Dental Research Journal

Original Article

Comparing the mechanical properties of the polymer orthodontic bracket materials with the conventional orthodontic bracket materials: A systematic review

Srinidhi Ramasundaram, Dilip Srinivasan, K. Ravi, Davis Devasahayam

Department of Orthodontics and Dentofacial Orthopedics, SRM Dental College and Hospital, Chennai, Tamil Nadu, India

ABSTRACT

Background: The aim of this study was to compare the mechanical properties of the polymer brackets with metal and ceramic brackets and verify if the polymer brackets could be used clinically.
Materials and Methods: A thorough search was conducted in four electronic databases, including Scopus, PubMed, Cochrane, Ovid, and Lilacs, with article selection based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis standards. A computerized search of the database was done from January 1990 to June 2024. Two independent reviewers were involved in study selection, data extraction, and synthesis. Disagreements were resolved by discussion with a third reviewer. The risk of bias was assessed by the quality assessment tool for *in vitro* studies (QUIN tool). The outcomes measured included permanent deformation, hardness, and torquing capacity.
Results: Ten studies were selected after excluding duplicates, screening, and complete text reading to identify the articles that met the eligibility criteria. All ten studies showed medium risk based on the quality assessment tool for *in vitro* studies (QUIN Tool).
Conclusion: The following findings were obtained: Polymer brackets have lower mechanical properties in terms of torque loss, fracture resistance, hardness, and torsional creep compared to metal brackets. Among the polymers listed in the studies, it was found that polyamide exhibited low hardness and polyoxymethylene exhibited the highest torque loss. Torque deformation was highest with a ceramic-reinforced polymer bracket, followed by pure polymer. Torque deformation was minimal with metal slot- and ceramic-reinforced polymers, followed by metal slot-reinforced polymers.

Key Words: Dental materials, hardness, orthodontic appliances, orthodontic brackets, torque

Received: 14-May-2024
Revised: 21-Jul-2024
Accepted: 11-Oct-2024
Published: 21-Nov-2024

Address for correspondence:
Dr. Srinidhi Ramasundaram, SRM Dental College and Hospital, Ramapuram, Chennai - 600 089, Tamil Nadu, India.
E-mail: srinidhiramasundaram@gmail.com

INTRODUCTION

Orthodontics is a branch of dentistry that embraces correcting tooth position by delivering force to the malaligned teeth. This is achieved with orthodontic brackets bonded to the tooth. Force is applied with the help of an archwire engaged in the slots of the bracket.

Stainless steel, which has been used promisingly in the field of orthodontics for decades, was introduced by Lucien De Coster.[1] The initial brackets made from stainless steel had a mesh base morphology. This was based on the mechanism

Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480
DOI: 10.4103/drj.drj_196_24

How to cite this article: Ramasundaram S, Srinivasan D, Ravi K, Devasahayam D. Comparing the mechanical properties of the polymer orthodontic bracket materials with the conventional orthodontic bracket materials: A systematic review. Dent Res J 2024;21:59.

that increased surface area increases bond strength. Maijer and Smith demonstrated the release of corrosive products from American Iron and Steel Institute type 316 stainless steel brackets.[2] A newer stainless steel alloy was proposed by Oshida called 2205 stainless steel alloy, which has better corrosion resistance and improved microhardness compared to 316 L stainless steel. As stainless steel is less biocompatible and allergic due to the presence of nickel, other metal brackets have been launched. This includes titanium brackets and cobalt chromium brackets. In the 1980s, there was an increasing surge in the number of adult patients in the field of orthodontics, which paved the way for research into esthetic orthodontic brackets. In 1960, the first transparent bracket was introduced by Newman *et al.* In 1980, the first alumina-based ceramic brackets emerged. It suffered from the limitations of being bulky, an increased incidence of tie wing fracture, higher reports of enamel damage during debonding, and increased friction. This led to further research, leading to the discovery of zirconia-based ceramic brackets. The first plastic bracket was an unfilled polycarbonate bracket launched in the early 1970s. These plastic brackets, which were fabricated earlier, had the disadvantages of having a low elastic modulus and increased absorption of colorants.[3] To overcome these shortcomings, reinforced polycarbonate brackets were launched. Other polymers that have been utilized in the fabrication of orthodontic brackets are polyurethane, polyoxymethylene, and many more. Studies are being conducted worldwide to minimize their drawbacks and provide brackets for improved properties.

