Clinical Evaluation of Differences in Proximal Contact Strength of Various Fixed Dental Prosthesis Materials

Abstract

Objective: The study compared the proximal contact strength (CS) of different fixed dental prosthesis (FDP) materials. Materials and Methods: Thirty volunteers participated in this study with definitive inclusion and exclusion criteria. Participants were divided into full metal, zirconia, and metal ceramic groups. The CS between the natural teeth and the maxillary posterior quadrant FDP was measured with force gauge. The data were evaluated with one-way analysis of variance test, and Tukey’s honest significant difference post hoc was done to compare the mean values. Paired samples t-test was used to compare the mean values between pre- and postoperative CS. Results: The postoperative CS observed in the full metal group in premolar was $0.320 \pm 0.1092 \text{N}$ and in second molar was $0.385 \pm 0.1130 \text{N}$. CS obtained with zirconia FDP in both premolar ($0.679 \pm 0.0927 \text{N}$) and molar ($0.770 \pm 0.0960 \text{N}$) was highest among all groups. The results were statistically significant ($P < 0.001$). Conclusion: Postoperative CS was greater in zirconia when compared with metal and metal ceramic FDP. Clinical Relevance: FDP materials had acceptable CS. Zirconia is preferable for optimal CS.

Keywords: Axial contact, contact area, interdental contact, interproximal contact, proximal contact, proximal contact strength

Introduction

Proximal contact (PC) is one of the major interests in dentistry because of its complex relationships in its role in occlusion, esthetics, and periodontal health. PC protects the periodontal tissues and maintains the integrity of the dental arch. PC is important for the growth of jaws and has a significant role in preventing food impaction and transmission of stresses along the arch. PC manifests in accordance with the location, tooth type, arch, mastication, and time of the day. The proximal contact strength (PCS) is a physiological entity with multifactorial origin. The resistance to separation of PC of teeth during function is identified as CS. In literature, the CS was evaluated by the ease of passing of dental floss, various thicknesses of shim stocks, metal strips or blade insertion, and tooth pressure meter. The CS studies focused on the changes in tightness of dental contact with respect to clenching, the anterior component of force, mandibular malalignment, postural position, chewing, and food impaction, but only fewer literatures are available on the influence of CS on fixed dental prosthesis (FDP) materials. The choice of a material can influence or limit food impaction, maintain arch integrity, and aid in clinical success of restoration. The objective of this in vivo study was to evaluate and compare the CS of different FDP materials. The null hypothesis was that there would be no difference in CS between the chosen materials used in the fabrication of FDP.

Materials and Methods

Thirty volunteers (14 males and 16 females) participated in the study. The institutional ethical board clearances and the volunteers consent were obtained for the study. The study population was divided into three groups ($n = 10$): metal, metal ceramic, and zirconia FDP. The age of the subjects ranged between 21 and 40 years (average age 35.1 years). The subjects had no alterations in the proximal surface because of dental procedures, healthy periodontal tissues, Class 1 molar relationship, and asymptomatic temporomandibular joint. The subjects chosen had missing left teeth.
maxillary first molar to fabricate three-unit FDP (second premolar, first molar, and second molar – 25, 26, 27) with a minimum mouth opening of 20 mm. Patients with diastema, parafunctional habits, restorations, limited mouth opening, deviation, clicking, and myofacial pain dysfunction syndrome were not considered, and recordings in mandibular teeth were avoided.\cite{10,11}

Tooth preparation was done with sufficient space in accordance with the type of restoration. Single-step putty reline impression (Aquasil; DENTSPLY, De Trey GmbH, Germany) was made to fabricate the definitive FDP. Provisional restoration (Structur 2 SC; VOCO Gmbh) was constructed by direct–indirect technique using the matrix made from the diagnostic cast and intraoral relining. Provisional FDP was luted (Provicol; VOCO GmbH) for an interim period of 1 week until definitive restorations were cemented. The required precautionary measures were followed before FDP cementation. FDP was tried: PC, marginal fit, occlusion, and esthetics were evaluated. A 12-μm Shimstock used with Arti-Fol® PC forceps (Bausch®, GmbH & Co.) was used to evaluate the proximal high spot and was corrected to confirm the fit. PC adjustment was considered complete when equal light resistance was felt on passing a dental floss in both interproximal spaces.\cite{12} The FDP was luted with type 1 glass ionomer cement (GC Corporation, Tokyo, Japan). The material information on the used materials for the study is listed in Table 1. The prosthesis was reviewed for postoperative complaints. The evaluation of CS was done after a week of FDP cementation on participants with no postoperative complaints.\cite{13}

