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Effect of implant-supported prosthesis on the bite force and masticatory efficiency in subjects with shortened dental arches

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SUMMARY **The aim of the study was to assess changes in bite force and masticatory efficiency in shortened dental arch (SDA) subjects rehabilitated with implant-supported restoration for 1st molar. Ten SDA subjects with bilaterally missing mandibular molars (experimental group) were recruited. In each subject, one tapered threaded implant was placed bilaterally in 1st mandibular molar region and restored. Masticatory efficiency was evaluated objectively by measuring the released dye from chewed raw carrots, with a 'spectrophotometer' at 530 nm preoperatively and at 3 months after restoration. Bite force was evaluated using 'bite force measuring appliance' preoperatively, at 6 weeks and at 3 months after restoration. Ten completely dentate-matched subjects (in terms of age, sex, height and weight) acted as control. The results revealed that as compared with the control group, the experimental group showed significantly less ($P < 0.05$) mean maximum bite force at pre-restoration and at 6 weeks after restoration. Although at 3 months the mean maximum bite force value was less than the control group but the mean difference was statistically insignificant. The mean difference of masticatory efficiency between control and experimental group was statistically significant ($P < 0.05$) before restoration, but was statistically insignificant at 3 months after restoration. Thus it was concluded that after the restoration of mandibular arch with implant-supported prosthesis, both bite force and masticatory efficiency of all SDA subjects increased and were comparable to that of matched completely dentate subjects after 3 months.**

KEYWORDS: **Occlusal contact area, implant-supported dental prosthesis, mastication, shortened dental arch, temporomandibular disorders**

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Introduction

Shortened dental arch (SDA) is a term describing a dental arch with missing posterior teeth and also represents a treatment philosophy of non-replacement of all missing teeth in the dental arch in this condition (1, 2). It is defined as a dentition of a minimum of 10 occluding pairs (e.g. all anterior teeth and premolars) as a suboptimal but still acceptable functional level (3).

This philosophy is mainly supported by epidemiological findings, indicating that occlusal changes resulting from missing molar teeth are self-limiting (4, 5). It offers advantage as an alternative treatment option that is less complicated, less time-consuming and less expensive. This may avoid the risk of over-treatment of the patient while still providing a high standard of care and minimising cost (6).

The SDA concept is still considered controversial by many clinicians regarding side effects of non-replaced molars such as: higher rates of temporomandibular disorders (TMDs), tooth migration, over eruption, increased wear, insufficient chewing efficiency and

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performance, occlusal instability and compromised aesthetics (7–9) affecting oral-health-related quality of life (10).

The aim of restorative dentistry is shifting from preservation of complete dental arches towards the preservation of functional dental arches, using a functionally oriented approach (11). Essentially four different therapeutic concepts/viable approaches to rehabilitation exists: (i) preserving or restoring a premolar occlusion, (ii) molar replacement with a removable partial dental prosthesis (RPDP), (iii) fixed restoration with one or two cantilever pontics, and (iv) fixed restoration with dental implants (12).

Adverse effects of tooth borne bridges include endodontic complications, tooth fracture, gingivitis and secondary caries (3). The patients with RPDPs are compromised by a high incidence of side effects and complications such as increased plaque accumulation, high caries rates and periodontal breakdown (13).

Dental professionals consider the replacement of missing posterior teeth with implants as a favourable choice especially with regard to the prevention of bone loss after tooth loss (14). Subjects with implant-supported overdentures have fewer complaints, feel more satisfied and rate their chewing comfort and ability higher than conventional complete dentures (15).

Although numerous studies in literature suggest that SDA subjects have reduced masticatory efficiency (1, 2, 16), information is scant regarding its effect on bite force. Therefore, this study was designed to evaluate the effect of shortened dental arch restored with implant-supported prosthesis up to 1st molar on masticatory efficiency and bite force and to compare that with completely dentate subjects.