With the ongoing research, the polymer brackets might be considered an effective alternative to the conventional bracket system, but there is no clear evidence available in the literature comparing the mechanical properties of the polymer brackets with the conventional brackets.

Objective

The main objective of this systematic review was to compare the mechanical properties of the polymer brackets with those of metal and ceramic brackets and verify if the polymer brackets could be used clinically. This systematic review also focuses on identifying the limitations of polymer brackets so that it can lead to newer polymer brackets with advanced mechanical properties.

MATERIALS AND METHODS

This systematic review was prepared according to the Cochrane Handbook for Systematic Reviews of Interventions and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[4-6] This systematic review could not be registered in the International Prospective Register of Systematic Reviews (PROSPERO) as it is only dedicated to reviews of studies in humans or animals, and this is a review of *in vitro* studies.

Search strategy

A thorough search was conducted in four electronic databases, including Scopus, PubMed, Cochrane, Ovid, and Lilacs, with article selection based on PRISMA standards.[7] A computerized search of the database was done from January 1990 to June 2024. The search was done using MESH (Medical Subject Headings) terminologies, and the keywords used were hardness, tensile resistance, wear resistance, plastic, polymer, and orthodontic brackets. The search items were concatenated using the Boolean operators (or and and).

PICOS question: Population, intervention, comparison, outcome, and study design

Do polymer orthodontic brackets have better mechanical properties than conventional orthodontic bracket materials? Do polymer orthodontic brackets have clinically accepted mechanical properties?

PICOS analysis

- Population (P): Orthodontic brackets
- Intervention (I): Polymer orthodontic bracket material
- Comparison (C): Metal and/or ceramic bracket
- Outcome (O): Mechanical properties (other than friction) such as hardness, fracture resistance, torsional creep, and torquing capacity
- Study design (S): *In vitro* studies.

Inclusion criteria

- Studies comparing the mechanical properties of the polymer brackets with either one of the conventional bracket systems or both were included
- Only *in vitro* studies analyzing the mechanical properties of the polymer brackets, irrespective of the polymer, were taken into account
- Studies published in English were included.

Exclusion criteria

- Studies analyzing the frictional properties and biocompatibility of the polymer brackets were excluded, as a review of these studies is available in the literature

- Studies analyzing the mechanical properties of different polymer bracket materials without comparing them with conventional bracket materials were excluded
- Human clinical studies were excluded.

Study selection

- The screening was performed in two phases. The initial screening was done based on the title and abstract. This was followed by a full text screening of the eligible articles, and the articles that met the inclusion criteria were extracted. The search was carried out by two independent observers using mesh terms in the following search databases: Scopus, Pubmed, Ovid, Lilacs, and Cochrane. Discrepancies were resolved through discussion and by consulting a third investigator.

Risk of bias or quality assessment

- The risk of bias was assessed by the QUIN tool (a quality assessment tool for *in vitro* studies).[8] It was done through full-text reading. The QUIN tool has 12 qualities. Each article will be assessed for 12 qualities by two reviewers independently. Each quality will receive one of the three responses: High risk, low risk, or quality with some concerns. High-risk quality will be given a score of 2 (adequately specified), quality with some concerns (inadequately specified quality) will be allotted a score of 1, and high-risk quality will not be allotted any score. The percentage will be calculated based on the obtained scores and used to grade the *in vitro* study as high, medium, or low risk (>70% = low risk of bias, 50% to 70% = medium risk of bias, and <50% = high risk of bias).[8] Any discrepancies will be resolved through discussion and by a third reviewer.

