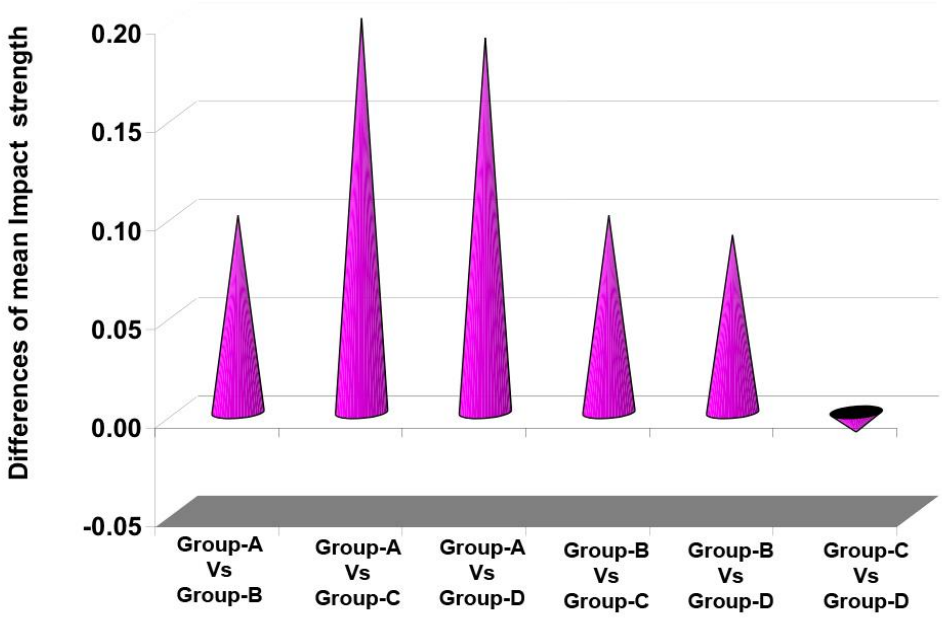


Figure 4 compares the mean impact strength of four Groups

DISCUSSION

The loss of teeth has plagued mankind throughout the ages. In order to restore a degree of function and appearance, it has been necessary always to adapt contemporary materials to dental applications.

The level of aesthetic demand has established over the ancient decades and this has made it necessary for dentist to explore the field of newer materials and technology in order to satisfy the existing needs of the Patients. As time has progressed, there has been continued refinement of the artificial tooth materials available for dental practice with the development of biological, chemical and physical sciences.[7].

Good mechanical & physical properties are also needed for materials used for artificial teeth. Out of these mechanical properties, hardness & impact strength are of the most important properties of acrylic tooth. The factors affecting the wear rate include the pressure between the abrading surfaces, the relative speed of movement between the surfaces, the characteristics of the surfaces & the composition of the materials in contact. Lack of sufficient wear resistance &hardness will result in excessive reduction in structure, resulting in loss of posterior tooth support, loss of vertical dimension of occlusion, loss of masticatory efficiency[8], alterations in the functional path of masticatory movement[9], fatigue of masticatory muscles[10], faulty tooth relationship, and loss of aesthetics. Wearing away of denture teeth will compromise both the function and the aesthetics of the denture. Hence, it is important for the clinician to choose acrylic resin teeth with high wear resistance & hardness.

There have been studies which found a correlation between hardness and wear resistance of artificial denture teeth[14,15,16].
Several manufacturers have developed resins purported to provide improved wear resistance. Among those are the multiplex polymer matrix resin teeth, resin teeth containing an interpenetrating polymer network of polymers, and double cross- linked resins[6]. Interpenetrating polymer network of polymers teeth have become quite popular as denture teeth. Attempts to increase wear resistance of resin teeth have been the focus of many researchers. Incorporation of inorganic fillers, such as amorphous silica filler in the polymer matrix has improved the wear resistance significantly but was accompanied by an increase in the adhesion of microbial biofilms onto the teeth.