Methods

The study was conducted after obtaining ethical clearance from the institutional ethics committee (Ref No. IESC/T-140/01.04.2011). A total of 10 SDA subjects with bilaterally missing mandibular molars (experimental group) and having approximately full complement of teeth in maxillary arch, within the age group (18–45 years), irrespective of sex were selected for the study. They were matched with 10 completely dentate subjects (control group) with respect to age (±5 years), height (±5 cms) and weight (±5 kg). Subjects having good oral hygiene, healthy periodontal support and willing for prosthetic treatment were included in the study whereas subjects with temporomandibular disorders (TMDs), parafunctional habits, medically compromised condition and psychological disorders were excluded. The maxillary arch of the selected subjects was restored to full complement of teeth before starting with the actual study and collection of baseline data. Of the 10 subjects, eight had full complement of teeth in the maxillary arch, that is, up to second molar bilaterally. Among the remaining two subjects, one had a missing canine and other had a missing first premolar on one side only. For missing canine, implant-supported prosthesis was placed, and for missing first premolar, a cantilever fixed partial denture (FPD) was placed.

In each SDA subject (experimental group), two tapered thread implants (Vision™ Hi-Tec implants*), one implant per side, were placed in 1st mandibular molar region. The implant treatment was carried out free of cost as the subjects were included in the present study. After 3 months of implant placement, stage II surgery was carried out, and implants were loaded with definitive restorations/porcelain fused to metal single crowns. After cementation, both the bite force and masticatory efficiency were measured. For the control group, measurement of bite force and masticatory efficiency was made only once.

Bite force measuring appliance

The bite force was recorded by using a bite force measuring appliance (17, 18) having a quartz sensor that relies on the piezoelectric effect. It consisted of an extraoral and an intraoral part. The extraoral part was a charge metre† (procured by). The intraoral part consisted of piezoelectric quartz sensor (height 6·0 mm, procured by†) covered with customised stainless steel (SS) plates (1·5 mm thick) fixed at one end and mounted on the base (Fig. 1).

Method of bite force measurement

The subjects were seated comfortably on a dental chair in upright position, and bite force measurement method was explained. The intraoral part of appliance

*Life Care, Devices pvt. ltd., New Delhi, India.

†M/s Kistler Inc., Winterthur, Switzerland.

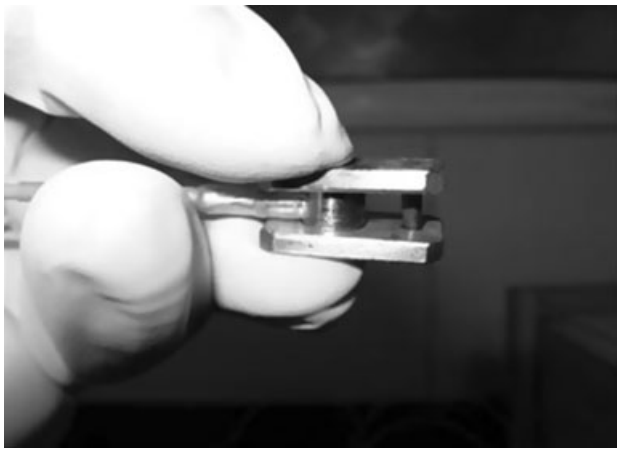

Fig. 1. Piezoelectric quartz sensor.

Fig. 2. Recording of bite force.

was covered with a disposable plastic sheet and placed at the premolar/molar area, and an acrylic block of same dimensions was placed on the contralateral side to counter balance the force (Fig. 2). The subjects were asked to bite on the sensor with maximum force, and the peak reading of bite force in newton (N) was recorded on the charged metre. Three readings were taken with 3-min interval in between them to prevent muscle fatigue. The average of the three readings was recorded. Same procedure was repeated for contralateral side. For each SDA subject, bite force was recorded before restoration, at 6 weeks and at 3 months after restoration. To record the maximum bite force after restoration, sensor was placed in first mandibular region. Bite force of matched controls was measured only once using the same technique, and sensor was placed in first molar region.