Data extraction and the data items

- Data were extracted independently by two reviewers from each article by full-text reading. The data collected included the author and year of study, type of polymer bracket material, type of conventional bracket material, mechanical property that was assessed, and results obtained. The outcomes measured included slot deformation, torquing capacity, fracture resistance, and hardness.

Data synthesis

- Studies for each outcome were decided through complete text reading. The data were collected from the tabular columns and figures provided in the included articles. The collected data were represented in the form of a tabulation, with the table contents being: Author, year of publication, type of polymer bracket material, type of conventional bracket material, the mechanical property assessed, and the results obtained.

RESULTS

Study selection

- The selection procedure is illustrated by the flow diagram [Figure 1]. 3286 articles were extracted through an electronic database search. 1192 duplicate articles were excluded. 2077 articles were excluded after reviewing the title and abstract. Seven articles were excluded after reading the whole text as they did not meet the inclusion and exclusion criteria. Hence, 10 articles were extracted at the end of the selection process.

Risk of bias or quality assessment

- All the articles under review are at medium risk. Certain qualities such as sample size calculation, sampling technique, operator details, and blindings were not specified in any of the reviewed studies. Randomization and operator assessor details were inadequately mentioned in one study and not specified in the rest of the studies. The risk of bias in all the included articles is represented in Figure 2.

Data collection

- The collected data are summarized in Table 1.

Types of polymer brackets

- Polycarbonate brackets with or without reinforcement were evaluated in seven studies.[9-15] Polyurethane brackets with or without reinforcement were evaluated in three studies.[2,16,17] Polyamide brackets with or without reinforcement were evaluated in two studies.[17,18] Brackets made of polyoxymethylene were evaluated in one study.[11] Polycarbonate and polyethylene terephthalate brackets with stainless steel slots were evaluated in one study.[17]

Types of conventional brackets

- Five studies used only metal brackets.[9,11-13,16] Five studies used both metal and ceramic brackets.[10,14,16-18]

Mechanical properties studied

- Six studies evaluated the torque capacity of the brackets.[9,11-14,16] Torsional creep was evaluated in

