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Comparison of torsional resistance of five orthodontic mini implants (TADS) commercially available in India- an in vitro study

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Abstract

Temporary anchorage devices (TADs) are adjunctive devices that can be inserted into specific intraoral bony structures, to provide anchorage and are subsequently removed after use. TADs can be located trans-osteally, sub-periosteally or endo-steally and are either cortically stabilized or osseointegrated.[1]They are of various kinds and include Mini implants, Micro implants, Onplant etc.

Mini implants have expanded treatment possibilities by decreasing dependence on patient compliance, reducing unwanted tooth movements and facilitating previously unattainable or difficult tooth movements.In clinical practice, mini implants are loaded immediately and therefore achieving maximum stability is very important. Primary stability depends upon the bone quality, and also on various miniscrew designs, implant site preparation and insertion angle.[2]

Fracture during mini implant placement or removal is a nightmare for every orthodontist due to the difficulty in removal of fractured segments. Excessive torque and wrong angulation on placement and removal is one of the reasons for fracture of these mini implants and is most

common when attempting to insert them into thick cortical bone. Researches show variability in fracture torque among different manufactures. Also rate of fracture of mini implants is more in thick cortical bone like mandible[3] and can be studied using bovine rib bones which present same architectural pattern as human mandible.[2]

It is important for clinicians to know the fracture resistance of their preferred mini implants.[4] The purpose of this study is to compare the peak fracture torque values of five commonly used self-drilling mini implants as well as their point of fracture by inserting them into high density animal bone (D1 bone density) using a standardized insertion and force measurement system

Aim of the study

- To compare the fracture resistance of 5 commercially available orthodontic mini implants due to torsional force

Objectives

To analyze the threshold torque values resulting in fracture of 5 different orthodontic mini implants on insertion.

- To analyze the point of fracture in these mini implants when subjected to excessive torque

Materials and methods

The bovine rib bone used for inserting TADs was obtained from a slaughter house. Since no animal was harmed for this study, no animal ethical committee certificate was required. The bone piece was cleaned of debris and tissue and stored in Formal saline at 4°C for 24 hours. Formal saline was prepared in the laboratory from 900 ml tap water, 100ml Formaldehyde (37%) and Sodium chloride 9gm. Then the bovine bone were cut into segments to obtain bone blocks of 5cm length and width and minimum 8mm thickness and stored again in formal saline at 4°C until implant insertion occurred between first and third day .

The implant placement sites were marked using gutta percha. CT scan of the bone piece was done to determine its density. Density of 1350 to 1750 HU was noted along the entire length of the bone piece corresponding to D1 bone density according to Misch classification.[5]

75 self-drilling orthodontic mini implants of length 8mm, head width 1.4mm and tapered type made of Titanium alloy (Ti-6Al-4V) were divided into 5 groups according to their manufacturer.

Group 1: Favanchor (S.H.Pitkar Ortho tools pvt ltd, Pune)

Group 2: AbsoAnchor (Dentos India pvt ltd)

Group 3: Genesis (JJ Orthodontics pvt ltd, Kerala)

Group 4: Ortho One (Ortho One Inc)

Group 5: BK surgical (BK Inc, Karnataka)

Insertion of mini implants:

Mini implants were inserted manually without predrilling into bone blocks stabilized on a custom made device using a vise with the frequency of 20 to 30 rpm (one complete rotation per 2-3 sec). Although insertion speed has been found to have little effect on fracture torques obtained, this rate was chosen to best simulate a typical clinical scenario. Each placement site were at 10 mm distance from each other in accordance with the requirements of the American Society for Testing and Materials (ASTM) standards.[6] Torque–Driver (FTD50CN2-S dial indicating type, Tohnichi, Japan) was used to measure the maximum torque reached upon fracture of mini implants in Ncm.[7] The same procedure is followed for all the mini implants, whereas the driver bits were changed according to the head design of the mini-implants.

The head of the mini implants were engaged with their specific manufacturer provided driver adaptors. The opposite end of the driver was adapted to a custom built chuck, connected to a torque driver (FTD50CN2-S dial indicating type, Tohnichi, Japan). The device incorporated a stabilizing bar and was specifically designed to support driver shaft and prevent oblique forces during manual screw placement. This allowed the mini-implants to be inserted vertically without introducing off-axis loading along the length of the mini-implants.[4] The same calibrated operator performed the whole assay. Maximum torque reached at fracture of mini implants was recorded and expressed according to the scale in Ncm. The torque measurement device was calibrated prior to each new group tested.