Measurement of Masticatory efficiency by Spectrophotometer

The method to measure the masticatory efficiency was based on naturally occurring dye (β-carotene) present in raw carrot, which was released on chewing. This dye was determined using a spectrophotometer at 530 nm (Shimadzu Medical (India) Pvt. Ltd., UV/Visible Spectrophotometer[‡]). Each subject was instructed to chew homogenous piece (10 gm) of carrot using 20 strokes without swallowing the particles of the carrot or saliva. After chewing, all the chewed part of carrot and saliva produced during the process was expectorated in a graduated cylinder and studied under spectrophotometer. The masticatory efficiency of the subjects was expressed in terms of optical density (OD). For each SDA subject, masticatory efficiency was measured twice (pre-restoration and at 3 months after restoration).

Statistical analysis

Statistical Package for Social Science[§] statistical software was used. 'Student's *t*-test' was used to assess the difference in bite force values between the right and left side and for comparison of bite force and masticatory efficiency between groups. For comparison of bite force within experimental group, 'repeated measured analysis' followed by *post-hoc* comparison by Bonferroni method was used. We also did statistical analysis for bite force measurement of those eight out of ten subjects having complete maxillary arch. For comparison of masticatory efficiency within experimental group, 'Paired *t*-test' was used.

Results

Bite force

The maximum bite force of all the subjects in control and experimental group was measured on both the right and left sides, and the difference was not statistically significant ($P > 0{\cdot}05$). Hence, the mean of both the sides was taken as mean maximum bite force for the subject for further analysis. It was observed that the mean maximum bite force within the experimental group increased from $165{\cdot}5 \pm 19{\cdot}5$ N pre-restora-

[‡]Shimadzu Medical Pvt. Ltd., New Delhi, India.

[§]SPSS, version 15.0, Chicago, IL, USA.

Table 1. Comparison of bite force (in N) between control group and experimental group at different time intervals

Time intervals	Bite force (in N)		Mean difference (in N)	*P*-value
	Control group (Group I) (Mean ± SD)	Experimental group (Group II) (Mean ± SD)		
Pre-restoration	335·7 ± 48·8*	165·5 ± 19·5	170·2	0·01
6 weeks after restoration		292·2 ± 35	43·5	0·03
3 months after restoration		301·50 ± 34·3	34·2	0·09

Statistically significant ($P < 0·05$).
*Bite force was measured only once in the control group.

Table 2. Comparison of masticatory efficiency (in nm) between control group and experimental group at different time intervals

Time intervals	Masticatory efficiency (in nm)		Mean difference (nm)	*P*-value
	Control group (Group I) Mean ± SD	Experimental group (Group II) Mean ± SD		
Pre-restoration	1·09 ± 0·15*	0·81 ± 0·17	0·27	0·01
3 months after restoration		1·01 ± 0·12	0·07	0·24

Statistically significant ($P < 0·05$).
*Masticatory efficiency was measured only once in the control group.

tion to 292·2 ± 35 N at 6 weeks after restoration and to 301·5 ± 34·3 N at 3 months after restoration (Table 1). There was an increasing trend in the bite force measurements. The mean difference of mean maximum bite force pre-restoration to 6 weeks after restoration (−126·7 N), 6 weeks to 3 months after restoration (−9·3 N) and pre-restoration to 3 months after restoration (−136 N) was statistically significant ($P < 0·05$).

The comparison of experimental group with control group revealed that the mean maximum bite force values of experimental group at different time intervals were less than the control group (335·7 ± 48·8 N). The mean difference was statistically significant at pre-restoration (170·2 N, $P < 0·01$) and at 6 weeks (43·5 N, $P = 0·03$), but not significant at 3 months after restoration (34·2 N, $P = 0·09$). Results of bite force measurements of eight out of ten subjects having complete maxillary arch revealed that the mean maximum bite force values of experimental group at different time intervals were less than the control group (342.4 ± 52.3 N). The mean difference was statistically significant at pre-restoration (169.6 N, $P < 0.01$) only but not significant at 6 weeks (40.9 N, $P = 0.2$) and at 3 months after restoration (32.9 N, $P = 0.4$).