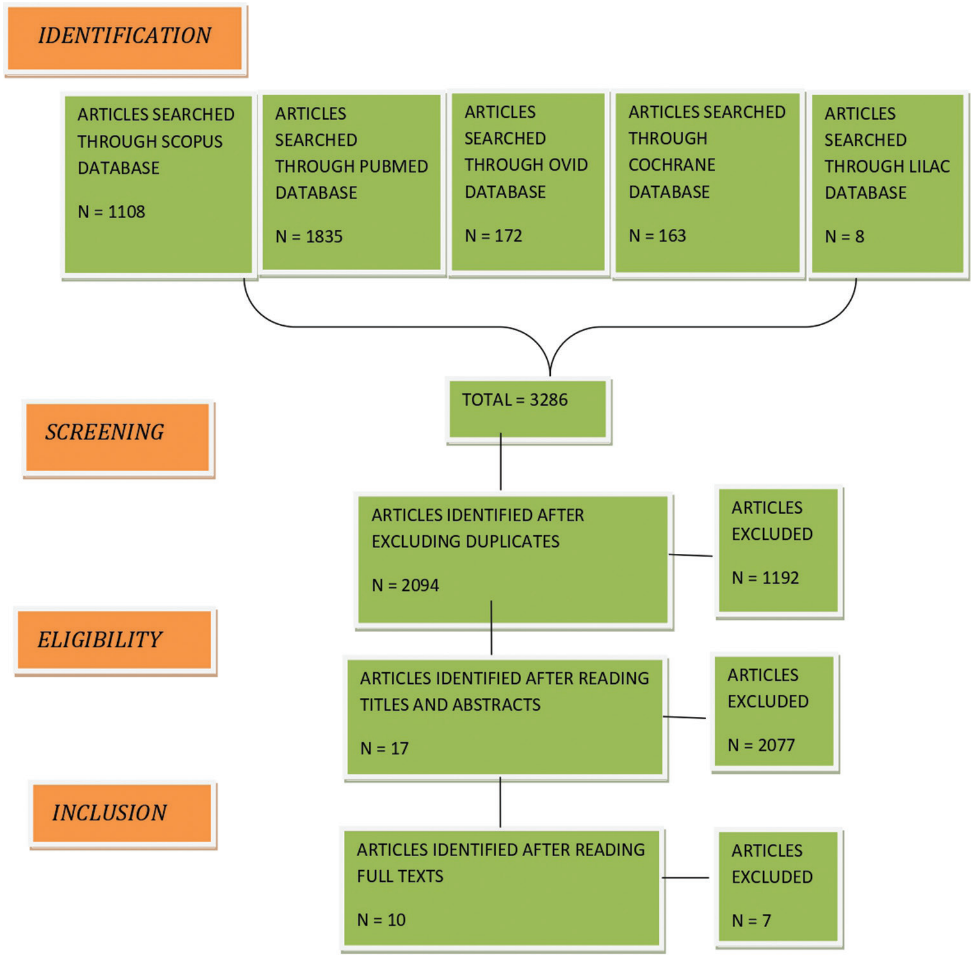

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

REFERENCE	AIM/ OBJECTIVE	SAMPLE SIZE CALCULATION	SAMPLING TECHNIQUE	CAMPARISON GROUP	EXPLANATION OF METHODOLOGY	OPERATOR DETAILS	RANDOMIZATION	METHOD OF MEASUREMENT OF OUTCOME	OUTCOME ASSESSOR DETAILS	BLINDING	STATISTICAL ANALYSIS	PRESENTATION OF RESULTS	OVERALL
Joseph C Feldner et al (1994)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Randy G Alkire et al (1997)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Henner Gmyrek et al (2001)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Reza Sadat-Khonsari et al (2003)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Winfried Harzer et al (2004)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Enver Morina et al (2008)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Clarice Nishio et al (2009)	+	X	X	+	+	X	-	+	-	X	+	+	58% MEDIUM RISK
Matthias Möller et al (2009)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Shigeyuki Matusi et al (2015)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK
Taro Iwasaki et al (2022)	+	X	X	+	+	X	X	+	X	X	+	+	50% MEDIUM RISK

X - HIGH RISK; + - LOW RISK; - - SOME CONCERN

Figure 2: Risk of bias.