The CS was measured by recording the frictional force (FF) required to withdraw the floss with a Digital Force Gauge (model: FG-5005). The device is validated by an in vitro pilot study. The device was checked on a typhodont, validated on patients during the pilot study with three different operators and during preoperative PC evaluation by the operator during the study. The CS was related to FF by the following equation: CS = FF/2μ [N]. The dental floss (Oral-B, Essential Floss®) of two-inch length was inserted between two adjacent teeth. The pulling of dental floss was done perpendicular to the occlusal surface with a controlled speed of 10 mm/s. The FF occurring opposite to the pulling direction was converted by the force gauge and recorded as CS. The assessment was done thrice at each contact at a gap of 2 min interval to ensure validity. CS assessments were made at late morning around 10 am. The mean value was determined and recorded for analysis. The measurement was made at rest state and the subjects were restricted not to occlude during measurement. The subjects were asked to be in a comfortable state and not to eat for at least 1 h before and throughout the evaluation procedure. They were allowed to close their mouths and occlude on their teeth normally. The patients were allowed to clench and swallow during the resting period. The subjects were in an upright posture for at least 1 h before beginning of the experiment to negate the postural effects of the musculoskeletal, neural, and circulatory system.\cite{14,15} Preoperative measurements were obtained at the maxillary second to third molar and first to second premolar PCs. Postoperative measurements were recorded with the cementation of FDP. The recordings were done by one investigator for standardization.

The data were analyzed using statistical software SPSS 17.0® (SPSS, Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) test was used to compare the PCS values. Tukey’s honest significant difference post hoc test was used to compare the pair-wise mean values. Paired samples t-test was used to compare pre- and postoperative values.

### Results

The data obtained were analyzed for tests for normality [Table 2]. The mean pre- and postoperative CS between groups was compared with one-way ANOVA [Tables 3-6].

#### Table 1: Material information

| Material                        | Manufacturer                  | Batch No.          |
|---------------------------------|-------------------------------|--------------------|
| Nickel chromium metal           | Wiron 99; Bego               | Ref. No. 50225, lot no. 3038 |
| Ceramics                        | IPS design, Ivoclar Vivadent  | Ref. 558221        |
| Zirconia                        | 3M ESPE Lava Essential        | Lot no. P49516     |
| Non eugenol cement              | Provicol; VOCO GmbH          | Lot no. 1340111    |
| Provisional material            | Structure 2 SC; VOCO GmbH    | Lot no. 1482, Lot no. 1347322 |
| Type 1 glass polyalkenoate cement | GC Corporation, Tokyo, Japan | Lot no. 1309141 |
| Articulating paper              | Arti-Fol (Bausch, GmbH & Co.) | Ref. No. BK 28    |

#### Table 2: Tests of normality

| Group                        | Kolmogorov-Smirnov Statistic | df | P   | Shapiro-Wilk Statistic | df | Sig. |
|------------------------------|-----------------------------|----|-----|-------------------------|----|------|
| Metal                        |                             |    |     |                         |    |      |
| 24-25 Preoperative           | 0.17                        | 10 | 0.2 | 0.91                    | 10 | 0.27 |
| 24-25 Postoperative          | 0.16                        | 10 | 0.2 | 0.97                    | 10 | 0.87 |
| 27-28 Preoperative           | 0.17                        | 10 | 0.2 | 0.94                    | 10 | 0.50 |
| 27-28 Postoperative          | 0.15                        | 10 | 0.2 | 0.96                    | 10 | 0.76 |
| Metal ceramic                |                             |    |     |                         |    |      |
| 24-25 Preoperative           | 0.18                        | 10 | 0.2 | 0.97                    | 10 | 0.89 |
| 24-25 Postoperative          | 0.14                        | 10 | 0.2 | 0.96                    | 10 | 0.82 |
| 27-28 Preoperative           | 0.13                        | 10 | 0.2 | 0.98                    | 10 | 0.94 |
| 27-28 Postoperative          | 0.15                        | 10 | 0.2 | 0.96                    | 10 | 0.79 |
| Zirconia                     |                             |    |     |                         |    |      |
| 24-25 Preoperative           | 0.14                        | 10 | 0.2 | 0.98                    | 10 | 0.94 |
| 24-25 Postoperative          | 0.12                        | 10 | 0.2 | 0.99                    | 10 | 0.99 |
| 27-28 Preoperative           | 0.17                        | 10 | 0.2 | 0.96                    | 10 | 0.77 |
| 27-28 Postoperative          | 0.12                        | 10 | 0.2 | 0.98                    | 10 | 0.94 |

df: Degree of freedom
The differences between pre- and post-operative PCS of both first to second premolar (24–25 region) and second to third molar (27–28 region) was calculated using paired samples t-test. The preoperative mean value of 0.45 ± 0.10 and 0.52 ± 0.12 N in first to second premolar and second to third molar, respectively, for metal group was greater than postoperative mean CS [Table 7], and the results were statistically significant (P < 0.001).