Masticatory efficiency

In experimental group, the masticatory efficiency pre-restoration was 0·81 ± 0·17 nm, which increased to 1·01 ± 0·12 nm at 3 months after restoration, and the mean difference (−0·20 nm) was statistically significant ($P < 0·05$). Control group had masticatory efficiency value 1·09 ± 0·15 nm which was higher as compared with experimental group and the mean difference was significant at pre-restoration (0·27 nm, $P < 0·01$), but not at 3 months after restoration (0·07 nm, $P = 0·24$) (Table 2).

Discussion

Analysis of the results showed that subjects in both the experimental and control groups had approximately equal bite force on the left and right side, which is in agreement with previous studies (19, 20). Our study further demonstrated that the mean maximum bite force of SDA subjects was significantly less than that of the control group. Hattori *et al.* (21) and Gibbs *et al.* (22) stated that total maximum bite force of subjects with SDA is lower compared to that of completely dentate subjects.

Within the experimental group, the mean maximum bite force increased significantly from pre-resto-

ration to 3 months after restoration. This progressive increase in bite force might be due to increase in number and extent of occlusal contact area. Similar findings were reported by Goto *et al.* (16). Although the mean maximum bite force values of SDA subjects at 3 months after restoration were less than control group, their mean difference was not statistically significant. The reason might be that until 6 weeks after restoration, the surrounding tissues may not have adapted completely and also the SDA subjects might not have clenched his/her teeth forcefully due to fear of damage to the prosthesis. However, in 3 months of duration, the SDA subjects would have developed increased confidence as well as increased surrounding tissue adaptation with the prosthesis, thereby enhancing their bite force. SDA patients with complete natural maxillary dentition showed progressive improvement in bite force after rehabilitation of mandibular first molar. As these patients had no artificial teeth or restorations in their maxillary jaw so they gave higher values for bite force immediately after 6 weeks and after 3 months as compared to patients with artificial restoration in maxillary arch.

Masticatory efficiency and masticatory ability are important components of oral functionality in terms of dental arch length (6). Results showed that the pre-restoration masticatory efficiency of SDA subjects was significantly less than that of the control group. It has been well established that chewing performance declines linearly with decrease of the chewing platform area (7). Fontijn-Tekamp *et al.* (15) concluded that chewing efficiency of the SDA subjects was significantly less than that of completely dentate arch subjects due to the reduced occlusal contact area.

There was a statistically significant increase in masticatory efficiency of SDA subjects from pre-restoration to 3 month after restoration. At 3 months after restoration, masticatory efficiency value of the experimental group was closer to the control group and the mean difference was statistically insignificant. Baba *et al.* (23) observed that patterns of missing occlusal units (OU) are likely to be related to the oral-health-related quality of life (OHRQoL) impairment in SDA subjects with the presence of first molar contact having a particularly important role. This indicates that the presence of first molar occlusion (at least unilateral) seems to be important for preventing OHRQoL impairment and affecting masticatory performance. Similar results were reported by Sarita *et al.* (24) who stated that SDA with intact premolar regions and at least one occluding pair of molars provided sufficient chewing ability even when compared with complete dental arch. In the present study, also improvement in chewing ability of SDA subjects was seen after replacement of missing first molar, and this improvement was seen based on objective measurements, that is, laboratory tests. However, patient-based assessments that give an indication of patients' own perspective on their perceived ability to chew foods may be more relevant. Thus, future studies including subjective assessment of masticatory efficiency may be necessary to check whether the replacement of first molar in SDA subjects is effective in changing the patient's functions and satisfaction level.

Within the limitations of this study, it can be concluded that restoration of SDA subjects with implant-supported prosthesis replacing the mandibular first molar improvement in both masticatory efficiency and bite force is seen. However, a minimum of 3 months is required for functional adaptation of surrounding musculature to the new prosthesis and for the masticatory efficiency and bite force to be comparable to matched completely dentate subjects.

Ethics approval

Ethical clearance was obtained from the Institutional Ethics Committee, All India Institute of Medical Sciences, New Delhi-110029, India (Ref No. IESC/T-140/01.04.2011).

Source of funding

This was an institutional study; therefore, institute bearded the cost/expenses of the study. No external source of funding present.

Conflicts of interest

The authors declare no conflict of interst.

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