Table 1: Characteristics of the included studies

Author and year of study	Polymer bracket materials	Conventional bracket materials	Mechanical property	Result
Feldner *et al.*, 1994[9]	Pure polycarbonate - (RMO Miura) Ceramic-reinforced polycarbonate - (American - Silkon) Metal slot-reinforced polycarbonate - (Tella Tech) Metal slot- and ceramic-reinforced polycarbonate - (Ormco Spirit)	Stainless steel (Mini Diamond)	Torque deformation	The metal slot-reinforced polycarbonate produced the highest torque and lowest deformation values, followed by the metal slot- and ceramic-reinforced polycarbonate, ceramic-reinforced polycarbonate, and pure polycarbonate
Alkire *et al*. (1997)[10]	Pure polycarbonate (RMO Miura) Ceramic-reinforced polycarbonate (American - Silkon) Metal slot-reinforced polycarbonate - (Tella Tech) Metal slot- and ceramic-reinforced polycarbonate - (Ormco Spirit)	Stainless steel - (Mini - Metal) Alumina - (Lumina)	Torsional creep	The bracket effect on creep was analyzed for each time period: 1, 2, 4, 7, 14, 20, and 28 days. Creep was first seen in ceramic-reinforced polycarbonate; the second to exhibit creep was pure polycarbonate; the third was metal-slot-reinforced polycarbonate, followed by metal and alumina
Gmyrek *et al*. (2002 [11]	Poly-oxymethylene - (Brilliant-old) Filler-reinforced polycarbonate bracket - (Aesthetik-line®) Poly - oxymethylene - (Brilliant-new)	Metal - (Mini Mono)	Slot deformation and equivalent torque capacity - both *in vitro* and OMSS	Metal brackets recorded the significantly highest torquing moment with both archwires, followed by filler-reinforced polycarbonate brackets, poly-oxymethylene (Brillant®-new), and poly-oxymethylene (Brillant®-old)
Sadat-Khonsari *et al*. (2004 [12]	Metal slot- and ceramic-reinforced polycarbonate - (Elan®me) Metal slot reinforced polyurethane - (Esthetic Gold®) Metal slot and fiberglass reinforced polycarbonate - (Elegance®) Pure polyurethane - (Esthetic®) Pure polycarbonate - (Miura®) Fiberglass reinforced polycarbonate - (Image™) Ceramic reinforced polycarbonate - (Silkon-M™)	Stainless steel - standard edgewise twin bracket (Ormco)	Torque deformation	Metal slot-reinforced brackets showed the lowest degree of deformation, followed by pure polyurethane, pure polycarbonate, and fiber-reinforced polycarbonate. The ceramic-reinforced polycarbonate brackets expressed the highest deformation
Harzer *et al*. (2004)[13]	Polycarbonate without metal slot (Brillant) Polycarbonate with metal slot (Elegance)	Metal - (Mini Mono)	Slot deformation and equivalent torque capacity - both *in vitro* and OMSS	Maximum torquing moment and low torque loss were obtained with a metal bracket, followed by polycarbonate with a metal slot, and high torque loss was seen in polycarbonate without a metal slot
Morina *et al*. (2008)[14]	Polycarbonate bracket - (Brillant®)	The self-ligating - (Damon™ 2 and Speed™) Stainless steel - (Ultratrimm® and Discovery®) Ceramic bracket - (Fascination® 2)	Torque capacity	The highest torquing moment was exhibited by ceramic, followed by metal and polycarbonate, with self-ligating being the least. The torque loss was minimum with ceramic and maximum with polycarbonate
Nishio *et al*. (2009)[15]	Traditional polycarbonate brackets - (Blonde) Polycarbonate brackets reinforced with a stainless steel slot - (Elation) Polycarbonate brackets reinforced with ceramic fillers and a stainless steel slot - (Spirit MB)	Ceramic brackets - (Transcend 6000) Ceramic brackets reinforced with a stainless steel slot - (Clarity) Ceramic brackets reinforced with a gold slot - (Luxi II)	Resistance to fracture or deformation	The deformation among the brackets in decreasing order is as follows Ceramic with stainless steel, ceramic with gold, pure ceramic, Polycarbonate reinforced with ceramic fillers and a stainless steel slot, polycarbonate with a stainless steel slot, and polycarboante

Contd...

Table 1: Contd...

Author and year of study	Polymer bracket materials	Conventional bracket materials	Mechanical property	Result
Möller *et al*. (2009)[16]	Polycarbonate - (Miura) Ceramic-reinforced polycarbonate - (Silkon - M) Fiberglass-reinforced polycarbonate - (Image) Ceramic-reinforced polycarbonate with a metal slot - (Elan) Fiberglass-reinforced polycarbonate with a metal slot - (Elegance) Polyurethane - (Esthetys) Polyurethane with a metal slot - (Esthetys)	Stainless steel - standard edgewise twin bracket with Ormesh wtwin (Ormco)	Torque stability	The bracket slot deformed after a single torque load in those brackets made of polycarbonate, whether with or without fiberglass or ceramic reinforcement. Brackets made of polyurethane and those with a metal slot, however, resisted repeated loads. All the bracket types exhibited increased elasticity during the loads, with the highest being ceramic-reinforced polycarbonate with a metal slot. However, none of the plastic brackets equaled the steel bracket's elasticity
Matsui *et al*. (2015)[17]	Polycarbonate with stainless steel slot Polyamide with stainless steel slot Polyurethane Polycarbonate, polyethylene terephthalate with stainless steel slot	Ceramic Stainless steel	Deformation and stress distribution under wire load	Plastic brackets reinforced with a stainless steel slot are more rigid than pure polymer brackets. The polyamide brackets showed the largest displacement of the bracket wing, which was 0.014 mm on average despite the stainless steel-reinforced slots. Among the plastic brackets, polycarbonate with a stainless steel slot showed the smallest displacement
Iwasaki *et al*. (2022)[18]	Polyamide - (Crystabrace) Glass fiber-reinforced polycarbonate - (Silkon Plus)	Polycrystalline alumina - (Clarity and Fli Clear) Monocrystaline alumina - (Inspire Ice and Radiance) Zirconia - (Coby and Insire ice)	Dynamic hardness and indentation elastic modulus	Polycrystalline alumina exhibited the highest hardness, followed by monocrystalline alumina, then zirconia. Polyamide has the least hardness, glassfibre-reinforced polycarbonate being the second least. Indentation elastic modulus also followed the same order