Comparison between the materials revealed that zirconia with a postoperative mean CS of 0.68 ± 0.09 N in the premolar area and 0.77 ± 0.010 N in the molar area was always significantly greater than postoperative mean CS in metal and metal ceramic groups (P < 0.05) [Table 8]. The mean CS value of second to third molar was greater than the mean CS value in first to second premolar among all groups [Table 8].

The postoperative values of metal, zirconia, and metal ceramic groups in molars and premolars showed that the highest mean value was observed in the molar contact areas and in zirconia group followed by metal ceramic group, and the lowest was observed in the metal group. The mean CS for males is slightly higher compared with females, and the postoperative CS is more than the preoperative CS [Table 9].

**Discussion**

The results of the study reject the null hypothesis that there would be no difference in CS between the materials used in the fabrication of FDP. The postoperative mean CS values of 0.68 ± 0.0927 and 0.77 ± 0.10 N in the premolar and molar contact areas, respectively, for zirconia group were the highest among three groups, whereas the lowest

| Group     | n  | Mean | Std dev | Min | Max | P     |
|-----------|----|------|---------|-----|-----|-------|
| Metal     | 10 | 0.45 | 0.10    | 0.26| 0.57| 0.018 |
| Metal ceramic | 10 | 0.45 | 0.12    | 0.27| 0.66|       |
| Zirconia  | 10 | 0.32 | 0.08    | 0.17| 0.45|       |
| Total     | 30 | 0.40 | 0.12    | 0.17| 0.66|       |

ANOVA: Analysis of variance

| Group     | n  | Mean | Std dev | Min | Max | P     |
|-----------|----|------|---------|-----|-----|-------|
| Metal     | 10 | 0.52 | 0.12    | 0.31| 0.67| 0.09  |
| Metal ceramic | 10 | 0.51 | 0.11    | 0.35| 0.71|       |
| Zirconia  | 10 | 0.42 | 0.08    | 0.26| 0.54|       |
| Total     | 30 | 0.48 | 0.11    | 0.26| 0.71|       |

ANOVA: Analysis of variance

| Group     | n  | Mean | Std dev | Min | Max | P     |
|-----------|----|------|---------|-----|-----|-------|
| Metal     | 10 | 0.32 | 0.11    | 0.12| 0.51| <0.001 |
| Metal ceramic | 10 | 0.55 | 0.11    | 0.39| 0.77|       |
| Zirconia  | 10 | 0.68 | 0.09    | 0.52| 0.82|       |
| Total     | 30 | 0.52 | 0.18    | 0.12| 0.82|       |

ANOVA: Analysis of variance

**Table 6: One-way ANOVA 27-28 postoperative mean comparison values’ between groups**

| Group     | n  | Mean | Std dev | Min | Max | P     |
|-----------|----|------|---------|-----|-----|-------|
| Metal     | 10 | 0.39 | 0.11    | 0.17| 0.55| <0.001|
| Metal ceramic | 10 | 0.63 | 0.11    | 0.47| 0.85|       |
| Zirconia  | 10 | 0.77 | 0.10    | 0.60| 0.91|       |
| Total     | 30 | 0.59 | 0.19    | 0.17| 0.91|       |

ANOVA: Analysis of variance

**Table 7: Paired samples t-test to compare the mean values between pre- and postoperative findings**

| Type of FDP | Contact area | Evaluation phase | Mean | Std dev | P  |
|-------------|--------------|------------------|------|---------|----|
| Metal       | 24-25*       | Preoperative     | 0.32 | 0.10    | <0.001|
|             |              | Postoperative    | 0.45 | 0.11    |    |
| Metal ceramic| 27-28*   | Preoperative     | 0.52 | 0.12    | <0.001|
|             |              | Postoperative    | 0.39 | 0.11    |    |
| Metal       | 24-25*       | Preoperative     | 0.46 | 0.12    | <0.001|
|             |              | Postoperative    | 0.55 | 0.11    |    |
| Metal ceramic| 27-28*   | Preoperative     | 0.51 | 0.11    | <0.001|
|             |              | Postoperative    | 0.63 | 0.11    |    |
| Zirconia    | 24-25*       | Preoperative     | 0.32 | 0.08    | 0.007|
|             |              | Postoperative    | 0.68 | 0.10    |    |
| Zirconia    | 27-28*       | Preoperative     | 0.42 | 0.08    | 0.022|
|             |              | Postoperative    | 0.77 | 0.10    |    |

FDP: Fixed dental prosthesis*24-25: Proximal contact area between first premolar (natural teeth) and second premolar (fixed partial denture) *27-28: Proximal contact area between second molar (fixed partial denture) and third molar (natural teeth)