Fig 1: Bovine bone used to insert mini implants

Fig 2: Implant placement site marked on the bone with GP

Fig 3: CT scan of the bone piece

Fig 5: Favanchor mini implant with driver

Fig 6: AbsoAnchor mini implant with Dentos driver

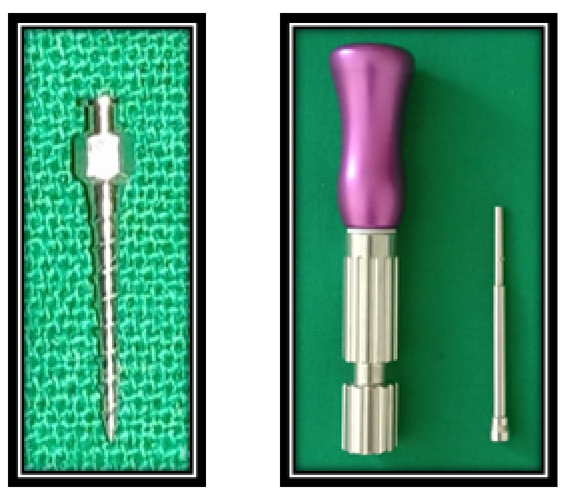


Fig 7: Genesis mini implant with driver

Fig 8: Ortho One mini implant with driver

Fig 9: BK Surgicals mini implant with driver

Fig 10: Torque–Driver (FTD50CN2-S dial indicating type, Tohnichi, Japan)

Fig 11: Dial of the torque driver

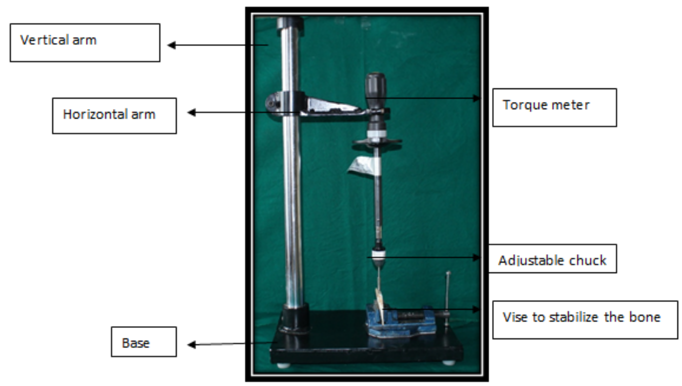


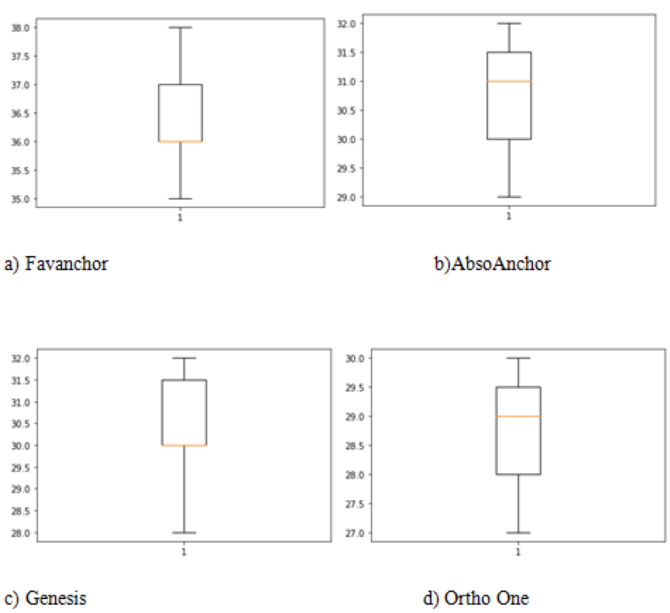
Fig 12: Parts of the custom made device holding the bovine bone and torque driver

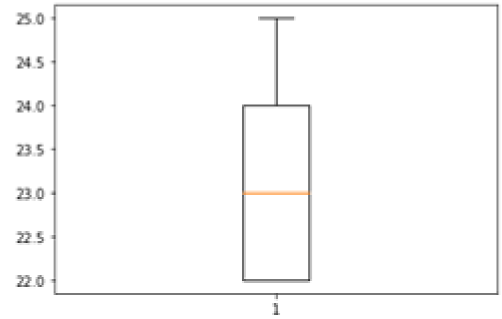
Fig 13: Manual insertion of mini implant into bovine bone

Fig 14: Comparison of fractured mini implants with their original lengths

Results

The fracture torque value of 5 groups of mini implants was evaluated in Ncm and compared.