OMSS: Orthodontic measuring and simulation system; RMO: Rocky Mountain Orthodontics

one study.[10] Fracture resistance was evaluated in one study.[15] Deformation and stress distribution were evaluated in one study and hardness in one study.[17,18]

Comparison of the polymer groups

Torque capacity

- A study conducted by Feldner *et al*. showed that metal slot-reinforced polycarbonate produced the highest torque and lowest deformation values.[9] It was followed by the metal slot- and ceramic-reinforced polycarbonate. Pure polycarbonate exhibited the lowest torque. However, the study results of Sadat-Khonsari *et al*. showed the degree of deformation was greater in the ceramic-reinforced polycarbonate group than in the pure polycarbonate group[12]
- All the polymer groups exhibited a lower torquing moment in comparison to the conventional group.[9,11-14,16] Among the conventional group, ceramic exhibited the highest torquing moment.[14]

Torsional creep

- The bracket effect on creep was analyzed for each time period: 1, 2, 4, 7, 14, 20, and 28 days. Creep was first seen in ceramic-reinforced polycarbonate; the second to exhibit creep was pure polycarbonate; the third was metal slot-reinforced polycarbonate, followed by metal and alumina.[10]

Fracture resistance

- Fracture resistance was the highest in ceramic with stainless steel, followed by ceramic with gold, pure ceramic, polycarbonate reinforced with ceramic fillers and a stainless steel slot, polycarbonate with a stainless steel slot, and polycarboante.[15]

Deformation and stress distribution under wire load

- Polycarbonate with a stainless steel slot showed the smallest displacement. The polyamide brackets showed the largest displacement of the bracket wing, which was 0.014 mm on average despite the stainless steel-reinforced slots.[17]

Dynamic hardness and indentation elastic modulus

- Polycrystalline alumina exhibited the highest hardness, followed by monocrystalline alumina, then zirconia. Polyamide has the least hardness, with glass fiber-reinforced polycarbonate being the second least.[18] Indentation elastic modulus also followed the same order.

DISCUSSION

Stainless steel brackets are the conventional bracket system being used clinically. With aesthetics becoming an important requisite, it has become indispensable to incorporate a ceramic bracket system into the treatment plan. Scott discussed the mechanical properties of ceramic brackets with metal brackets, especially fracture toughness.[19] He concluded that ceramics are more likely to fracture than metals under the same conditions. Even though ceramic has transparency attributes, high hardness, and high strength, it has the limitation of having low fracture toughness. Furthermore, the efficiency of tooth movement was reduced with the ceramic bracket due to increased friction.

Torque is an activation generated by the torsion of an archwire in a bracket slot, and the archwire moves the root in a palatal direction through the torsional tension. Some authors have specified that a minimum torque of 0.5 Ncm is necessary.[20] As the deformability of the bracket during torsional force has an impact on the torquing moment, it is dispensable to know the torquing capacity of the bracket. Harzer *et al*. and Morina *et al*. concluded that polycarbonate brackets have the highest torque loss in comparison with conventional brackets.[13,14] This is due to the elastic deformation of the bracket slot. The results obtained are in accordance with the results of Feldner *et al.* and Alkire *et al.*[9,10] The transmitted torquing moment is less predicted in polycarbonate, as the shock absorber effect claimed by the manufacturer is not to be expected. Only polycarbonate brackets with metal slots displayed adequate stability.