Conventional methacrylate resin teeth usually achieve a better bond to the resin bases, more than highly cross-linked teeth. The reason is that high amounts of cross- linking restrict the availability of unlinked polymer chains to bond with the denture base to form a polymer network. Most resin teeth are thus highly cross-linked in the coronal portion to improve strength and provide resistance to crazing but with little or slight cross-linking in the gingival or body portion to improve bonding to the denture base[6].
Hardness is elicited as the resistance of a material to the superficial indentation by another body. Most hardness tests are based on the ability of the surface to resist penetration by a diamond point or steel ball under specified load[12.] Hardness is measured under an indentation load[13].

Conventional acrylic resin teeth have linear polymer chain structures that contribute to the durability of the material. Modified acrylic resin teeth have cross-linking structures, interpenetrating networks, incorporated micro fillers or nano fillers, and altered monomer compositions, which result in improved physical properties and increased price compared to conventional artificial teeth[11] .

In this study a load of 0.3 kgf for 15 sec was applied to right permanent first molar teeth occlusal fossa & Vickers micro hardness tester (LECO, MODEL NO LV 700, USA) was used to find out the micro hardness. The area of indentation was then measured using a ruler under microscope.

Mean micro hardness of group A was 18.67±0.13, for group B it was 19.18±0.28 and for group C it was 19.77±0.22 & for group D it was 18.22±0.23. Statistically significant variation was found in mean micro hardness in four groups ($F_{3,36}$=88.98, p-value=0.0001) and on comparing mean micro hardness in four groups statistically significant difference was found in four groups.

Impact strength[4] is defined as the energy required to fracture a material under an impact force. The Izod Impact tester is used for testing the Impact strength. With appropriate values for the velocities and masses involved, a blow by a fist to the lower jaw can be considered an impact situation. A moving object possesses a known amount of kinetic energy. If the struck object is not permanently deformed, it stores the energy of the collision in an elastic manner. This ability is reflected by the resilience of a material which is measured by the area under the elastic region of the stress -strain diagram. Thus, a material with a low elastic modulus and a high tensile strength is more resistant to impact forces. However, a low elastic modulus and a low tensile strength suggest low impact strength[4]. The impact property determines overall toughness of the material. Toughness is defined as the ability of the material to absorb applied energy. The higher the impact strength of the material, the higher is its toughness. When specimen tooth was subjected to impact loading, it fractures. A crack is initiated due to impact loading. Crack continues to propagate and complete fracture occurs if load applied is greater than the energy needed to crack the specimen.

Impact strength is affected by many factors like Orientation of polymer molecules with fillers increases the toughness of material, Processing of specimens, where inadequately processed specimens reduce the toughness. Voids act as stress concentrators created by poor processing conditions. High processing temperatures can also cause thermal degradation and thereby reduce the impact strength, High degree of crystallinity reduces the impact strength & reduction in the average molecular weight decreases impact strength[11].

In this study mean impact strength of group A was 0.55±0.13, for group B it was 0.45±0.19 and for group C it was 0.35±0.08 & for group D it was 0.36±0.08. Statistically significant variation was found in mean impact strength in four groups ($F_{3,36}$=4.98, & p=0.0054).

CONCLUSION

From the above study it can be concluded that acrylic denture teeth are very important for the success of rehabilitation prosthetic treatment, not only for aesthetics but also for function. Highly wear resistant artificial resin teeth may have a significant clinical advantage. Wear resistance and ability of these teeth to maintain a stable occlusal relationship overtime is most important requirement of artificial teeth. High strength resin tooth are shown to have more abrasive resistance.

The higher the impact strength of the material, the higher is its toughness. Impact properties can be modified by addition of impact modifiers like plasticiser and fillers, which appear to act as stress transfer agents. The results of this study may assist dentists in selecting acrylic denture teeth from the standpoint of good impact strength and high micro hardness & can be useful to the clinicians when selecting artificial teeth for denture as there would be greater need of teeth with improved impact strength & hardness.

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