e) BK Surgicals

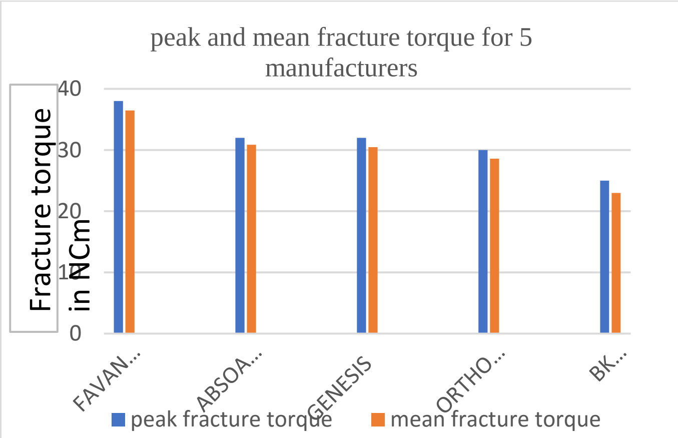
Graph 1- Box plot representation of distribution of peak torque values of different manufacturers

Descriptive statistics including mean value, standard deviation, and ranges were

calculated for the five groups using the Statistical Package for Social Sciences (SPSS v.13.0)s. With significance level pre-determined at $P<0.05$, a one way analysis of variance (ANOVA) followed by post hoc Scheffe's test was used to detect significant differences between the five manufacturers. Descriptive statistics are summarized in Table 1. It includes the mean and standard deviation along with the minimum and the maximum torque values of all the manufactures.

Table 1: The Minimum, Maximum, Standard Deviation and Mean torque values at fracture

	Favanchor	Abso Anchor	Genesis	Ortho one	BK Surgicals
N	15	15	15	15	15
Minimum (NCm)	35	29	28	27	22
Maximum (NCm)	38	32	32	30	25
Mean(NCm)	36.46	30.86	30.46	28.6	23
Standard Deviation	0.99	0.91	1.24	1.12	1



Graph 2: Bar graphs of the peak and mean fracture torque values depending on the mini-implant manufacturers

There was a significant difference among the groups of different manufacturers in the fracture torque values. The Favanchor mini-implant had the highest mean torque value whereas the lowest was recorded for BK Surgicals with the values 36.46 NCm , standard deviation ± 0.99 and 23 Ncm, standard deviation ± 1 respectively . The mean peak fracture torque values of all the mini implants are depicted in Table 1.

One way ANOVA statistical analysis followed by a post Hoc Scheffe's test revealed significant differences ($p<0.05$) in the peak fracture torques among all groups tested (Table 2). Null hypothesis can be rejected since the Scheffe test statistic is greater than the critical value.

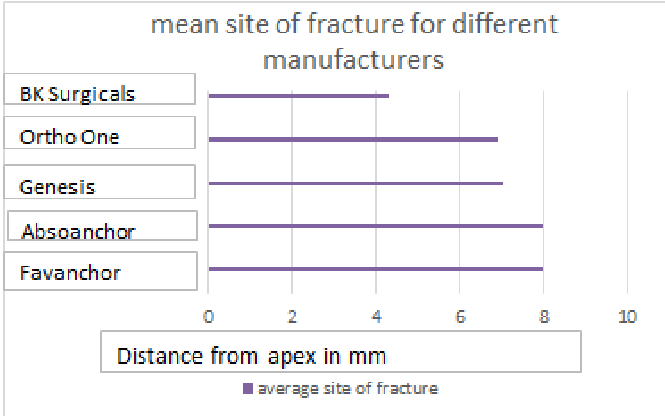
Genesis mini implants showed the greatest range in fracture torques (28 – 32Ncm (SD =1.24)); while the Favanchor and AbsoAnchor were the most consistent (35 - 38 Ncm (SD 0.99), and 29 - 32 Ncm (SD 0.91), respectively.

Table 2: Post Hoc Scheffe test result

	FAVANCHOR	ABSOANCHOR	GENESIS	ORTHO ONE	BK SURGICALS
FAVANCHOR	1.00E+00	2.63E-20	6.87E-22	1.42E-28	2.40E-43
ABSOANCHOR	2.63E-20	1.00E+00	8.99E-01	1.11E-05	1.42E-28
GENESIS	6.87E-22	8.99E-01	1.00E+00	4.30E-04	3.10E-27
ORTHO ONE	1.42E-28	1.11E-05	4.30E-04	1.00E+00	2.63E-20
BK SURGICALS	2.40E-43	1.42E-28	3.10E-27	2.63E-20	1.00E+00

Table 3: Descriptive data of the site of mini implant fracture for different groups

	Favanchor	AbsoAnchor	Genesis	Ortho one	BK Surgicals
N	15	15	15	15	15
Minimum distance from apex(mm)	8	8	6	6	4
Maximum distance from apex(mm)	8	8	8	8	5
Mean(mm)	8	8	7.06	6.9	4.3
Standard Deviation	0	0	0.7	0.8	0.4



Graph 3- Mean site of fracture for different manufacturers

Among the five groups tested , one way ANOVA statistical analysis revealed that there was significant difference ($p<0.05$) in the site of fracture of different mini implants. All the fifteen mini implants of group Favanchor and AbsoAnchor fractured after complete insertion into the bone at the neck of the mini implants. In the Genesis group only four mini implants were inserted completely into the bone before fracture. Rest of the mini implants fractured at 6-7 mm from the apex in their body region during insertion. In the Ortho One group five mini implants underwent full insertion before fracture while rest of them fractured at 6-7mm from apex similar to Genesis mini implant group. All of the BK mini implants failed to undergo full insertion into the bone and fractured at 4-5 mm from apex in the body of the mini implant region.