Creep is a permanent deformation that occurs when a material is subjected to a constant load over an extended period of time. Creep is important for thermoplastic materials such as polycarbonate resins. Dobrin *et al*. found that polycarbonate bracket slots distorted with time under physiological stress of 2000 g/mm^2.[3] Henner *et al*. reported that the torquing capacity of the filler-reinforced polycarbonate bracket showed better torquing capacity than the nonreinforced polymer brackets, even though they were lower than the conventional metal brackets.[11] Feldner *et al*. have concluded that ceramic-reinforced polymer brackets lacked clinically acceptable strength to withstand torquing forces and would lead to distortion.[9] Moreover, this was confirmed by Möller *et al*. and Sadat-Khonsari *et al*.[12,16] The addition of ceramic or fiberglass particles may influence the water absorption properties of plastics. This absorbed water reduced the adhesion between the ceramic fillers and the polycarbonate resins. If these phenomena occur, increased creep may result. If the filler particles added are silanized and their size and proportion are varied, it might show improved mechanical properties. Other factors that influence their mechanical properties are their manufacturing processes and the design of the apparatus. Within each bracket type, the bracket width was always greater than the displacement of the bracket wings, suggesting that the deformation occurred not only at the bracket wings but also at the bracket base when torquing force was applied.

Hence, reinforcing the polycarbonate material with ceramic filler did not significantly affect the resulting creep. Polymer brackets with a metal slot were more effective in reducing creep. Based on the data of this study and Feldner *et al.*'s, clinicians who use polycarbonate brackets and fill the bracket slot with a full-size wire to apply significant torque to teeth should consider using brackets with metal slot reinforcement.[9] The polycarbonate bracket experiences approximately 12% to 15% torque loss as a result of creep. Hence, an additional torque to the wire to obtain the intended torque has been suggested in the clinical use of polycarbonate brackets.

In terms of ceramic brackets, Nishio *et al*. reported that the ceramic brackets showed significantly higher deformation resistance than plastic brackets, and in particular, ceramic brackets reinforced with a stainless steel slot showed the highest resistance.[15] However, the plastic brackets are reversibly or plastically deformed on loading.

The clinical torque was simulated using the orthodontic measuring and simulation system (OMSS). Although this integrated system had the advantage of analyzing the issues faced in the field of orthodontics, it had some downsides. It failed to take into effect the long-term effect of the torque on the brackets, the influence of saliva on the bracket material, and its effects on the adjacent teeth. In the clinical dental model in OMSS, the neighboring brackets permitted additional play. The actual torque loss was thus well above the values registered in the *in vitro* experiments.

Another reason for the low torques was that the torque generated by the outer edges of the wire resulted in the shortening of the archwire, causing deformation of the continuous archwire. This leads to auxiliary forces that generate counter torque in the anterior segment and at the incisors. The simulated tooth then starts the torque movement and reacts rapidly to these forces. Then, the force as well as the torque disappear.

In terms of hardness, Iwasaki *et al*. measured by the microindentation method ceramic and polycarbonate brackets. Alumina has a higher hardness and is superior to that of CO made of zirconia, and monocrystalline alumina is harder than polycrystalline alumina. The hardness depends on the orientation of the crystals.[18] A decrease in grain size increases the strength of polycrystalline alumina. The ceramic brackets have low plastic deformation compared with the polymer bracket materials. Glass fiber-reinforced polycarbonate brackets showed increased hardness whereas glass fiber acts as a reinforcing material. This study lacked the influence of water absorption, hence the varied results from the previous studies.

Limitations

Due to the lack of *in vivo* studies, the reliability of the result cannot be proved. Only one study of the rest compared the hardness of the polymer bracket with the metal bracket. Hence, the influence of metal slots and ceramic or fiber-reinforced polymers on hardness could not be determined.