**Table 8: Independent samples t-test to compare preoperative/postoperative mean values between premolar and molar in each group**

| Type of FDP | n  | Evaluation phase | Contact area | Mean | Std dev | P  |
|-------------|----|------------------|--------------|------|---------|----|
| Metal       | 10 | Preoperative     | 24-25        | 0.45 | 0.10    | 0.16|
|             |    | Postoperative    | 27-28        | 0.52 | 0.12    |    |
| Metal ceramic| 10 | Preoperative     | 24-25*       | 0.32 | 0.11    | 0.21|
|             |    | Postoperative    | 27-28*       | 0.39 | 0.11    |    |
| Metal       | 10 | Preoperative     | 24-25        | 0.45 | 0.12    | 0.24|
|             |    | Postoperative    | 27-28        | 0.55 | 0.11    |    |
| Metal ceramic| 10 | Preoperative     | 24-25        | 0.55 | 0.11    | 0.15|
|             |    | Postoperative    | 27-28        | 0.63 | 0.11    |    |
| Zirconia    | 10 | Preoperative     | 24-25        | 0.32 | 0.08    | 0.01|
|             |    | Postoperative    | 27-28        | 0.42 | 0.08    |    |
| Zirconia    | 10 | Preoperative     | 24-25        | 0.68 | 0.09    | 0.04|
|             |    | Postoperative    | 27-28        | 0.77 | 0.10    |    |

FDP: fixed dental prosthesis *24-25: Proximal contact area between first premolar (natural teeth) and second premolar (FDP) *27-28: Proximal contact area between second molar (FDP) and third molar (natural teeth)
Table 9: Independent samples t-test comparing the mean contact strength between genders

| Contact area | Gender | n  | Mean  | Std dev | P     |
|--------------|--------|----|-------|---------|-------|
| 24-25*       | Male   | 14 | 0.47  | 0.10    | <0.001|
| Preoperative | Female | 16 | 0.35  | 0.10    |       |
| 24-25        | Male   | 14 | 0.59  | 0.16    | 0.03  |
| Postoperative| Female | 16 | 0.45  | 0.18    |       |
| 27-28*       | Male   | 14 | 0.56  | 0.09    | <0.001|
| Preoperative | Female | 16 | 0.42  | 0.08    |       |
| 27-28        | Male   | 14 | 0.67  | 0.17    | 0.04  |
| Postoperative| Female | 16 | 0.53  | 0.19    |       |

*24-25: Proximal contact area between first premolar (natural teeth) and second premolar (Fixed dental prosthesis)  
*27-28: Proximal contact area between second molar (fixed dental prosthesis) and third molar (natural teeth)

postoperative mean was observed in metal FDP. The study reciprocated trials of Denry et al.,[16] Manicone et al.,[17] Sailer et al.,[18] and Raigrodski[19] on zirconia ceramic and metal ceramic on their technical, biologic, and mechanical outcomes.

The postoperative CS was higher in all materials than preoperative CS. The ignored quantification of CS during restoration fabrication procedure, adaptation mechanism of teeth on the basis of orthodontic movement, and resistance to proximal wear because of inherent material strength can be attributed to higher postoperative CS.[20] The KHN for zirconia oxide was 1600 kg/mm², which was much higher than the hardness of enamel or metal ceramic (460 kg/mm²). Zirconia had higher flexural strength (800–1500 MPa) and fracture toughness [plane strain fracture toughness (KIC) = 5–10 MPa m½] when compared with other dental ceramics.[21‑23] Zirconia has greater amount of crystalline phase than metal ceramics that improves mechanical properties and stress transformation.[17]

The results revealed that the molar pre- and postoperative CS was higher than the premolar CS. The resistance theory suggested that the size and number of roots were the major factors in determining the tightness of dental contact points (CPs).[24] Hence, the force required to displace the molars was comparatively higher than that required to displace the premolars which is manifested as increased CS.

Modifications of the instruments for recording CS are described in literature.[25‑27] The data obtained from the studies by Osborn[28] and Southard et al.[29] were insignificant since the CP tightness was measured after the two adjacent teeth were separated to the thickness of the strip. The force interacting at the CP before displacing the teeth was unknown. This study determined the CS with a force gauge which reduced the limitations of these methods and devices in determining the PCS.

The PC and CS vary with occlusion, mouth opening, and postural changes. This study standardized the variables, and limitations can exist with noninclusive parameters. A long-term evaluation on the effect of CS on the factors other than posture is required for higher validation. Inconvenience existed in using force gauge beyond the second premolar. A modification of the instrument is required for further studies in CS evaluation of posterior teeth.

Conclusion

Within the limitations of the study, it was concluded that all the materials provided acceptable CS. The CS was highest in zirconia FDP in comparison to metal ceramic and full metal FDP.

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Conflicts of interest

There are no conflicts of interest.

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