Discussion

Self-drilling mini implants are associated with high placement torque especially in high density bone. Identifying the maximum fracture torque values of these could help in prior determination of the risk of this complication.[4]

In this study mini implants of same size, length, design and alloy were compared. However, resistance to fracture varied significantly among implants from different manufacturers. The mean values obtained ranged from 23Ncm (BK Surgicals) to 36.46NCm (Favanchor).

This variability in torque values may be due to increased variability in the manufacturing process, heat treatment or alloy composition.[4]

The mini implants were inserted into most dense cortical bone similar to a study done by Assad Loss et al. [8] D1 bone density was chosen to assess maximum torque value at fracture so as to prove that mini implants which had maximum resistance to fracture on these site would have same resistance to fracture on other sites as well, especially D2 and D3 bone density which are more common in maxilla and mandible.[9] Even though the manufacturers recommend predrilling when inserting into thick cortical bone, in this study it was avoided to evaluate the performance of mini-implants in challenging clinical conditions without pre-drilling.

A torque screwdriver used in this study is manufactured by Tohinichi Mfg. Co. Ltd. It has the accuracy rate of ±3% and can be reliable on the torque readings shown during insertion.[7]

Studies have shown that the placement angle of the screw can have an effect on its anchor value and the stress transmitted.[9] 90° insertion angle was chosen for the present study and a custom made device was manufactured to insert the mini implants in this position

Earlier many researches were conducted to know the optimum torque level required for the insertion in maxilla and mandible in both clinical and laboratory conditions. Motoyoshi et al measured the mean insertion torque required for mini-implants in maxilla and mandible in clinical conditions which was between 8.3 Ncm in maxilla and 10 Ncm in mandible.[7]

The values for Genesis mini implants showed the greatest variance in fracture torques (30.46Ncm ± 1.24) suggesting that the composition of the titanium alloy among the mini-implants tested may not have been as homogeneous as that of Favanchor (36.46Ncm ± 0.99) and Absoanchor (30.86Ncm ±0.91).

While most mini-implants exhibited failures occurring in their body region at the level of the insertion medium, Favanchor and Absoanchor screws experienced fractures occurring in the region of the neck and driver interface. This is similar to the findings in the study by Wilmes et al [10] who concluded that mini implant and driver shaft design may play a role in the various fracture patterns found.

Favanchor mini implants have a large and buslky head design explaining the largest torque value achieved at fracture . Absoanchor mini implants on the other hand also underwent complete insertion into the bone block similar to Favanchor but fractured at a less torque value. This may be due to the very small head design compared to all the other manufacturers.

All mini-implants belonging to the Genesis, Ortho One and BK Surgicals group consistently fractured within the threaded portion of the tapered body, at or within 1mm from the level of the bone block, indicating that this is the region experiencing the highest concentration of internal stress during insertion.

Removal of a fractured mini implant segment may need surgical exposure of the site and removal of bone around the implant to gain proper access to the fractured segment. This might cause local necrosis of bone at the site in addition to causing a traumatic experience to both patient and the orthodontist.[4]

Therefore cautious use of self drilling mini implants in areas of dense cortical bone is needed. Choice of mini implant must depend on maximum torque it can withstand. In addition the use of torque limiting drivers and gauges as well as predrilling pilot holes may be beneficial in controlling insertion torque and decreasing risk of fracture.[10-12]

Conclusion

Significant differences exists in fracture torques among different manufacture specific mini implants. Despite the variation between groups, all mini-implants evaluated were found to be suitable for clinical use. Knowing their fracture resistance is very important before choosing the mini implants especially when inserting into high density bone.

Future study

The main weakness of this *in-vitro* study is that it was carried out in a laboratory setting so we cannot be certain that the results can be translated to the clinical setting. In the future, the present study design could be used to confirm the insertion torques reached and fracture resistance associated with drill-free placement of all above studied mini-implants in high density human cadaveric bone, as opposed to bovine bone substitute. Also individual mini implant design and surface characteristics could be studied using optical microscope and SEM study to support the variation of peak fracture torque values among each groups.

List of abbreviations

TAD- Temporary Anchorage Devices

RPM- Rotations per minute

Ncm- Newton centimetre

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