CONCLUSION

The following conclusions were obtained: Polymer brackets have low mechanical properties in terms of torque loss, fracture resistance, hardness, and torsional creep compared to metal brackets. Among the polymers listed in the studies, it was found that polyamide exhibited low hardness and polyoxymethylene exhibited the highest torque loss. Torque deformation was maximum with a ceramic-reinforced polymer bracket, followed by pure polymer. Torque deformation was minimal with metal slot- and ceramic-reinforced polymers, followed by metal slot-reinforced polymers. Future studies must be carried out to check for the reliability of the obtained results.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Lucien de Coster. The use of rustless steel in dentofacial orthopedics. International Journal of Orthodontia, Oral Surgery and Radiography 1932;18:1191-5.
2. Maijer R, Smith DC. Corrosion of orthodontic bracket bases. Am J Orthod 1982;81:43-8.
3. Dobrin RJ, Kamel IL, Musich DR. Load-deformation characteristics of polycarbonate orthodontic brackets. Am J Orthod 1975;67:24-33.
4. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, *et al.* Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. BMJ 2015;350:g7647.
5. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, *et al.* The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. BMJ 2009;339:b2700.
6. Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions. Hoboken, New Jersey: Wiley; 2008. p. 672.
7. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
8. Sheth VH, Shah NP, Jain R, Bhanushali N, Bhatnagar V. Development and validation of a risk-of-bias tool for assessing *in vitro* studies conducted in dentistry: The QUIN. J Prosthet Dent 2024;131:1038-42.
9. Feldner JC, Sarkar NK, Sheridan JJ, Lancaster DM. *In vitro* torque-deformation characteristics of orthodontic polycarbonate brackets. Am J Orthod Dentofacial Orthop 1994;106:265-72.
10. Alkire RG, Bagby MD, Gladwin MA, Kim H. Torsional creep of polycarbonate orthodontic brackets. Dent Mater 1997;13:2-6.
11. Gmyrek H, Bourauel C, Richter G, Harzer W. Torque capacity of metal and plastic brackets with reference to materials, application, technology and biomechanics. J Orofac Orthop 2002;63:113-28.
12. Sadat-Khonsari R, Moshtaghy A, Schlegel V, Kahl-Nieke B, Möller M, Bauss O. Torque deformation characteristics of plastic brackets: A comparative study. J Orofac Orthop 2004;65:26-33.
13. Harzer W, Bourauel C, Gmyrek H. Torque capacity of metal and polycarbonate brackets with and without a metal slot. Eur J Orthod 2004;26:435-41.
14. Morina E, Eliades T, Pandis N, Jäger A, Bourauel C. Torque expression of self-ligating brackets compared with conventional metallic, ceramic, and plastic brackets. Eur J Orthod 2008;30:233-8.
15. Nishio C, Mendes Ade M, Almeida MA, Tanaka E, Tanne K, Elias CN. Evaluation of esthetic brackets' resistance to torsional

forces from the archwire. Am J Orthod Dentofacial Orthop 2009;135:42-8.

16. Möller M, Klocke A, Sadat-Khonsari R, Schlegel V, Kahl-Nieke B. Torque stability of plastic brackets following multiple loading and artificial material aging – an *in-vitro* comparison. J Orofac Orthop 2009;70:385-95.
17. Matsui S, Umezaki E, Komazawa D, Otsuka Y, Suda N. Evaluation of mechanical properties of esthetic brackets. J Dent Biomech 2015;6:1-7
18. Iwasaki T, Nagata S, Ishikawa T, Tanimoto Y. Mechanical characterization of aesthetic orthodontic brackets by the dynamic indentation method. Dent Mater J 2022;41:860-7.
19. Scott GE Jr. Fracture toughness and surface cracks – The key to understanding ceramic brackets. Angle Orthod 1988;58:5-8.
20. Reitan K. Effects of force magnitude and direction of tooth movement on different alveolar bone types. Angle Orthod 1964;34:244-53.